Geologic and Seismic Studies Related to Construction of the Northern Tier Pipeline in Clallam County, Washington

by

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Abstract

This report presents the results of our review and analysis of geologic and geophysical information submitted to Clallam County by the Northern Tier Pipeline Company (NTPC) as part of their proposal for construction of a marine pipeline facility and pipeline which passes through the county. This report addresses in detail the seismicity of the region; estimates maximum probable and possible design earthquakes for this region; estimates ground acceleration in different soil types; and calculates soil liquefaction potential for materials in the pipeline corridor. Particular points investigated are the effects on the local water table; estimated scour depth at the Dungeness River crossing; depth of anchor penetration in sediments, and possible subsidence or liquefaction on Ediz Hook due to pile driving operations. Two conclusions can be drawn from the review: first, that the information submitted by NTPC is inadequate with regards to scope and content; and secondly that from what information is available the Ediz Hook terminal site should be abandoned.

SECTION I SEISMICITY

IA. Introduction

The Port Angeles and east Clallam County area, along the proposed pipeline corridor, is in the Puget Sound-Vancouver Island Tectonic Province. This province is approximately 2 degrees wide and has a north-south trend in Washington State to about latitude 48°N, where it contin-uses in a north-westerly direction through Vancouver Island.

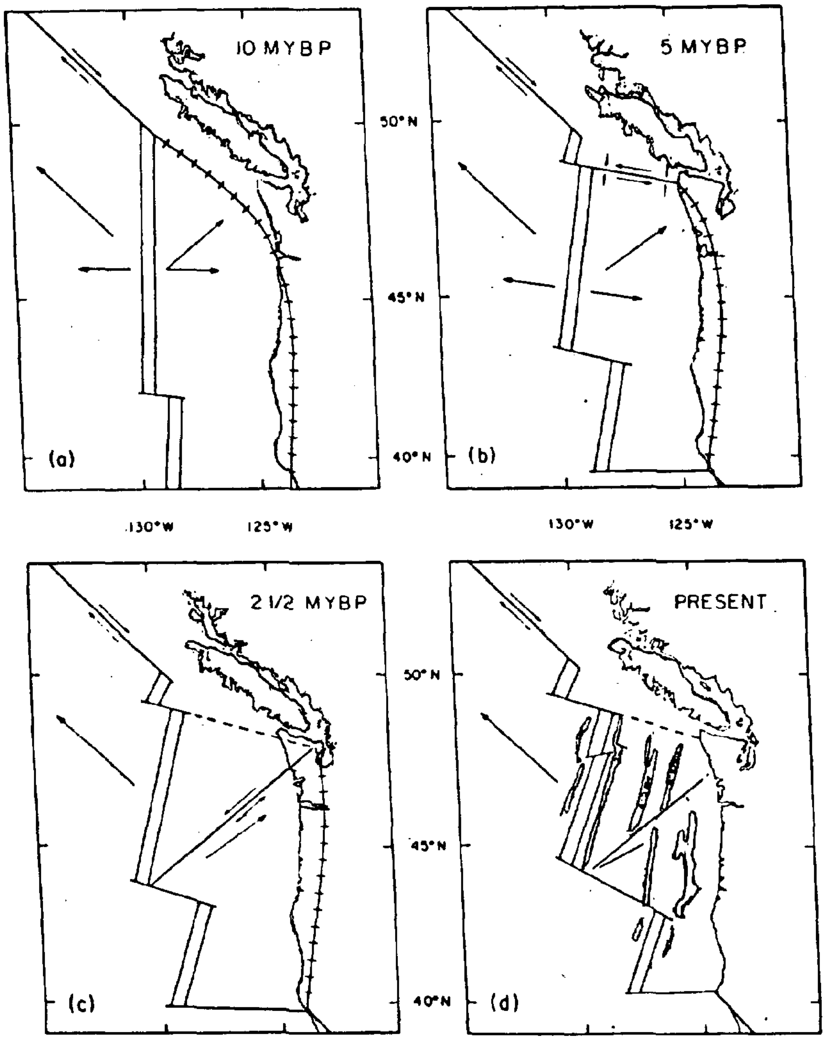
The Puget Sound-Vancouver Island Province lies to the east of, and is parallel to, the subducted Pacific plate, (Crosson, 1972). Figures I-1 and I-2 shows the tectonic setting as described above.

In east Clallam County there are no known surface ruptures associated with recorded seismicity. There are some mapped surface faults in east Clallam County. However, there is no history of their surface movement during any felt or instrumentally recorded earthquake. There are some inferred faults (Gower 1978) with previous movement which was at least pre-Fraser (i.e., 1100-1200 years). Any post-Fraser seismic activity appears to be warping and folding, similar to the rest of the seismically active tectonic province described above. It is therefore believed that past large earthquakes have been deep enough to preclude surface rupture, but there has been surface warping from past large earthquakes, (Gower, 1978; Slawson, 1978).

The east Clallam County area, which is in the same tectonic province as Puget Sound and Vancouver Island, can be subjected to rather large earthquakes. We have had a magnitude 7.3 shock on Vancouver Island in 1946, a magnitude 7.1 event in southern Puget Sound in 1949, and a magnitude 6.5 earthquake also in Puget Sound in 1965. Between these two energy release volumes is a seismic gap which includes southeast Vancouver Island and northern Puget Sound (Milne, 1966). Port Angeles and the proposed pipeline route including the Strait of Juan de Fuca and Saratoga Passage, is actually in this gap area and therefore can be expected to be subjected to a large earthquake someday. See figure I-3 for seismicity map.

Because the seismic record for the above mentioned tectonic province is for only about 120 years, the actual occurrence rate and occurrence pattern of the larger events is not clear. In the last 120 years all the large earthquakes have occurred in a 20-year period--between 1946 and

Fig. I-1



Diagramatic sketch of several phases of plate interactions in the northeast Pacific during the past 10 m.y. showing hypothetical relationships of Puget Sound region to larger features. Large arrows indicate the direction of gross plate motion relative to the American plate. Double line represents spreading center, hatched line a trench zone and single line a strike slip fault. (Crosson 1972)

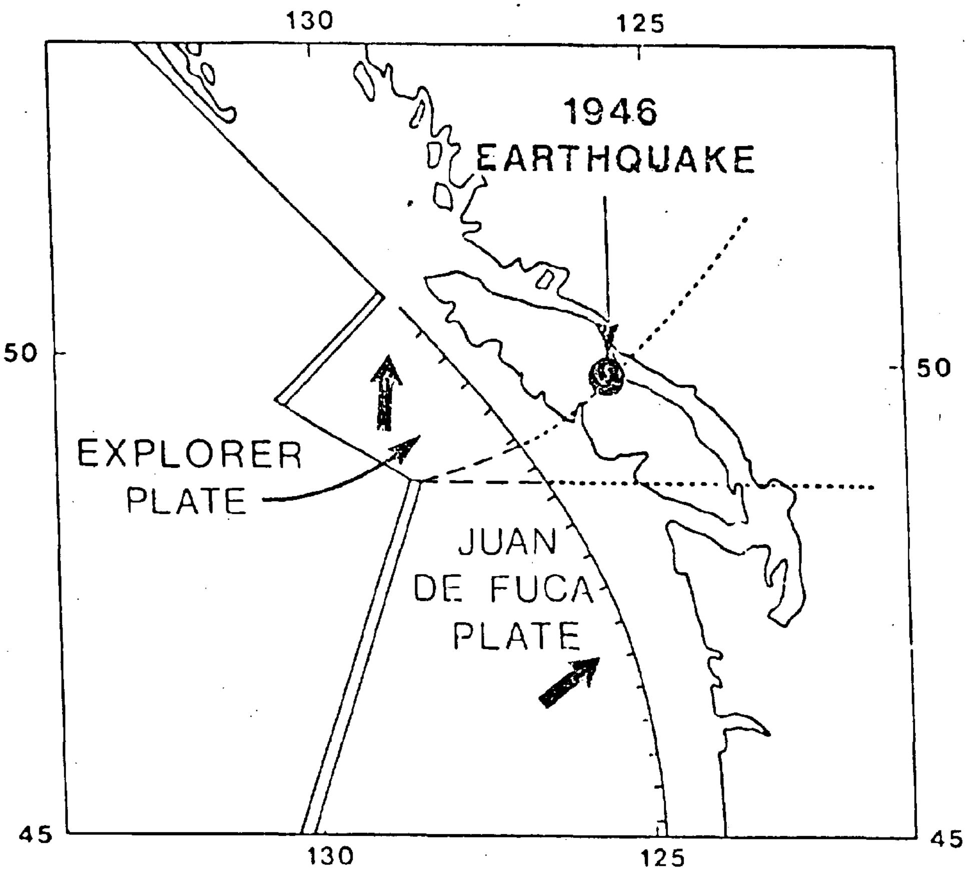


FIG. Earthquake epicenter shown relative to the plate interaction model of Riddihough (1977). Arrows indicate relative movement of small plates relative to the America plate.

