GROUND MOVEMENT STUDY
HAUSSLER ROAD AREA
KELSO, WASHINGTON

Prepared by:

Michelle Howell
Darren Beckstrand
A.G. Flynn

Prepared for:

Environmental Geology, G561
Portland State University
Winter Term 1999

Abstract

This report summarizes the ground movement study conducted on the Haussler Road area of Kelso, Washington (Figure 1). The Haussler Road area is a residential neighborhood constructed on an ancient landslide. The purpose of the study is to determine if ground movement is occurring, and if so, to determine whether the movement exhibits a spatial pattern. The study was conducted using quantitative data collected from a ground surface survey and qualitative data collected from resident interviews and questionnaires. As a result of the study, it appears that ground movement is occurring in the Haussler Road area. Of the 46 homes included in the study, approximately 46% are exhibiting signs of movement. Approximately 30% of the homes located above the ancient landslide scarp are exhibiting signs of movement, while approximately 61% of the homes located on the ancient landslide are exhibiting signs of movement.

Introduction

According to the Geologic Map of Washington (Walsh et al., 1987), approximately 2 to 14 million years ago, the ancestral Columbia River deposited gravels, sands, silts, and clays in portions of what is now the northwestern United States. These deposits are now known as the Troutdale Formation. In certain areas, the Troutdale Formation was deposited upon a much older, near-shore marine sedimentary deposit known as the Cowlitz Formation. In areas where the Troutdale Formation overlies the Cowlitz Formation, landslides are known to occur. One such area exists in Kelso, Washington. The Troutdale Formation overlies the Cowlitz Formation on a northwest-southeast trending ridge located approximately one-half mile east of interstate I-5 (Figure 2).

FIGURE 1

Site Location

N

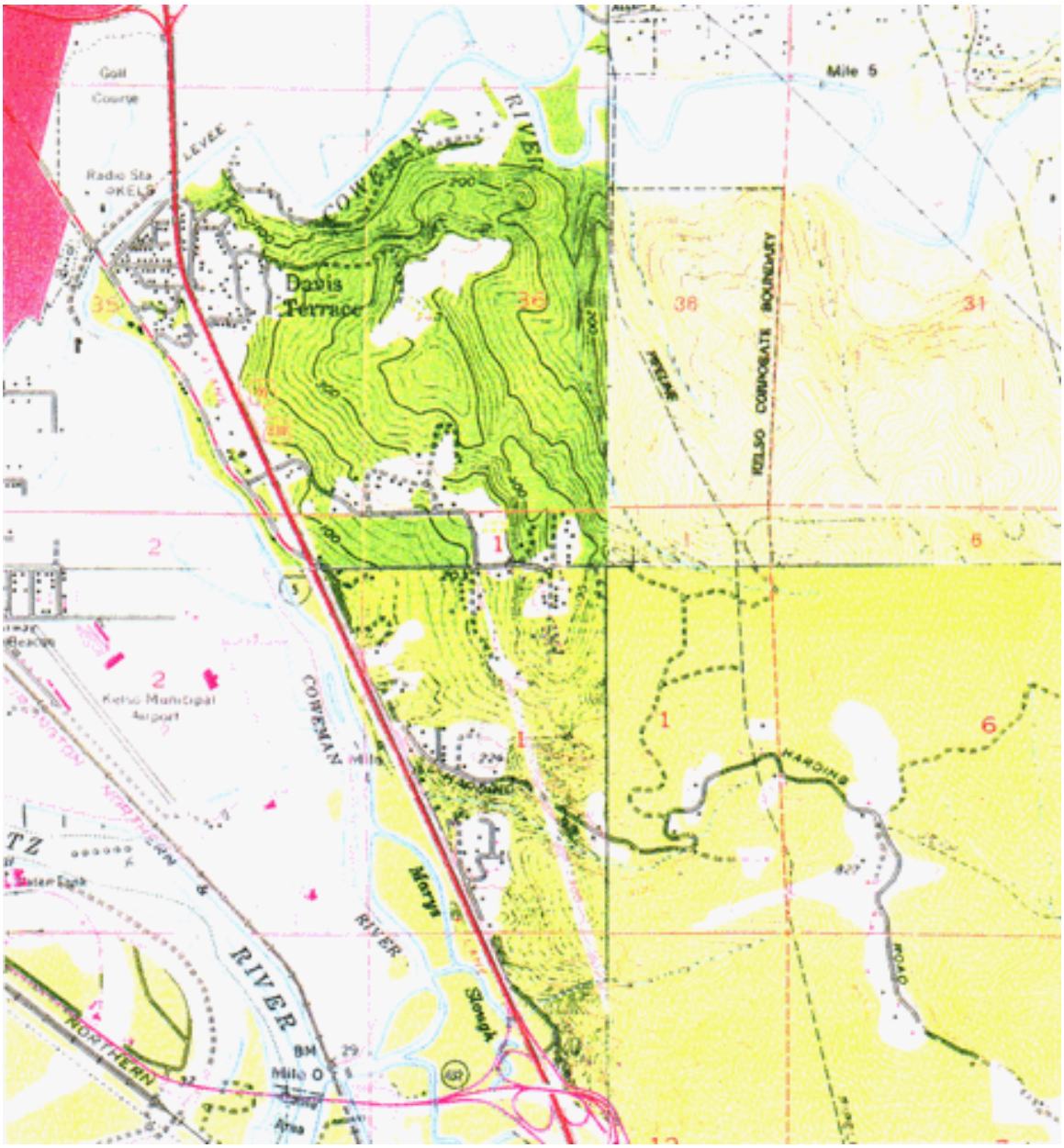


FIGURE 2

Composite of United States Geological Survey Topographic Quadrangles, 7.5 minute series

Kelso, WA, Mt. Brynion, WA, Rainier, WA-OR, and Kalama, WA-OR

In 1973, a slope stability study of this ridge was conducted by the Washington Department of Natural Resources (Fiksdal, 1973). As a result, the ridge was divided into classifications of slope stability ranging from 1 to 5. These classifications are now popularly known as the Fiksdal classifications, after Allen Fiksdal, who was the geologist working on the state project. A Fiksdal classification of 1 indicates a stable slope, and the classifications increasingly progress to a classification of 5, which indicates an area of active or historical landsliding. Figure 3 illustrates the Fiksdal classification boundaries in the vicinity of the ridge. Figure 4 provides an explanation of each classification.

Over the last 40 years, the north and west slopes of a portion of this ridge have been residentially developed. This portion of the ridge is called Davis Terrace. The north slope development was constructed in an area with a Fiksdal classification of 1. However, it now appears that this area should have been classified as a 5. An ancient scarp and landslide debris exist there (Koloski, 1998). This slide (popularly known as the Aldercrest-Banyon slide) caused millions of dollars in damage and caused many residents to lose their homes. Portions of the slope have even been declared federal disaster areas.

Since approximately December 1998, the residents on the western slopes of Davis Terrace have reported new cracks forming in their homes. This is of great concern to the residents as ground movement occurring in their area may be the beginnings of a catastrophic landslide similar to the Aldercrest-Banyon slide. One concerned resident contacted Portland State University (PSU) to request that a ground movement study be conducted. The purpose of the study is to determine if ground movement is occurring, and if so, to determine whether the movement exhibits a spatial pattern. The study was conducted as the graduate student project for the Environmental Geology course offered by Professor Scott Burns.

Selection of Study Area

An initial site visit was conducted on January 18, 1999. Homes located at 494 Apple Lane and 131 South Vista Way were visited as these were known to be exhibiting signs of ground movement. At this time, it was noted that many homes in the neighborhood are built on an ancient landslide (Fiksdal, 1973). Therefore, the study area was selected to include all homes in the neighborhood, from the top of the ridge (North and South Vista Way) down to Rons Court (Figure 5). Note that the study area includes homes both above and below the scarp of the ancient landslide. The study area will herein be referred to as the Haussler Road area.

Study Methods

In order to determine if ground movement is occurring in the Haussler Road area, two basic methods were used: (1) a ground surface survey was conducted, and (2) residential properties were evaluated in terms of degree of movement exhibited. Each method is described in detail below.

FIGURE 3

Fiksdal Classifications on Davis Terrace in Kelso, Washington
(see Figure 4 for classification explanations)

Fiksdal Classifications

CLASS 1: AREAS BELIEVED TO BE STABLE.
SLOPES GENERALLY LESS THAN 15%

CLASS 2: AREAS BELIEVED TO BE STABLE UNDER NORMAL CONDITIONS, BUT MAY BECOME UNSTABLE IF DISTURBED BY MAN'S ACTIVITIES.
SLOPES GENERALLY STEEPER THAN 15%

CLASS 3: AREAS INFERRED TO HAVE POOR NATURAL STABILITY.
SLOPES GENERALLY STEEPER THAN 15%

CLASS 4: AREAS OF FORMER STILL UNRECOGNIZED LANDSLIDES.

CLASS 5: AREAS OF RECENTLY ACTIVE, RAPID DOWNSLOPE MOVEMENT, PROBABLY WITHIN THE LAST 50 YEARS.

_ _ _ _ _ LINE REPRESENTS CONTACT BETWEEN SLOPE STABILITY UNITS.