Figure I-2. As can be seen by this diagrammatic map, the plate boundary (i.e. Explorer Plate and the Juan de Fuca Plate) are parallel to, and an integral part of the Vancouver Island-Puget Sound Tectonic Province.

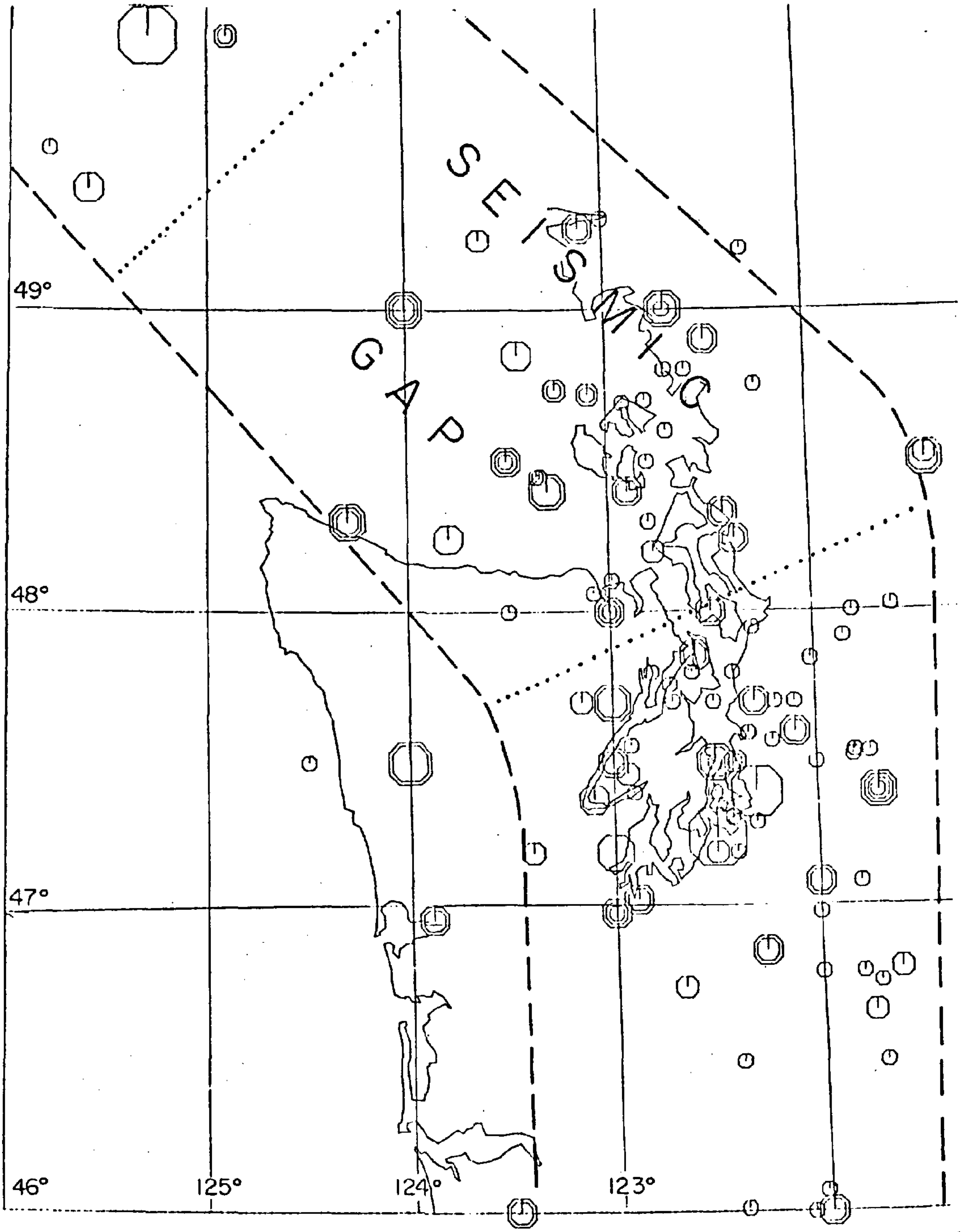


Figure I-3 shows the seismic gap where there has been no earthquakes with a magnitude above 6.0. This zone of low energy release strongly suggests that a large earthquake can occur within this area.

1965--and were about 3 1/2 degrees between epicenters. All of the epicenters of these large earthquakes are found along the central axis of the province.

Several people have tried to divide the Vancouver Island-Puget Sound Province into sub-provinces. Unfortunately, there is not a long enough seismic record to convincingly accomplish this. Another problem is that there is no firm evidence to explain the exact mechanism that has caused large past earthquakes in this region so as to be able to subdivide the area on a geologic/tectonic basis. For the above reasons the entire area must be treated as one province until more knowledge is obtained.

DISCUSSION AND CONCLUSIONS

IB. Possible and Probable Maximum Magnitude Earthquakes

Recurrence curves have been constructed for the above described tectonic province, figure I-4. The earthquakes used in this recurrence study are listed in Appendix 1. Before preceding with this report, a short discussion on Modified Mercalli Intensity data must be made. The largest Mercalli Intensity historically recorded for the Port Angeles area is a VII.

Intensity data can be misleading unless there is a large volume of data over a relatively small geographic area, for any particular earthquake. Unfortunately we do not have sufficient intensity data from any earthquake in the Clallam County area to be sure that the recorded intensity for a particular area is the real maximum intensity. For a felt earthquake there is usually one or two intensity estimates from any town or city the size of Port Angeles. This data is usually obtained from the local U.S. Postmaster.

Since about 1930 the federal government has supported an intensity gathering program. This data is used in several statical studies in Washington State (Stepp 1973, Algermissen 1975, Rasmussen 1975, Malone 1979).

Because we have limited intensity data from Clallam County this seismic investigation will not attempt to evaluate the largest probable or possible earthquake that can effect the pipeline facilities from intensity data.

Statistically we could have a magnitude 7.3 earthquake about every 500 years in the Vancouver Island-Puget Sound Province. We have had a magnitude 7.3, 7.1 and a 6.3 in less than three years, so the projected statistics for this area are not a good indication as to the expected occurrence of the larger seismic events. We must conclude that we do not know how often we can expect a magnitude 6.5 to 7.5 event. The past seismic record leads one to believe that we have statistically erratic and geographically concentrated seismicity, as far as the larger events are concerned. There is also evidence to suggest that the large events occur along the axial portion of the province; and if this is all true, as the past seismic history has shown us, we could expect a large event occurring with a hypocentral distance of 40 km from Ediz Hook and the proposed pipeline route in Clallam County.

The actual time of this large event is not predictable due to the short historic seismic record and also because of the unknown specific tectonic process which cause these large earthquakes. There is a good possibility that the next large event will occur in the seismic gap area of past low energy release. See figure I-3.

Because of the possible consequences of a large oil spill from earthquake forces, a conservative approach should be pursued in interpreting the seismic history of this area. The loss of human life from a large seismic event is not known; however, the ecologic and economic repercussions from a major oil spill would be of major consequences to the people of the entire state, and especially those of Clallam County and other counties bordering Puget Sound.