FIGURE 4

Explanation of Fiksdal Classifications

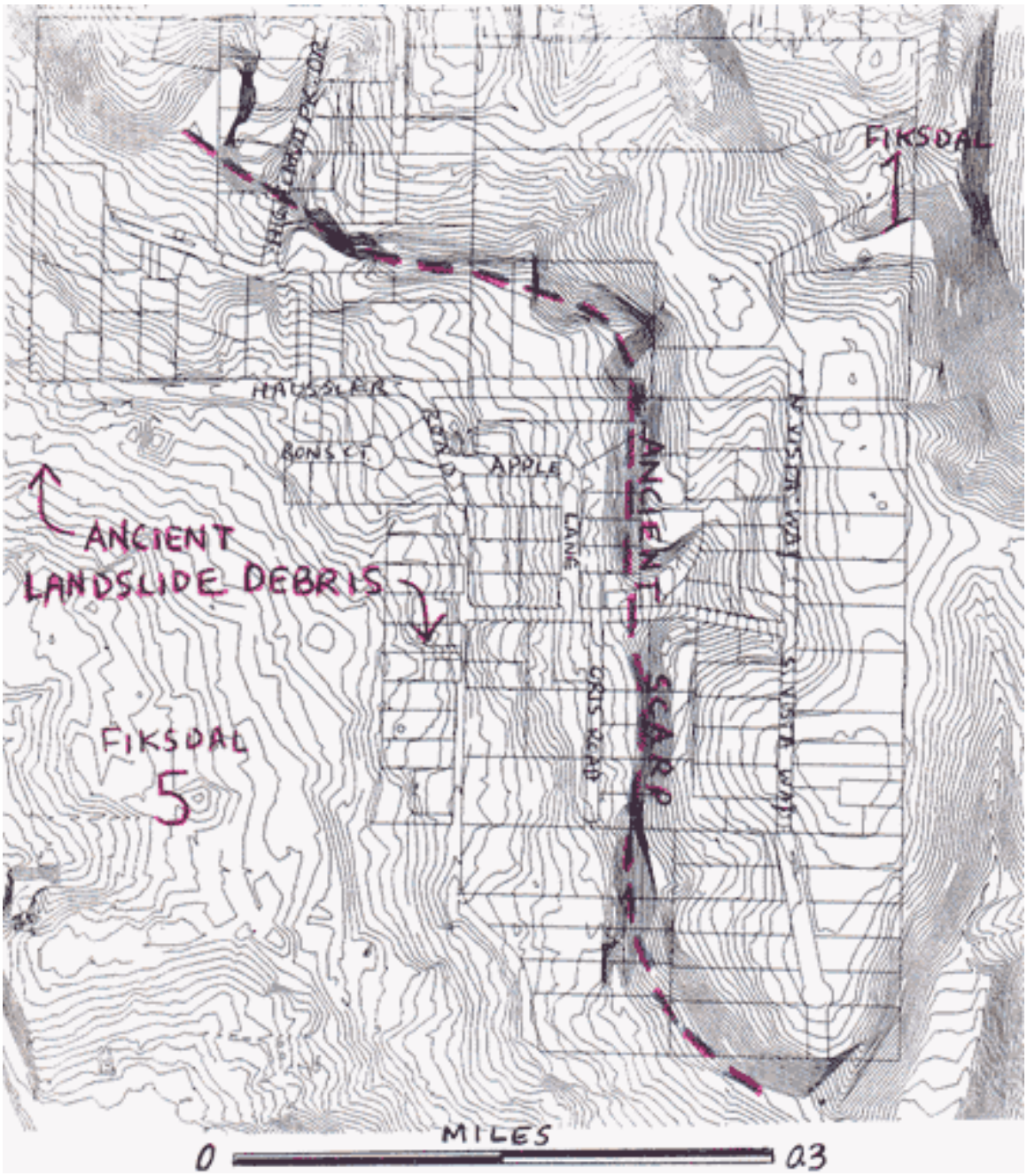


FIGURE 5

Ancient Landslide Boundaries, Haussler Road Area

N

A) Ground Surface Survey

On February 5, 1999, eleven sites ("stations") on the ground surface in the Haussler Road area were selected for surveying (Figure 6). The station locations were selected in order to represent the ground surface both above and below the scarp of the ancient landslide. The station locations also had to be situated such that they would be visible from our survey equipment, a total station.

Because of the large size of the study area (approx 0.5 square mile), it was necessary to set up the total station ("base") on Rons Court in order to have visual contact with as many stations as possible. This is problematic because the area around Rons Court is showing marked movement, and ideally the base in a survey should be stationary. However, since one station was located above the scarp and was assumed to not be moving, this was used as a control point. Figure 6 illustrates the location of these stations. Please note that station #2 is outside of the northern boundary of the photograph in Figure 6.

The ground movement study consisted of two separate survey events. On February 9, 1999, the locations of each of the eleven stations relative to the base were surveyed. This was accomplished by setting up a reflector on a tripod at each station. Locations were surveyed in terms of distance, horizontal angle, and vertical angle from the base. Subsequent to surveying each station, the height above the ground of each reflector was noted, and the exact station location was marked with masonry nails and spray paint on the ground. Using trigonometric principles, the x, y, and z coordinates of each point were established. Points #10 and 11 (control point) were then utilized to define a line of known azimuthal bearing. The bearing was corrected for true north, and as a result, the northing and easting of each station could be determined using an assumed northing and easting of 100 for the base. The elevation of each station was calculated using an assumed datum of 100 feet for the base.

On March 2, 1999, reflectors were again set up at each station, at the same height above the ground. Station #4 could not be located as the road at that location had been repaved. This was due to the road being torn apart by slumping at that location. The station locations were surveyed, and northing, easting, and elevation were once again calculated. The coordinates calculated from each event are summarized in Table 1.

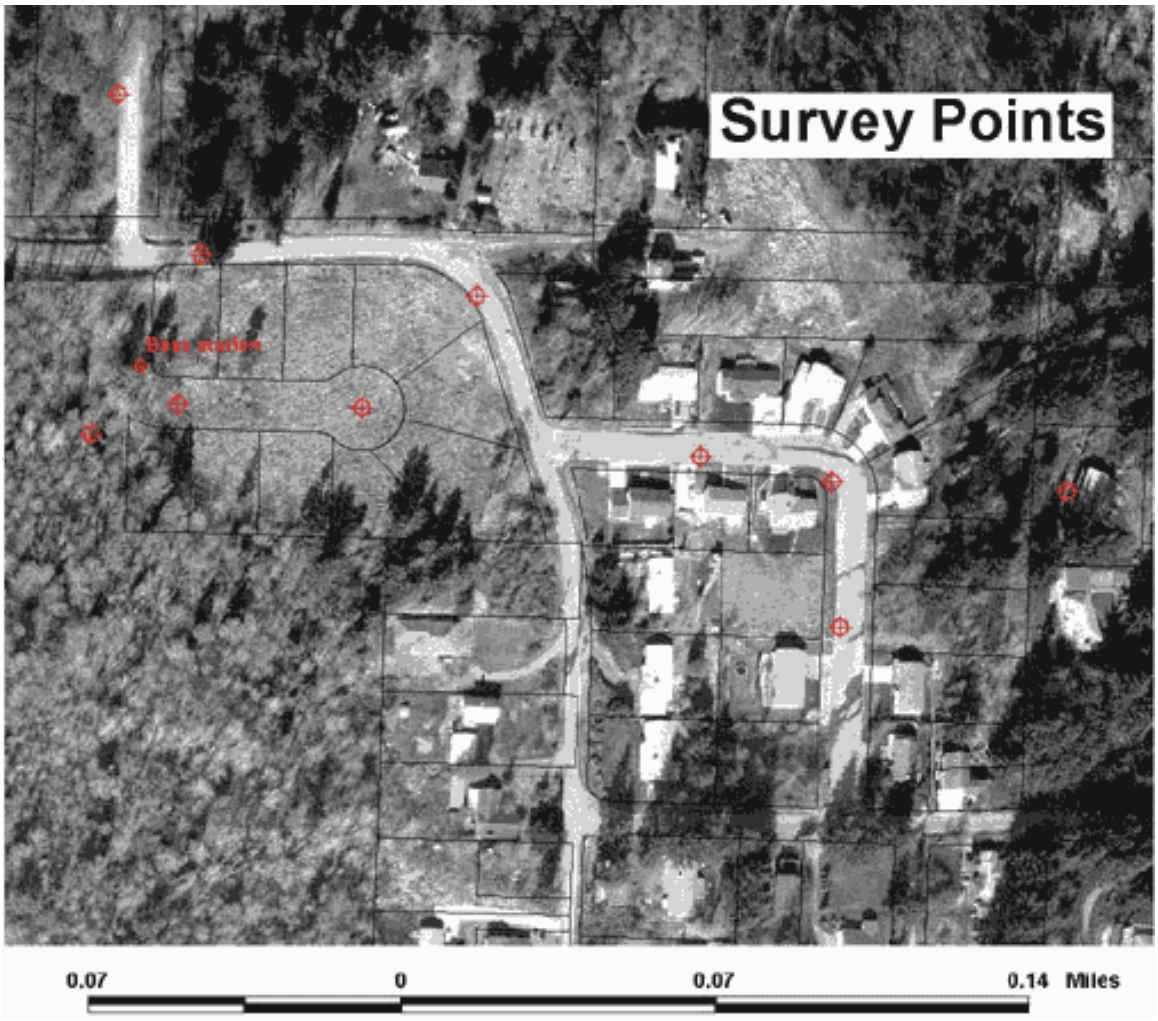


FIGURE 6

Station Locations - Ground Surface Survey

TABLE 1
RESULTS OF GROUND SURFACE SURVEY
Ground Movement Study of the Haussler Road Area
Environmental Geology Graduate Student Project
Portland State University
Winter 1999

	February 9, 1999 Survey			March 2, 1999 Survey			Results	
Station	Easting	Northing	Elevation (feet)	Easting	Northing	Elevation (feet)	Vectoral Movement (mm)	x-y Movement
1	89.19	202.00	108.34	89.17	201.99	108.26	24	6
2	100.00	100.00	269.82	100.00	100.00	269.82	16	3.7
3	155.52	192.81	110.10	124.30	140.62	102.94	~~6127~~	~~6083.6~~
4	184.91	121.03	106.69	Station location lost during repaving				
5	272.34	78.16	113.72	318.03	72.39	115.14	~~4611~~	~~4609~~
6	348.41	64.76	120.66	348.39	65.78	120.80	3	2.7
7	428.75	63.12	152.26	428.71	63.17	152.42	0	0
8	348.86	11.29	120.44	348.69	11.31	120.55	15	13.9
9	91.61	83.89	99.03	91.60	83.87	98.98	23	7.9
10	178.28	89.76	104.12	178.29	89.77	104.06	22	5.2
11	108.17	90.18	100.08	108.18	90.20	100.06	18	5.5

B) Residential Property Evaluation: Questionnaires and Home Visits

According to Koloski (1998), signs of movement which are exhibited in homes at the beginning of a landslide can include jammed doors and windows, cracks in concrete foundations, and changes in surface water seepage patterns. Other damage noted in the two homes initially visited included:

- separation of external chimney from foundation of home,
- recent propagation of household cracks,
- drywall over the nailheads bulging (likely due to the drywall sheet undergoing stress and strain),
- twisting ceiling beams,
- water seeping into basement through new cracks,
- bulging walls,
- separation of internal cabinetry from walls, and
- creaking, popping and snapping noises from house.

In addition to the above signs, the evaluation included searching for pistol-butt, tilting retaining walls, and sloping porches.

On February 15, 1999, questionnaires were delivered to approximately 50 homes in the Haussler Road area. The questionnaires included questions about the above mentioned signs of ground movement. The residents were asked to fill out the questionnaires and return them to the PSU geology department in pre-addressed envelopes which were provided. A sample questionnaire is included with this document as Appendix B. In addition, a concerned resident assisted the study by telephoning neighborhood residents and encouraging them to return their questionnaires. By the end of the study, 37 questionnaires were returned. This is an approximately 75% response rate.

On February 20, February 27, and March 2, 1999, the students conducted an exhaustive door-to-door survey on as many homes in the study area as possible. A total of 36 residents allowed the students to inspect their homes. These home inspections included both residences who answered the questionnaire and those who did not. Detailed field notes were collected during home inspections, and it was noted whether the home was exhibiting signs of movement or not. If signs of movement were exhibited, they were noted in detail.

Table 2 summarizes the results of the questionnaire responses. For evaluation purposes, "yes" responses were assigned a value of 1. "No" responses were assigned a value of 0. These responses were then summed up for each home, thus indicating the number of "yes" responses. For example, a home with a sum of 3 responded "yes" to three questions. Each home was then assigned a code which categorizes the number of "yes" responses and as a consequence, degree of movement exhibited in the home. Homes with a sum of 0 were assigned a code of "0" (no movement); homes with a sum of 1 or 2 were assigned a code of "1" (possible signs of movement); homes with a sum greater than 2 were assigned a code of "2" (noticeable signs of movement).