The largest possible earthquake to take place in the Vancouver Island-Puget Sound Province is believed to be a magnitude 7.5 at Ediz Hook, Green Point or along the pipeline route. The reason for predicting this magnitude event is because we have had earthquakes of 7.3, 7.1, 6.5 and 6.3 magnitude in this province in the last 120 years. Algermissen has concluded that from his studies of this area a magnitude 7.5 event can occur in the Puget Sound region which is part of the above described province, (Algermissen 1975). Any critical facilities built in the Vancouver Island-Puget Sound tectonic province should be designed to withstand this 7.5 magnitude event.

The largest probable earthquake to occur in the province is estimated to be a magnitude 6.5 with an hypocentral distance of 40 km from Ediz Hook, Green Point or along the pipeline route. This 6.5 magnitude shock has a statistical recurrence rate of approximately 80 years; but due to the nearness of the seismic gap and the real uncertainty of the recurrence rate, there is good reason to believe that an event of this magnitude will occur during the lifetime of the oil pipeline transmission facilities. See figure I-4 for the recurrence curve of the Vancouver Island-Puget Sound Province.

Noncritical facilities could be constructed to maintain their structural integrity from this magnitude 6.5 event, as long as there would be no oil spill or loss of life if structural failure occurred. For the actual pipeline loading and docking facilities and critical facilities at the tank farm, the largest possible event must be used for the safety of the people and for the maintenance of an acceptable environment in western Washington and southern British Columbia.

Estimated Acceleration

The thickness of the unconsolidated sediments along the Clallam County pipeline route and at the storage facilities are approximately 600 feet (Hall and Othberg, 1974). This means that projected Bedrock accelerations may be used, but one must be aware of possible amplification at sites which are not Bedrock (Algermissen, 1976).

To develop some realistic accelerations for Green Point, Ediz Hook and along the pipeline route, several acceleration attenuation studies were reviewed. Those studies taken into consideration inorder to arrive at a conservative estimate of ground surface acceleration for the area of interest include Espinosa, 1980; Boore et al., 1980; Algermissen, 1976; Trifunac, 1976; Schnabel and Seed, 1973; Seed et al., 1976; and strong motion records from past earthquakes in the Puget Sound-Vancouver Island Province.

Predictions of accelerations from earthquakes at a site in Clallam County, Straits of Juan de Fuca and Saratoga Passage, with a hypocentral distance of 40-60 km will be considered to have a hypocentral distance of 40 km and a epicentral distance of zero. This was done because a large earthquake could take place at any location along the pipeline route or its related facilities; also, because of the limited amount of data available from strong motion accelerations in western Washington. Another reason is that most of the published acceleration data is from California, where earthquakes are shallow (5-20 km) and attenuation is greater than from the deeper events in western Washington having the same epicentral distance.

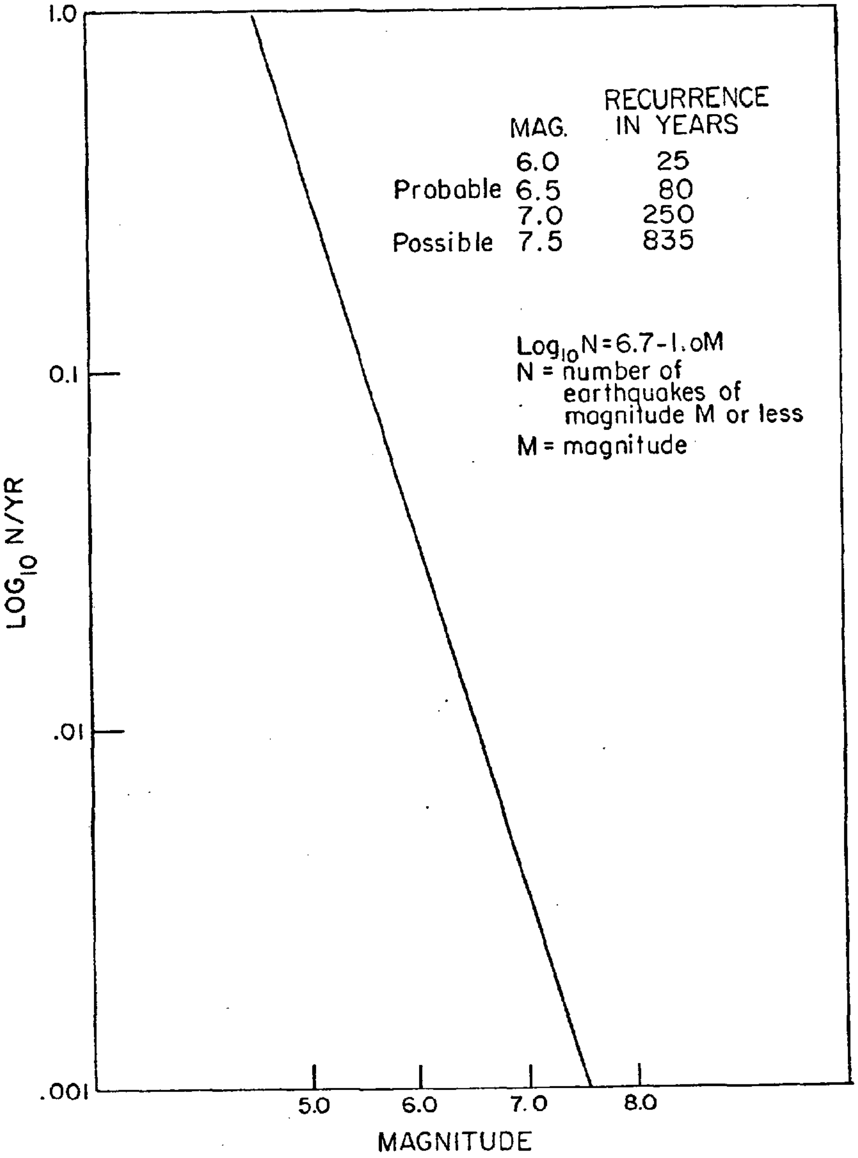


Figure I-4 reflects a statistical recurrence curve. This is an average recurrence rate and doesn't reflect the past seismic history because the seismic record is for only 120 years and because of the seismic gap.

Based on the past record of acceleration data from this province and a review of the accepted published literature it is estimated that a magnitude 6.5 event at a 40 km hypocentral distance directly below a facility will generate horizontal accelerations in consolidate soils of 0.25 g. A magnitude 7.5 earthquake with a similar depth, epicentral distance and surface material will have an acceleration of 0.35 g. It is also believed that until careful dynamic testing is completed there will be at least a 100% amplification at Ediz Hook and all B type soil locations. (B type soils as defined by Shannon and Wilson, 1978)

Another approach to seismic ground motion, which gives relationships between acceleration, velocity and displacement has been done by (Boore 1978). His findings are shown in Appendix 2.

Below is a table of maximum ground motion for earthquakes in the magnitude range expected in the Vancouver Island-Puget Sound Province.

From Boore's findings:

Magnitude 7.1-7.6 earthquakes at 60 km distance

** Predicted Interval	Acceleration in g's	Velocity cm/sec	Displacement cm
95%	0.55	*	*
70%	0.25	24	12

*For velocity and displacement there are only six data points and therefore only the 70% predicted interval is shown.

**Predicted Interval is that interval containing a certain percent of the data points (i.e., 70% interval has 70% of the data points in that interval).

In any design phase it must be recognized that while accelerations appear to be similar for both soil and Bedrock, soil may be, however, higher in some cases by a factor of 2 to 3 times the estimated rock accelerations (Algermissen, 1976). The peak velocities and displacements are significantly greater on soil sites than at Bedrock sites in almost all cases (Boore, 1978).

Magnitude 6.0-6.4 earthquakes at 60 km distance

Predicted Interval	Acceleration in g's	Velocity cm/sec	Displacement cm
95%	0.19	36	19
70%	0.11	17	8

*Velocity and displacement are for magnitude 6.4 events only.

In applying our interpretation and Algermissens observations on the possible effect of acceleration on unstable soils, the following accelerations are predicted.

	Magnitude 7.5 event Acceleration in g's	Magnitude 6.5 event Acceleration in g's
Green Point	0.35	0.25
C type soils	0.35	0.25
B type soils	0.70	0.50
Ediz Hook	0.70	0.50
A type soils	*	*

*completely liquified   Soil types from Shannon & Wilson (July 1978)

IC. Summary and Recommendations

From the present seismic study of east Clallam County, the Straits of Juan de Fuca and Saratoga Passage, the Northern Tier Pipeline Company has done an inadequate and less than thorough analysis of the seismicity and related ground motion of the area.

Their findings appear to be a glossing over of the potential problems related to the construction of a critical facility in a seismically active area.

It is the conclusion from this present study that the predicted accelerations of Northern Tier Pipeline Company are less than realistic and it is strongly felt that the accelerations predicted from this report be adopted.

It is obvious that further dynamic analysis must be done before any conclusion can be drawn as to the safe construction and operation of a pipeline with its related facilities. The potential damage possible from a large oil spill warrants a very conservative approach to safeguard the people and their natural environment in Washington State and southern British Columbia.

Ediz Hook may have serious stability problems during strong earthquake motion and also during strong vibrational phases of construction. It is highly recommended that a thorough dynamic analysis of Ediz Hook be accomplished before even preliminary plans for design of docking facilities be attempted.

The Green Point storage area is rather sandy, and with some clay units present, increased hydrostatic pressures could cause the saturated sands to lose their cohesiveness. The same situation exists at Port Williams and proper soil analysis can confirm or eliminate this potential problem.

There is also evidence at the cliff at Port Williams of a quick clay unit which could liquify under dynamic loading. Design should take this into account also.

It is the recommendation of this report that unless a very thorough dynamic analysis of all the soil properties are related to a magnitude 7.5 earthquake, with a 40 km hypocentral distance from the area of study, and its appropriate accelerations, as outlined in this report, no critical facility should be constructed.

As of the writing of this report, Northern Tier Pipeline Company has not accomplished these studies, without which no definite conclusions to build can be made.

SECTION II
CLALLAM COUNTY AQUIFER IN THE VICINITY OF THE PROPOSED PIPELINE ROUTE

IIA. Introduction

The information used in the this study was from Noble (1960) and from the U. S. Geological Survey, Tacoma Office. The U. S. Geological Survey data is an uncorrected print-out of all reported wells drilled in the area of interest through the summer of 1979, (see appendix 3). Noble's water table investigation was to the east of Siebert Creek and along the proposed pipeline route in eastern Clallam County.

With the additional well data from the U. S. Geological Survey, the water table appears to be essentially the same as interpreted by Northern Tier Pipeline Company, Hydrological plate 27, Application for Site Certification Vol. IV, Maps. Minor fluctuations between our interpretation of the water table elevations and that of Northern Tier Pipeline Company may be due to additional well data not available to Northern Tier Pipeline Company during their study or poor well head elevation control used in Northern Tier Pipeline Company's and our investigation.

IIB. Discussion

Noble's water table map is essentially the map of Northern Tier Pipeline Company, plate 27 (cited above), except for the extreme western portion which Noble didn't include in his study. Figure II-1 shows our interpretation of the Clallam County water table in the vicinity of the proposed pipeline route using the U. S. Geological Survey preliminary data. The water table data west of Green Point was not included in this study. The reason was that the study only included that area along Northern Tier Pipeline Company's route in Clallam County.

At lower surface elevations in eastern Clallam County there are areas of interbedded silts, clays and sandy layers. Where this strata occurs, there are found perched water tables. These perched water tables are usually not exceptionally good water producers, and better discharge is found by drilling to the main aquifer below.

From Noble's (1960) work and the above mentioned

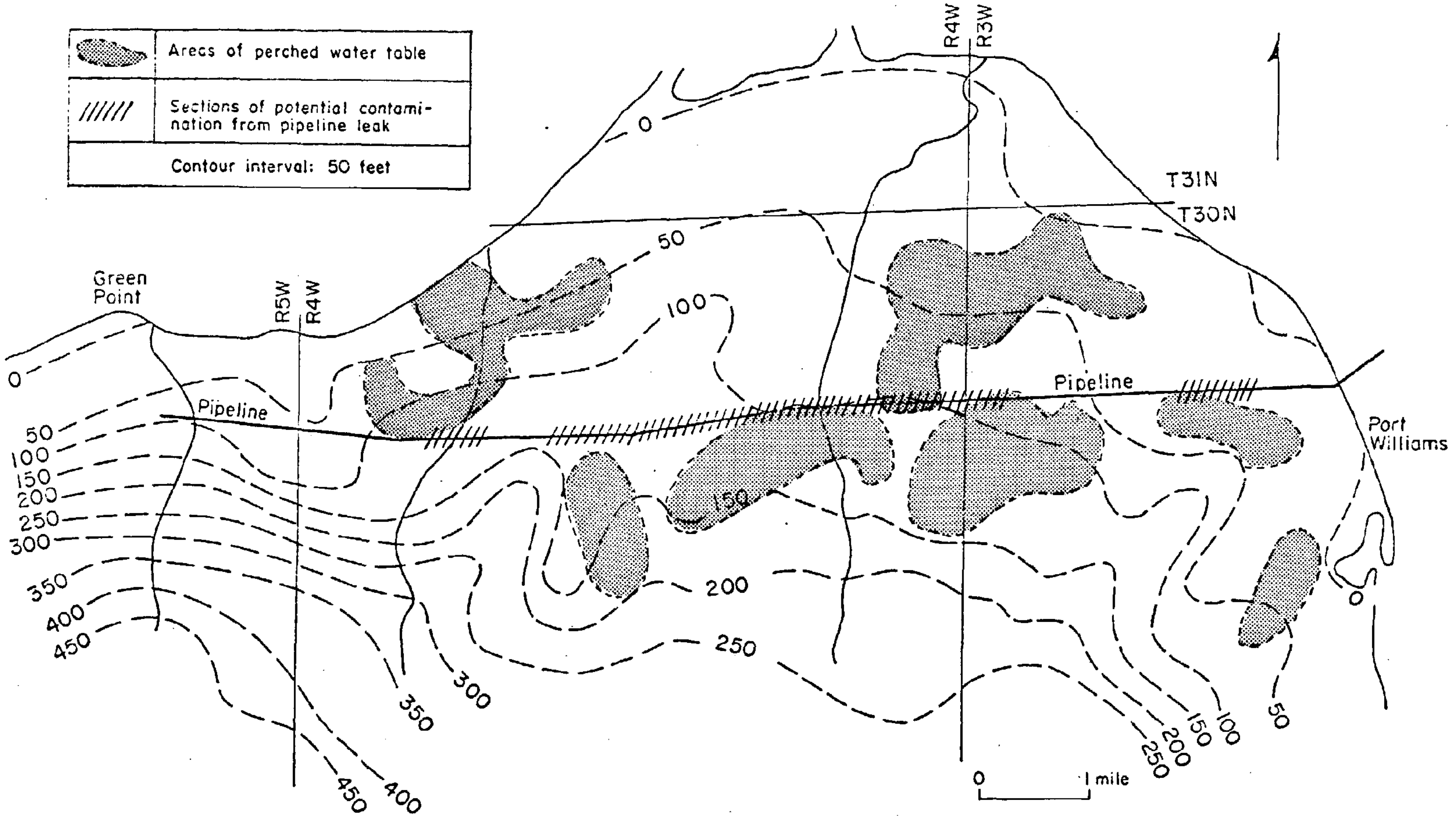


Figure II-1 is the map interpretation from the U. S. Geological Survey's preliminary data. The contours reflect the present water table surface along the proposed pipeline right-of-way.

U. S. Geological Survey data, there appears to be several zones to the Clallam County aquifer system in the area of interest. There are two recharge source zones. One is from annual rainfall in the mountains to the south of the area brought to the area by rivers and creeks. The other source is from irrigation canals, local flooding and sprinkling systems.

Just how much recharge the Dungeness River contributes to the main aquifer is not clear; however, a break in the pipeline at the Dungeness River crossing must not occur, due to the potential ground water contamination and ecological considerations downstream.

There are two zones of discharge also. One is from the main aquifer and the other is from the intermittent and discontinous perched water tables above the main water table. Figure II-1 shows our interpretation of the main water table and areas of known perched water tables.