TABLE 2
RESULTS OF HOUSEHOLD SURVEY

	Address	Answers to Survey Questionnaire										SUM	CODE (based on questionnaire)	CODE (based on site visit)	OVERALL CODE
		a.	b.	c.	d.	e.	f.	g.	h.	i.	j.				
1	229 W. Highland Park Drive	0	0	0	0	0	0	0	0	0	0	0	0	NV	**0**
2	231 W. Highland Park Drive	0	0	1	0	0	0	0	N/A	0	0	1	1	1	**1**
3	235 W. Highland Park Drive	0	0	0	N/A	0	0	0	0	0	0	0	0	0	**0**
4	207 Highland Park Drive	0	0	0	N/A	0	0	0	N/A	0	0	0	0	NV	**0**
5	219 Highland Park Drive	1	1	0	0	0	0	1	N/A	1	1	5	2	2	**2**
6	401 Rons Court	0	1	0	0	1	1	0	0	0	0	3	2	2	**2**
7	402 Rons Court	0	0	0	N/A	0	0	0	0	N/A	0	0	0	NV	**0**
8	404 Rons Court	1	1	0	N/A	1	1	0	N/A	N/A	1	5	2	1	**1**
9	406 Rons Court	0	0	0	N/A	0	0	0	N/A	N/A	0	0	0	0	**0**
10	409 Rons Court	0	0	0	N/A	0	0	0	0	1	1	2	1	2	**2**
11	490 Haussler Road													0	**0**
12	492 Haussler Road	1	1	1	0	0	0	1	0	1	1	6		2	**2**
13	493-A Haussler Road	0	0	0	N/A	0	1	0	0	0	0	1		1	**1**
14	505-A Haussler Road	1	N/A	0	N/A	0	1	0	N/A	1	1	4		1	**1**
15	520 Haussler Road													0	**0**
16	120 Apple Lane	1	1	1	N/A	0	1	1	0	1	1	7		1	**2**
17	122 Apple Lane	0	1	1	0	0	1	1	0	1	0	5		2	**2**
18	123 Apple Lane	0	0	0	N/A	0	0	1	0	N/A	0	1		0	**1**
19	124 Apple Lane	0	1	1	N/A	0	0	1	1	1	1	6		2	**2**
20	125 Apple Lane	0	1	0	0	0	0	0	0	0	0	1		0	**1**
21	127 Apple Lane	1	1	1	1	0	0	0	0	1	1	6		2	**2**
22	488 Apple Lane	1	1	1	1	1	1	1	0	0	1	8		2	**2**
23	494 Apple Lane	1	1	1	1	1	1	1	1	N/A	1	9		2	**2**
24	123 W. Vista Way	0	1	0	0	0	0	1	0	1	1	4		2	**2**
25	131 W. Vista Way	0	0	0	0	0	0	0	0	0	0	0		0	**0**
26	160 W. Vista Way	0	0	0	0	0	0	0	0	0	0	0		NV	**0**
27	505 Cris Road													1	**1**

TABLE 2 continued
RESULTS OF HOUSEHOLD SURVEY

28	100 N. Vista Way													0	**0**
29	110 N. Vista Way													0	**0**
30	111 N. Vista Way	0	0	0	0	0	0	0	0	0	0	0		0	**0**
31	117 N. Vista Way	0	1	0	0	0	1	0	0	0	0	2		NV	**1**
32	128 N. Vista Way													0	**0**
33	144 N. Vista Way	0	1	0	N/A	0	1	0	N/A	1	1	4		NV	**2**
34	116 S. Vista Way													0	**0**
35	119 S. Vista Way	0	0	0	0	0	0	0	0	0	0	0		0	**0**
36	127 S. Vista Way	1	0	0	0	0	0	0	0	0	0	1		NV	**1**
37	131 S. Vista Way	1	1	1	N/A	0	1	1	1	N/A	1	7		2	**2**
38	135 S. Vista Way	1	0	0	N/A	0	1	0	0	0	0	2		NV	**1**
39	139 S. Vista Way	0	0	0	0	0	0	0	0	0	0	0		NV	**0**
40	142 S. Vista Way													0	**0**
41	145 S. Vista Way	0	0	0	N/A	0	0	0	0	0	0	0		0	**0**
42	146 S. Vista Way	0	0	0	0	0	0	0	0	0	0	0		0	**0**
43	147 S. Vista Way	1	1	0	0	0	1	1	0	0	0	4		0	**0**
44	148 S. Vista Way	1	1	1	1	0	1	0	0	N/A	1	6		2	**2**
45	149 S. Vista Way													0	**0**
46	152 S. Vista Way	0	0	0	0	0	0	0	0	0	0	0	0	NV	**0**
TOTALS															
"1" (yes)		13	17	10	4	4	14	11	3	10	14	100			
"2" (no)		24	19	27	18	33	23	26	27	20	23	240			
CODE 0															**22**
CODE 1															**10**
CODE 2															**14**

Explanation:

* 1 = "yes" ***for survey answers only***
* 0 = "no" ***for survey answers only***
* NV = not visited
* N/A = not applicable
* CODE (based on questionnaire) derived from number of questions answered "1" (i.e., yes), as follows:

0 1's = CODE **0** (no appreciable signs of movement)
1-2 1's = CODE **1** (possible signs of movement)
> 2 1's = CODE **2** (noticable signs of movement)

Codes of 0, 1, or 2 were also assigned to each home visited. This code assignment was subjectively based on field observation. These codes are also included on Table 2. As indicated on Table 2, a relatively close correlation exists between coded based on survey responses and codes based on site visits. An overall code was then given to each home. Ultimately, for those homes with both a questionnaire code and a site visit code, the site visit code was used. It should be noted that these questionnaire codes are based only on the responses of the residents. As with any qualitative type study, a range of interpretation exists. For example, many residents may not have noticed signs of movement which are being exhibited in their homes. Some residents may have mistaken older cracks, which could be the results of normal settling, for new signs of movement. In addition, many residents may have been hesitant to report signs of movement in their homes due to understandable concerns about property value.