There are approximately 11 miles of pipeline in Clallam County between Green Point and Port Williams. There are about five miles of this pipeline area where, if there were a pipeline failure, the main water table would definitely be affected. These areas are at McDonald Creek (T30N, R4W, sect. 8) along the entire pipeline section between section nine through section 12 at T30N, R4W and also sect. seven of T30N, R3W. Another location where oil contamination could easily occur is at T30N, R3W, sect. nine. At all of these locations the water table is 20 feet or less from the surface (see Figure II-2).

On all sites visited along the land portion of the pipeline route the soil is very sandy and appears extremely permeable. A relatively small oil leak along the pipeline route described in the previous paragraph could cause contamination of the water table.

IIC. Summary and Recomendations

With the data available there is no way to predict the amount of aquifer contamination from an oil pipeline leak. This is because the exact depth from the ground surface to the water table varies, depending on location, the volume and rate of a possible oil spill is not known and the true permeability of the soil at the spill location is not

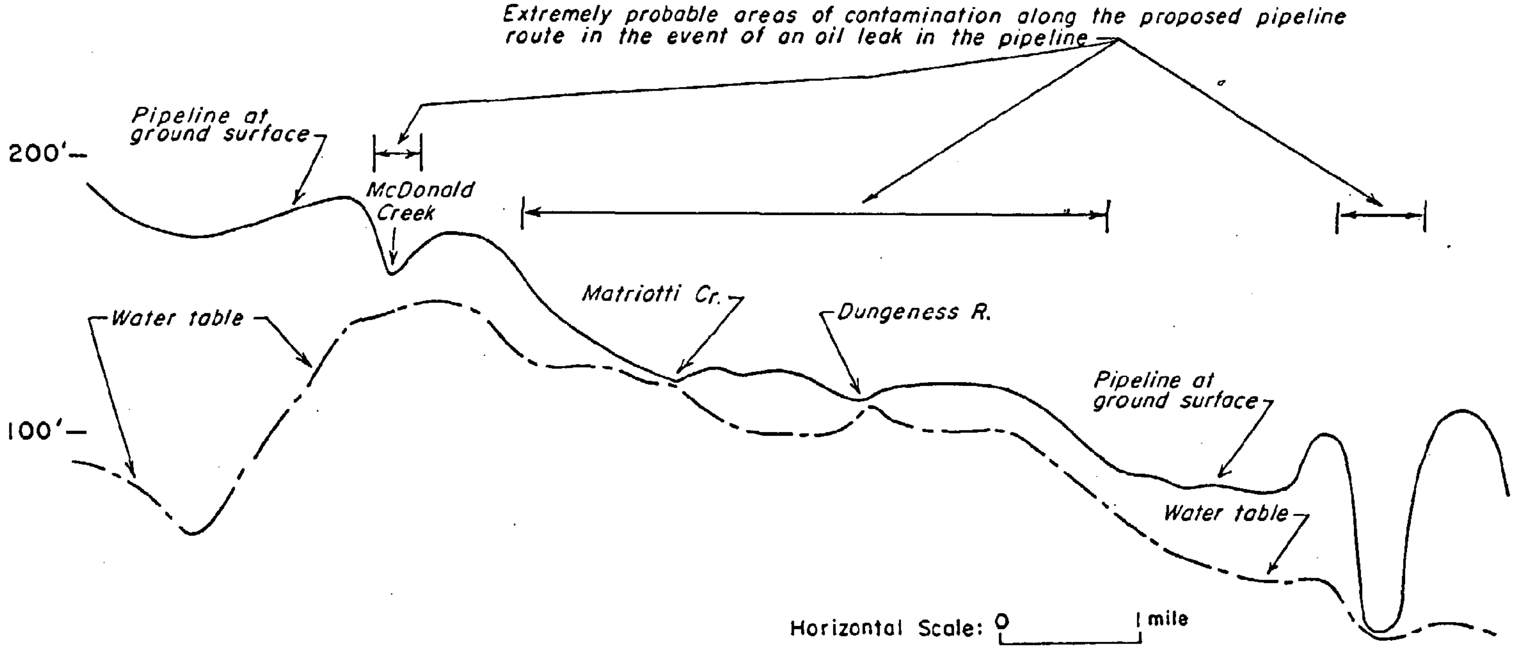


Figure II-2 shows the water table and the pipeline route from the Green Point tank farm on the left to Port Williams on the right. The unlabeled depression is approximately one mile east of Port Williams, where the water table almost reaches the ground surface, is Grays Marsh.

known. All these factors can be obtained or closely estimated along the pipeline route, especially in the critical areas shown in Figure II-5, on a worst case expectation.

To predict the extent of aquifer contamination for a particular spill can not be estimated until the actual ground water flow rate is established. The information needed is presently being gathered by the U. S. Geological Survey and Clallam County and a complete report is expected in about two years (Personal communication with USGS).

There maybe some permeability changes at water wells close to pile driving due to vibration during construction phases. It is recommended that the general public be aware of this possibility and the construction contractor be responsible for well restoration if wells become unuseable.

If there were a pipeline spill at the areas shown in Figure II-2, there could be contamination of the main aquifer.

It appears that if there were a spill at the Dungeness River, the main aquifer would be affected also.

If a spill occurs in an area where surface recharging of the main aquifer takes place, contamination of the main aquifer will occur.

Because the pipeline route is directly over the Clallam County's Aquifer, it is recommended that a fail-safe system be designed to protect the people and industry of Clallam County from any oil spill contamination.

SECTION III DUNGENESS CROSSING

Introduction

This section presents the results of our review and analysis of reports submitted by NTPC with regard to the Dungeness River Crossing (see map in figure III-1). These reports consisted of two documents from Roger Lowe Associates; RLA Files 173-04 and 173-08. The purpose of our report is to evaluate these documents with particular attention paid to the estimation of the maximum potential scour depth at the crossing location.

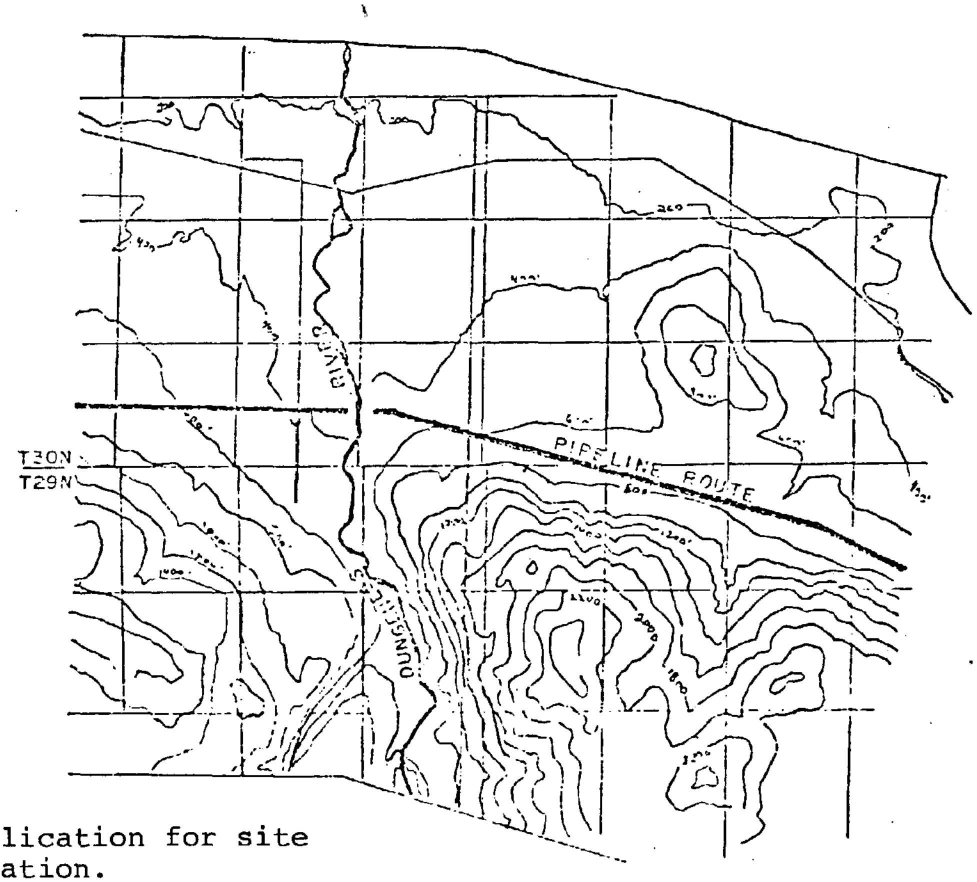
Discussion

The Roger Lowe reports provide a brief description of the Dungeness crossing point; estimate the maximum lateral deviation of the river; estimate maximum flow conditions and estimate scour depth. Personal field observation of the area substantiates the general observations of the Roger Lowe reports, and reveals standing water in the side terraces, several long channel scours and bars, and strong evidence of active channel migration within the central channel. No entrenching of the river was apparent, thus the river at this point appears vertically stable over the long term.

Since localized scour elements are known to exist at several points along the Dungeness, and that the flood data for the Dungeness River crossing indicate that strong flow variations will occur (Roger Lowe report 173-04, and Table III-1 of this report) it is clear that there is a significant potential for elliptical scouring at the Dungeness crossing. Determination of a maximum scour depth is therefore necessary for the safe burial of the pipeline below the river. It is not clear, however, that an appropriate value has been provided in the Roger Lowe report 173-08. The report does not mention any technique, methodology nor formulae for determining the eight foot maximum scour depth that they specify. The scouring problem is a difficult one due to the number of variables involved, and little work apparently has been done in this particular field (no references were cited in the report regarding scour depth determination). It appears that the technology does not exist for making a quantative calculation of maximum scour depth.

figure III-1

Dungeness River crossing



Map source: NTPC application for site certification.

TABLE III-1*

Flow conditions	Discharge	Velocity	Maximum Width	Maximum Depth	Expected Occurrence
Approx. 100 yr. flow	8,800 cfs	10-11 fps	890 ft	12 ft	Nov-Feb
Low Flow	70 cfs	3 fps	90 ft	1 ft	Aug-Dec

*Data source: Roger Lowe Associates Report 173-04.

SECTION IV EDIZ HOOK-EARTHQUAKE LIQUEFACTION

Introduction

This section presents the results of calculations made to evaluate the liquefaction potential of the soils and sediments that are found on Ediz Hook and in the submarine crossing between Ediz Hook and Green Point. The design earthquake accelerations, as determined in Section I of this report, are used in the calculations.

Discussion

During an earthquake, when the cyclic shear stresses caused by the event's oscillatory motion exceeds a prescribed shear stress in certain soils, liquefaction will occur. This phenomena occurs in the following manner. When a saturated, low to medium dense sand is subjected to ground shaking, the material tends to compact and decrease in volume. This change in volume will in turn cause an increase in pore pressure since fluid drainage is slow relative to the rapid loading of the volume. If this volume decrease causes a pore pressure that is equal to or greater than the overburden pressure, i.e., the intergranular stress becomes zero, then the soil has no strength and will physically become a flowing mud. The potential for liquefaction is a function of the initial relative density of the soil, the degree of severity of shaking, and its duration. In general, the probability of liquefaction increases as the relative density decreases, the shaking increases in severity and the number of cycles (duration) increases. Grain size distribution also plays an important role, with soils having a mean grain-size diameter of 0.1mm (very fine sand) considered most susceptible to liquefaction.

To assess the liquefaction potential at Ediz Hook, and the submarine crossing to Green Point, data found in the Shannon and Wilson reports (W-3516-00, W-3373-08) were used to compute parameters necessary for an evaluation. The procedure used was that of Seed and Idriss (1971), which is generally accepted as the most reliable of liquefaction computations.

The potential for liquefaction for a given soil type can be defined as the ratio of the earthquake induced stress in the soil, τ_e, to the stress τ_c required to

Recommendations

The estimated maximum scour depth is not acceptable. If subchannel burial is to be a feasible approach to the Dungeness River crossing, the eight foot scour depth must be adequately substantiated in some manner. If the technology does not exist for estimating quantitatively a maximum scour depth, then other means of crossing the Dungeness should be examined.

initiate liquefaction. A $^{\tau}e/^{\tau}c$ ratio greater than one indicates potential liquefaction of the soil. (See Table below)

Calculation of the earthquake induced stress can be made by the following relationship

$$\tau_e = 0.65\ r_o\ \frac{amax}{g}\ rd$$

where r_o is the overburden pressure at the specified depth, amax is the maximum ground surface acceleration (defined in Section I of this report), g is the accelerating of gravity and rd is soil deformation coeficient determined experimentally.

Calculation of the stress level τ_c required to initiate liquefaction is made using the formula

$$\tau_c = \sigma_{eo}\ C_r\ \left(\frac{\sigma dc}{2\sigma a}\right)\ \frac{Dr}{50}$$

where R_{eo} is the effective overburden pressure at the specified depth, C_r is a correction factor for laboratory data, D_r is the relative density, and $\left(\frac{\sigma dc}{2\sigma a}\right)$ is a stress ratio determined from dynamic triaxial soil tests.

The relationship defining the variables in these two equations are evaluated by Seed and Idress (1970) from numerous previous studies, and are presented in figures IV-1a, b, and c.

Calculations were made to determine the liquefaction potential for soil types B and C for the ground accelerations of the 6.5 and 7.5 design earthquakes of section I. Since no acceleration was determined for type A soil in section I because of the cohesionless nature of the soil, it is immediately assumed here that type A will liquefy during the 7.5 design earthquake. The results of the calculations are as follows:

Soil Type	Mag	D_r	D_{50}	Amax	τ_e/τ_c
A	6.5	50%	.1mm	--	4.5
B	7.5	60%	.15	.70	3.2
B	6.5	60%	.15	.50	2.1
C	7.5	75%	.2	.35	1.75
C	6.5	75%	.2	.25	0.85

From the results of the calculations it appears that for the 7.5 Richter magnitude design earthquake types A and B soils will liquefy, but that type C generally will not. The magnitude of the ground accelerations also will cause slope instability and slumping along the Hook (see Appendix IV-1 for submarine slope stability review). A map of the Ediz Hook area is given in figure IV-2. This map outlines the zones of high liquefaction potential as determined by these calculations, and also includes the location of the slump feature on Ediz Hook as determined from the side-scan sonar records (Shannon-Wilson W-3516-00). The presence of this slump is testimony to the slope instability of the locale.

Conclusions

It is apparent from the liquefaction calculations that Ediz Hook is not an appropriate location for a major pipeline facility. Given the design earthquake, the liquefaction of portions of the Hooks is a certainty. The Port Angeles submarine crossing, particularly the western half, is unstable as a result of liquefaction in the type A and B soils at this location.

Recommendations

An extensive drilling and soil testing program for Ediz Hook is recommended, and dynamic field tests should be conducted at the site. If these field data substantiate the preceding liquefaction analysis, then construction plans for Ediz Hook should be abandoned.

figure IV - I a,b,c.
liquefaction curves of Seed-Idress (1970)