Results

a) Ground Surface Survey

The total station survey data are included as Appendix A. The calculated coordinates are summarized in Table 1. As indicated in Table 1, movement at each station was calculated using the change in elevation and vertical coordinates between survey dates. The results for stations #3 and 5 were anomalous and were not considered in the study. As a result of the survey, measurable ground movement appears to have occurred at each location. A maximum movement of 24 millimeters (1 inch) was calculated (station #1).

b) Residential Property Evaluation

The results of the overall code assignment are summarized in Table 2 and spatially presented on Figure 7. The property boundary for a home with a code of 2 is indicated in red, yellow for a 1, and green for a 0. As illustrated on Figure 5, 46% of all participating homes exhibited signs of movement. Of these, 66% are located below the scarp (on the ancient landslide), and 34% are located above the scarp. Movement in homes located above the scarp could possibly be undergoing localized movement associated with sliding on small, local drainage slopes of settling.

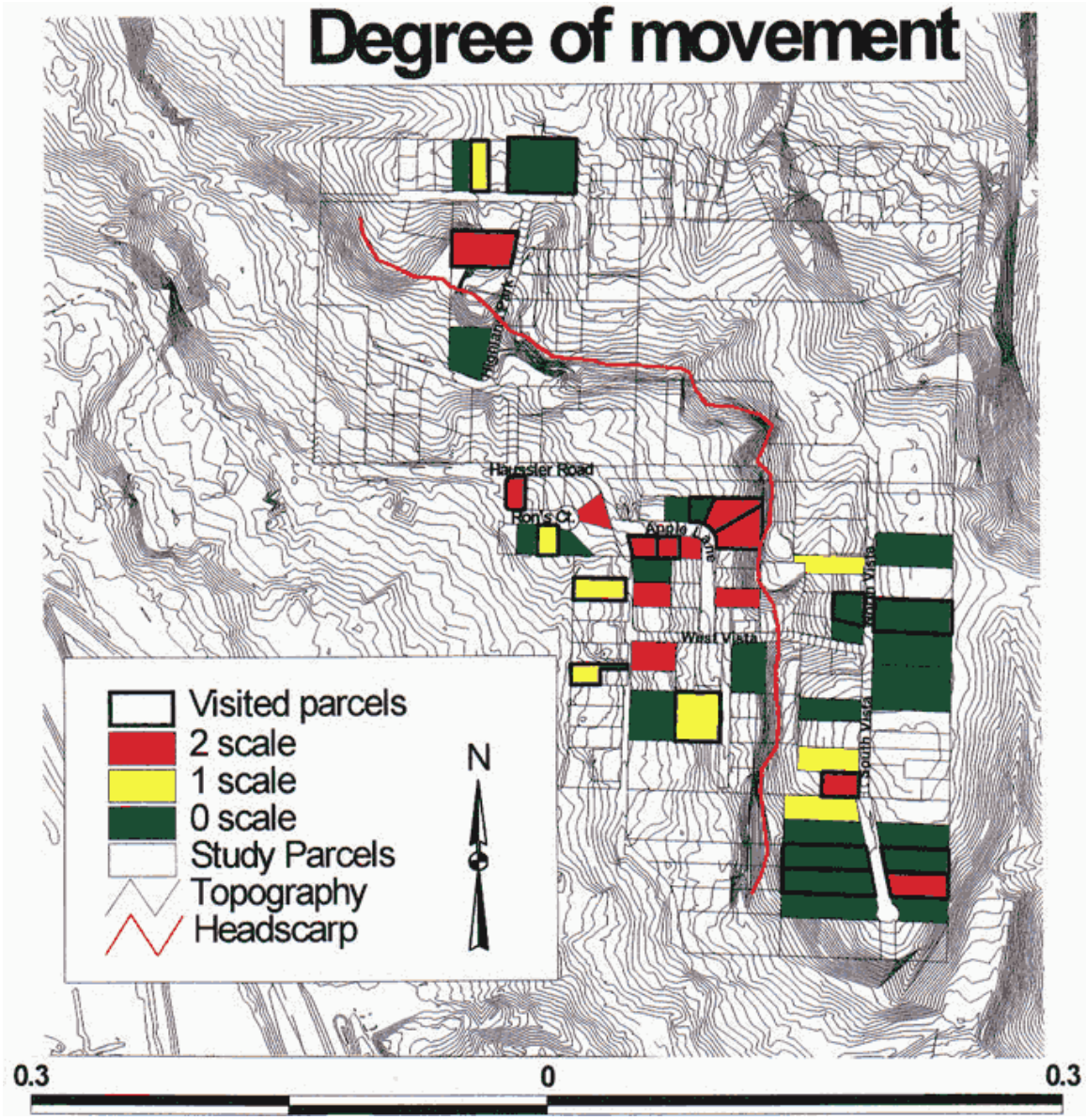


FIGURE 7

Results of Movement Evaluation

Conclusions and Recommendations

Based on the results of this study, it appears as though the ground is experiencing movement in the Haussler Road area in Kelso, Washington. In addition, a spatial pattern appears to exist among those homes exhibiting movement. A greater percentage of these homes are located on the ancient landslide than of those located above the landslide. Of the homes located above the ancient landslide scarp, 30% are exhibiting signs of movement. Of the homes located below the scarp (on the ancient landslide), 61% are exhibiting signs of movement.