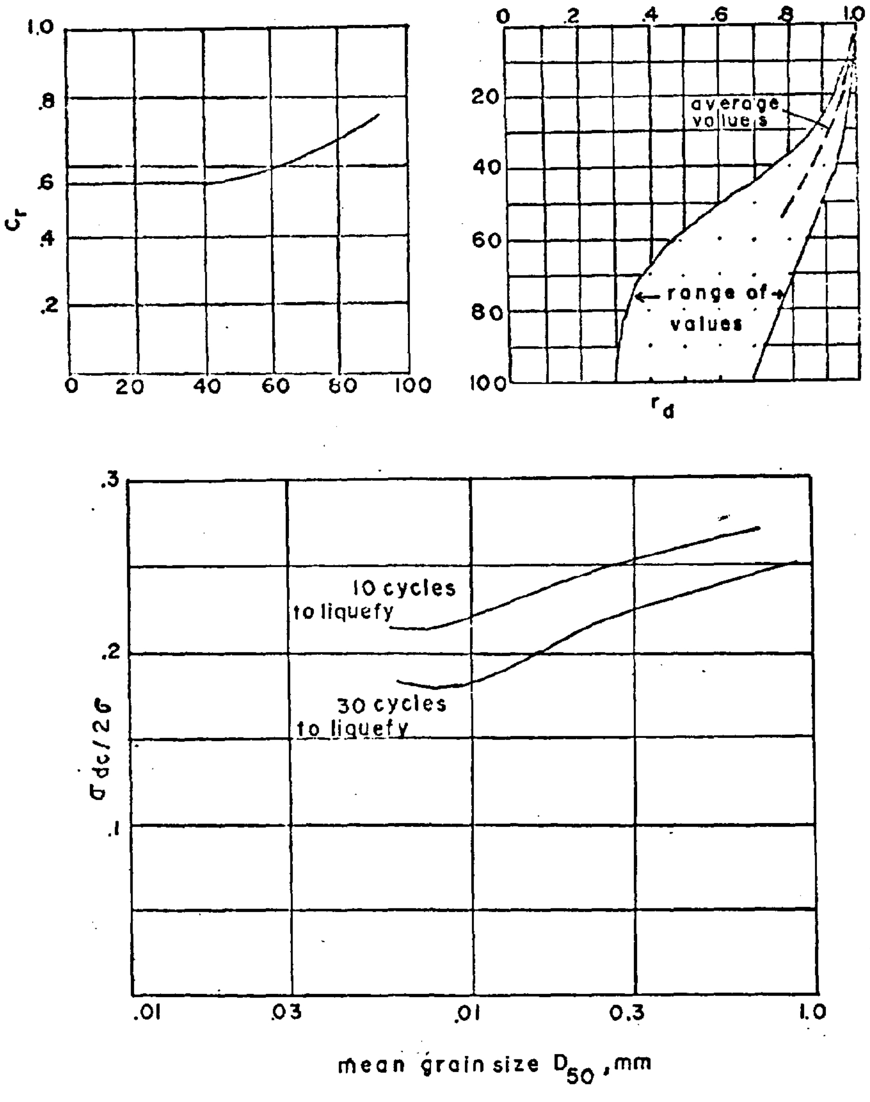
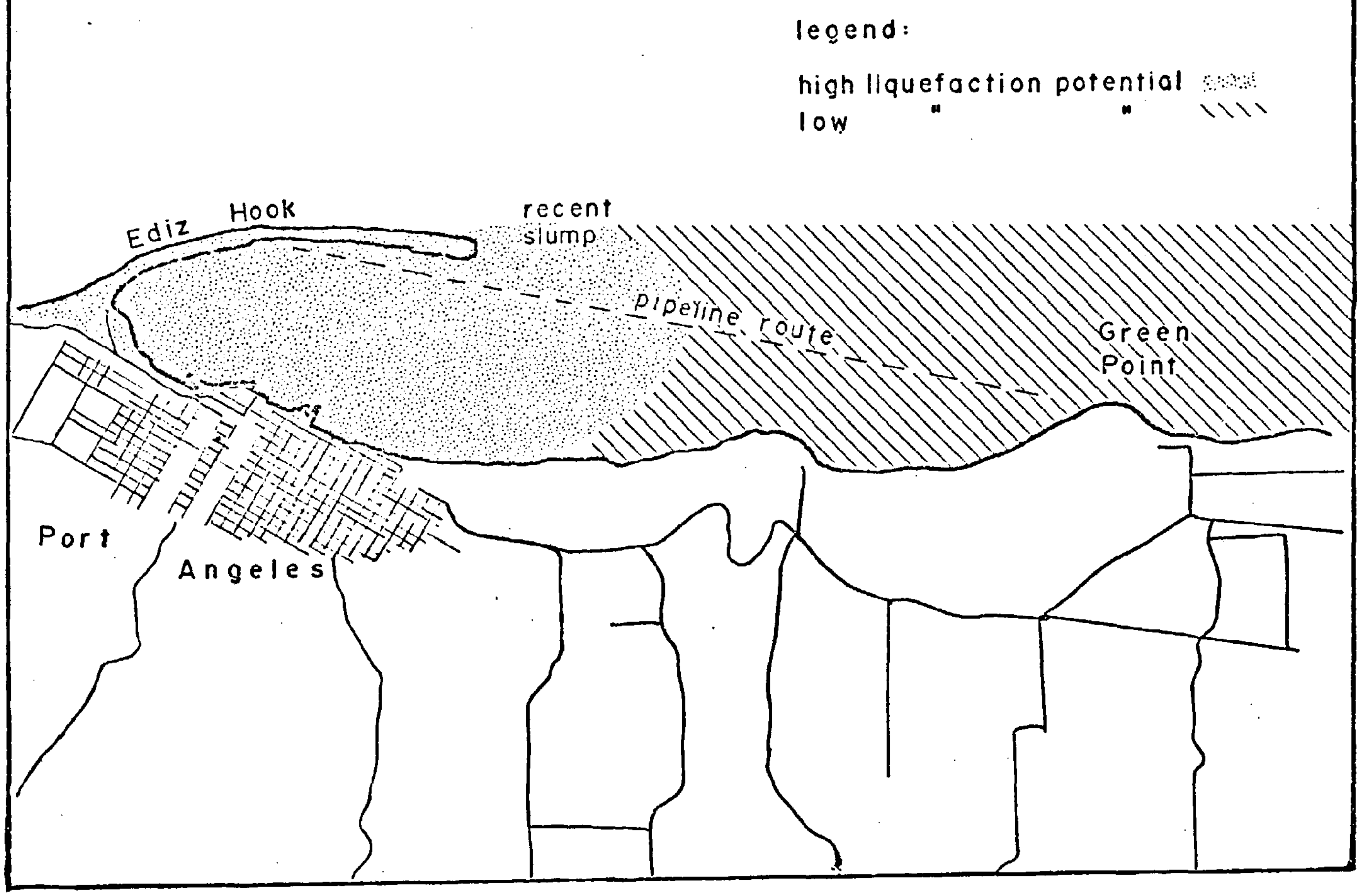


figure IV-2
potential soil liquefaction zones — Port Angeles, Wash.



SECTION V EDIZ HOOK-PILE-LIQUIFACTION STUDY

Introduction

This section presents the results of our study of the particular problem of pile-driving operations acting as a casual mechanism for soil liquifaction on Ediz Hook. This facet of the construction phase has not been directly considered in any of the technical reports submitted for our review. It is the objective of this section to demonstrate that the pile-driving operations can generate enough energy to cause soil subsidence, and that the potential for soil liquifaction is high and should be investigated in detail.

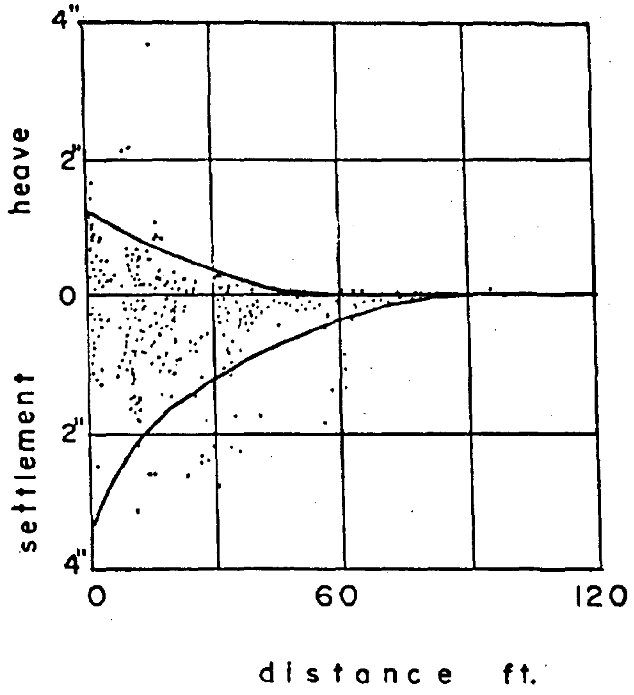
Discussion

It is known that pile-driving can effect significant movements in nearby structures. The phenomena is generally thought to be caused by the displacement of the soil and by the high pore pressures developed in clay subsoils. This is particularly true where a large number of long displacement piles are driven into sand-clay foundations. Horn (1966) describes several case histories including one where piles driven in cohesionless soil caused settlements as large as six inches within the pile-driving area and ground settlements as far as 75 ft. from the site. Horn also reports a study by Ireland (1955) which suggests that driving piles into clay can cause structure movements for a distance approximately equal to the length of the piles driven (figure V-1). Generally it appears that a large amount of energy (i.e., enough to cause settlement), is in fact transmitted into the surrounding soil during the pile driving operation.