Due to the subjective nature of the study, it is recommended that a more detailed study be conducted on the Haussler Road area as soon as possible. The detailed study will need to definitively determine if ground movement is occurring. In addition, the subsurface of the ancient landslide should be investigated to determine hydrology, slip plane location, and nature of the sediments and bedrock. The detailed study should utilize intrusive techniques such as slope inclinometer installation.

References:

Fiksdal, J.A., 1973. Slope Stability of the Longview-Kelso Urban Area, Cowlitz County. *Washington Department of Natural Resources Open File Report 73-2*, revised 1989.

Koloski, J.W., 1998. Slope Failure Evaluation, Aldercrest-Banyon Landslide, Kelso, Washington. Report, Geotechnical Engineering Services, Geo Engineers, Inc., Redmond, Washington.

McGuffey, V.C., Modeer, V.A, Jr., and Turner, K. A., 1996. Chapter 10 (Subsurface Exploration) in *Landslides, Investigation and Mitigation. National Research Board Special Report 247*, Transportation Research Council, Washington, D.C.

Walsh, T.J., Korosec, M.A., Phillips, W.M., Logan, R.L., and Schasse, H.W., 1987, Geologic Map of Washington – Southwest Quadrant. Washington Division of Geology and Earth Resources Geologic Map GM-34.

Appendix A

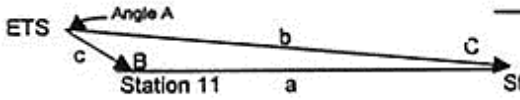
Trip Two Data

Corrected data from ETS

Station	Reflector Ht	HAR	ZA	SD
1	1.45	89.78472	85.39583	102.90
2	1.45	89.85000	83.00972	169.82
3	1.45	126.73333	86.44722	47.43
4	1.45			
5	1.45	193.06528	86.05972	220.29
6	1.45	193.69167	85.25833	251.60
7	1.45	192.24167	80.99444	334.90
8	1.45	205.47639	85.55000	264.83
9	1.45	303.34167	93.21806	18.22
10	1.45	193.29028	87.05278	79.06
11	1.45	235.99722	89.71389	12.77

Correction to North

Points 10 and 11 are known in real space (Ron's Ct survey data)



Angle A= 42.7069
Line a = 70.214043 Law of cosines

Angle C = 7.0835 Law of sines
Angle B = 130.2095

ETS angle of line a = 186.20675
North angle of line a = S 89° 38' 30"E
North angle of line a = 90.358333
95.84842

	Total x-y movement
0	0.0
Station 10 #VALUE!	#VALUE!
0	0.0
0.0000	
0	#VALUE!
0	0.0
0	#VALUE!
0	13021.0
0	0.0
0	#VALUE!
0	#VALUE!

Corrected coordinates, trip two *(North being 0°)*

1		353.93630	85.395833	102.895
2		354.00158		169.82
3		30.88491	86.447222	47.427
4		-95.84842	0	0
5		97.21686	86.059722	220.292
6		97.84325	85.258333	251.6
7		96.39325	80.994444	334.897
8		109.62797	85.55	264.834
9		567.49325	93.218056	18.217
10	1.45	97.44186	87.052778	79.059
11	1.45	140.14880	89.713889	12.766

Point	HAR	ZA	SD	*Easting*	*Northing*	*Elevation*
1	353.93630	85.39583	102.89500	89.17	201.99	108.26
2	354.00158	0.00000	169.82000	100.00	100.00	269.82
3	30.88491	86.44722	47.42700	124.30	140.62	102.94
4						
5	97.21686	86.05972	220.29200	318.03	72.39	115.14
6	97.84325	85.25833	251.60000	348.39	65.78	120.80
7	96.39325	80.99444	334.89700	428.71	63.17	152.42
8	109.62797	85.55000	264.83400	348.69	11.31	120.55
9	567.49325	93.21806	18.21700	91.60	83.87	98.98
10	97.44186	87.05278	79.05900	178.29	89.77	104.06
11	140.14880	89.71389	12.76600	108.18	90.20	100.06
			ETS point	100.00	100.00	100.00

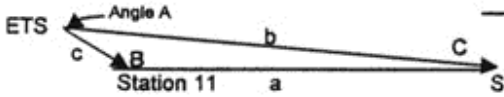
Trip One Data

Corrected data from ETS

Station	Reflector Ht	HAR	ZA	SD
1	1.45	204.45278	85.35347	102.91
2	1.45	204.50417	82.95556	169.815
3	1.45	241.39167	84.66319	108.62
4	1.45	286.58889	85.62569	87.735
5	1.45	307.72222	85.48403	174.2635
6	1.45	308.35	85.29097	251.6085
7	1.45	306.90185	81.02222	334.912
8	1.45	320.12083	85.57639	264.993
9	1.45	58.02361	93.04722	18.192
10	1.45	307.95556	87.01528	79.057
11	1.45	350.73611	89.63889	12.772

Correction to North

Points 10 and 11 are known in real space (Ron's Ct survey data)



Angle A= 42.7806

Line a = 70.220723 Law of cosines

Angle C = 7.0961 Law of sines

Angle B = 130.1233

ETS angle of line a = 300.85946

North angle of line a = S 89° 38' 30"E

North angle of line a = 90.358333

210.50113

		Total x-y movement
	0	0.0
Station 10	#VALUE!	#VALUE!
	0	0.0
0.0000		
	0	#VALUE!
	0	0.0
	0	#VALUE!
	0	13012.3
	0	0.0
	0	#VALUE!
	0	#VALUE!

Corrected coordinates, trip one *(North being 0°)*

1		353.95165	85.35347	102.91
2		354.00304		169.815
3		30.89054	84.66319	108.62
4		76.08776	85.62569	87.735
5		97.22109	85.48403	174.2635
6		97.84887	85.29097	251.6085
7		96.40072	81.02222	334.912
8		109.61970	85.57639	264.993
9		207.52248	93.04722	18.192
10	1.45	97.45443	87.01528	79.057
11	1.45	140.23498	89.63889	12.772

Point	HAR	ZA	SD	*Easting*	*Northing*	*Elevation*
1	353.95165	85.35347	102.91000	89.19	202.00	108.34
2	354.00304	0.00000	169.81500	100.00	100.00	269.82
3	30.89054	84.66319	108.62000	155.52	192.81	110.10
4	76.08776	85.62569	87.73500	184.91	121.03	106.69
5	97.22109	85.48403	174.26350	272.34	78.16	113.72
6	97.84887	85.29097	251.60850	348.41	65.76	120.66
7	96.40072	81.02222	334.91200	428.75	63.12	152.26
8	109.61970	85.57639	264.99300	348.86	11.29	120.44
9	207.52248	93.04722	18.19200	91.61	83.89	99.03
10	97.45443	87.01528	79.05700	178.28	89.76	104.12
11	140.23498	89.63889	12.77200	108.17	90.18	100.08
			ETS point	100.00	100.00	100.00

Corrections

Relative changes (m)

Station	Δ Easting	Δ Northing	Δ Elevation
1	0.02640	0.01167	0.07705
2	0.00000	0.00000	-0.00500
3	31.22552	52.18452	7.16382
4			
5	-45.68560	5.77214	-1.41674
6	0.01673	-0.02716	-0.14213
7	0.03513	-0.04738	-0.15801
8	0.17100	-0.02052	-0.10935
9	0.00193	0.02379	0.05556
10	-0.00688	-0.01658	0.05157
11	-0.01097	-0.01683	0.01675

Making station 7 the "non-moving" point

				Results		
Station	*Δ Easting*	*Δ Northing*	*Δ Elevation*	*Total vectoral movement (m)*	*Total vectoral movement (mm)*	*Total x-y movement*
1	-0.009	0.059	0.235	0.243	24	6.0
2	-0.035	0.047	0.153	0.164	16	3.7
3	~~31.190~~	~~52.232~~	~~7.322~~	~~61.275~~	~~6127~~	~~6083.6~~
4		*Gone*			*Gone*	
5	~~-45.721~~	~~5.820~~	~~-1.259~~	~~46.107~~	~~4611~~	~~4609.0~~
6	-0.018	0.020	0.016	0.032	3	2.7
7	0.000	0.000	0.000	0.000	0	0.0
8	0.136	0.027	0.049	0.147	15	13.9
9	-0.033	0.071	0.214	0.228	23	7.9
10	-0.042	0.031	0.210	0.216	22	5.2
11	-0.046	0.031	0.175	0.183	18	5.5

Station	Easting	Northing	Total x,y,z change (mm)
1	89.19	202.00	242.519
2	82.39	267.61	318.850
3	155.52	192.81	61274.960
4	184.91	121.03	
5	272.34	78.16	46106.791
6	348.41	65.76	31.616
7	428.75	63.12	0.000
8	348.86	11.29	146.801
9	91.61	83.89	227.559
10	178.28	89.76	215.958
11	108.17	90.18	183.304

Appendix B

Survey: Ground Movement Study
Haussler Road Area, Kelso WA.
(Ron's Ct., Apple Lane, North, South, and West Vista Way, Highland Park Dr. and West Highland Park Dr.)
Portland State University

Please take a moment to answer the following survey questions. This survey is an important part of a study being conducted by a group of geology graduate students from Portland State University. The purpose of the study is to determine if ground movement is occurring in your area. Answering the survey questions is optional, and the study is at no cost to you. You will, however, benefit from the results of the study. In addition, it will be a learning experience for the students. A copy of the final report will be available by mid-March, 1999 and will be presented to the city of Kelso and the residents of your area.

Name: (optional) _____
Address:
_____
_____
_____

Please answer the following questions, to the best of your knowledge, with "yes", "no", or "N/A" (not applicable). Please note that the questions are referring to observations you have made **within the last six months**.

1. Have you resided at this residence for at least the last six months?

2. Have you noticed, in the last six months:

    a. any new cracks forming in the foundation of your home? (i.e., the concrete floor of your garage or the walls of your basement)

    b. any new cracks forming in other concrete pads? (i.e., patio, driveway)

    c. any nail bulging or popping out of your drywall?

    d. if your chimney is external, has it separated from your house or shifted in any way?

    e. any windows jammed or cracked?

f. any doors behaving differently? (i.e., doors swinging open or shutting by themselves; doors no longer closing; doors becoming jammed shut)

g. any unusual noises coming from your house? (i.e., creaking)

h. any ceiling beams showing signs of twisting or bowing?

i. any fences or retaining walls leaning, breaking, or moving out of alignment?

j. any changes to your landscape? (i.e., trees beginning to lean, a change in water drainage)

3. Have you noticed any other changes to your home in the last six months? Do you have any comments?

4. Depending upon your responses to the above questions, we may want to take a brief look at your home. If this would be acceptable to you, may we contact you by telephone? If so, phone number: _____

Thank you for you assistance with our study. If you have any questions, you may contact our supervisor, Dr. Scott Burns of the Portland State University geology department, at (503) 725-3389.

Please return this form in the pre-addressed envelope by _____