The second question addressed here is if pile driving operations, when conducted on Ediz Hook, could cause a ground acceleration of sufficient magnitude to liquify the soil that makes up the Hook. Several elements in the driving operations increase the potential for liquifaction. The typical hammer-impact repetition rate is between one and two Hertz, a typical peak frequency range of earthquakes. The impact energy of the pile hammer (180,000 ft-Lb; data from Shannon & Wilson/ Swan Wooster report W3373-08) if modeled as a point source at the tip of the piling, is equivalent to approximately 1/8 of a pound of dynamite being shot at each impact (see Kramer, et al., 1968 for energy equivalents data). The effect that these points have upon liquifaction potential hinges upon the dynamic response of the soils that make up Ediz Hook.

figure V-1

displacement of soil as a function of distance from a driven pile.



Data source: Ireland (1955).

Since no field soil vibration tests have been reported for Ediz Hook by NTPC, the ground acceleration due to pile-hammer action cannot at this time be accurately determined. However, in view of the high impact energy of the pile hammer; the frequency range of this impact rate; and in view of a recognized pile-driving/soil settlement phenomena which has a lateral effect equal to at least the length of the pile, it is apparent that a substantial liquifaction risk may exist at Ediz Hook.

Recommendations

The risk of soil liquifaction due to pile driving can only be evaluated by making a series of dynamic pile tests on the Hook. These measurements should be conducted with a series of accelerometers placed radially from the test pile in a fashion that would enable accurate determination of ground motion acceleration as a function of distance from the pile. It is also clear that these tests must be conducted prior to project approval, since they are, in effect, feasibility tests that will determine the viability of large scale pile driving efforts on Ediz Hook.

SECTION IV ANCHOR PENETRATION

Introduction

A primary consideration in the location and deployment of the submarine pipeline is to protect it from anchor damage. The purpose of this section is to present the results of our review of data concerning anchor penetration into the sediments near the submarine crossings at Ediz Hook-Green Point and Port Williams-Partridge Point. The anchor penetration calculations have been presented in R. J. Brown reports 2129-2 and 2154.1.

Discussion

The resistance a soil has to anchor penetration can be calculated in a variety of ways, each with varying degrees of accuracy. The R. J. Brown reports, however, do not explain their method for calculation of penetration depth; consequently no critique of method can be made.

The results of their computations, unfortunately, do not correspond to all the soil types in the pipeline corridor. Their value of 3.7 feet penetration for a ten ton anchor in loose sand is clearly not a reasonable value for the Ediz Hook-Green Point crossing, since vibracore data in the Shannon and Wilson report W-3516-00 reveal penetration times of less than 10 sec/ft to an average depth of 14.5 feet, based on 32 vibracore stations. Sediments with penetration times of less than 10 sec/ft can be considered very weak in shear. Applying the same approach to the vibracore data for Port Williams to Partridge Point, with 55 valid vibracore tests, the average depth to 10 sec/ft 'strength' material is 11.6 feet (vibracore data from Shannon-Wilson report W-3496-06). These average depths to constant (low) strength point out the somewhat misleading 'safe' penetration depth of 3.7 feet. Furthermore they do not consider the penetration depth of the 30 ton anchors that would be carried by the 300,000 dwt tankers. Appendix A of R. J. Brown report no. 2154.1 predicted a 19 foot penetration of only a 15 ton anchor in 'mud'; why was the computation not presented for a 30 ton anchor?

Analysis of the line drawings of seismic profiles of the submarine crossings (Shannon and Wilson report W-3496-06) reveal significant variations in the latteral extent and thickness of the sediments that make up the top sediment layers. With this variability comes the question of which soil horizon to use as a reference depth for pipeline burial. Type A soils, with vibracore penetration times that sometimes approach zero (See Shannon-Wilson reports W-3516-00, W-3496-06), clearly will offer little resistance to anchor penetration. Type B soils, where they exists, appear to have variable strength properties. Type C soils are relatively dense and stiff, but their position relative to the mudline (water-sediment interface) ranges from right at the mudline to 20 feet or more below it. It is obvious that burying the pipeline a certain footage below a given soil horizon will not provide a consistant layer of protective material above the pipeline.

Recommendations

A better estimate for anchor penetration is needed from NTPC. This should include not only a description of methodology, but a series of calculations for all soil types found along the route, for all the typical anchor sizes, including 30 ton anchors.

Since Type A soils provide virtually no protection from anchor penetration, and since Type B soils appear to have variable strengths, it is recommended that a fixed soil type horizon not be used for burial depth reference. It is recommended that the burial depth be defined as four feet below the computed penetration depth of a 30-ton anchor, at any position along the route. This provides a maximum continuous protection for the pipeline and avoids the problems of depth-referencing to a particular soil type.

SECTION VII PORT WILLIAMS TO PARTRIDGE POINT SUBMARINE CROSSING

Introduction

This section presents the results of a review of the data and reports submitted by NTPC that are pertinent to the submarine crossing from Port Williams to Partridge Point. Topics found in these reports that that will be considered in this section are sediment liquefaction potential and geophysical surveying. Anchor penetration has been discussed in section VI of this report.

Discussion

The purpose of the Shannon and Wilson report no. W-3496-06 was to obtain geologic, geophysical and geotechnical data of the bottom and sub bottom sea floor in order to evaluate the engineering problems of the proposed submarine pipeline crossing. The data set consists of continuous sets of geophysical profiles (magnetics, bathymetry, side scan sonar, high resolution seismic and deep-penetration seismic), a sequence of vibracore samples, and a series of laboratory tests on these samples.

The geophysical profiles mentioned in the report have been combined and interpreted by Shannon-Wilson, and it is only the interpretations that are presented in their report.

The seismic source used was a "boomer type" (see Appendix VIII-1 for an explanation of different seismic sources), with deep penetration capability. The other seismic source used was a high frequency pinger source (again see Appendix VIII-1), which has the capability of detecting relatively small faults and structures. Thus with a double capability of high resolution near-surface measurements and good resolution deep-penetration measurements, it is difficult to understand why no traces of any fault, fault block or scarp were found in this area. Reproduction of composites of the seismic data is by far the best means of transmitting the data, since interpretation of the seismic records tend to be rather subjective. The fact that not a single fault has been mapped on the interpreted records is somewhat suprising in a tectonically active region. The tectonic map of Gower (1978) infers two regional fault systems passing

North by Northwest on the east and west of Protection Island, but no evidence of them are found in the interpreted records.

The geophysical public interpretation summaries (figures nine and 10 of the Shannon-Wilson report) can be used to infer the average minimum depth of penetration of a large anchor (see section VI) and a minimum thickness of liquefiable material. The depth to vibracore T value of 10 sec/ft is plotted on these summary charts. A T value less than 10 means that the sediment is very soft or loose, with low strength and low relative densities (less than 65%). Many of the vibracore stations showed T values of T=0 for depths as great as 20 feet. The average depth to T=10, however, was about 11 feet for the North and South profiles.

Liquefaction calculations were made using the 7.5 design earthquake of section I and the estimated acceleration for sediment type C, which is 0.46 g. The technique used was that of Seed and Idress, 1970, and is outlined in section IV of this report. Using a relative density of 60% for the sediments above the T=10 depth and the average depth of 11 feet, the calculations show, given the design earthquake acceleration, that this entire layer is subject to liquefaction. Generally, for types A and B sediments, liquefaction could occur to depths of 30 feet or more for a 7.5 event.

Conclusions

The information provided in the Shannon and Wilson report is not adequate to make an evaluation of the tectionic structure of the proposed pipeline route. The interpreted geophysical profiles cannot be used to evaluate faulting along the route. The vibracore data do however, provide an adequate preliminary sampling along the corridor, and provide a reasonable basis to evaluate near surface liquefaction potential. Liquefaction to the T=10 depth for the design earthquake will occur.

Recommendations

Further geophysical exploration of the route is required. All geophysical profiles (not interpreted profiles) should be released to the profile for review.

Liquefaction to the T=10 sec/ft depth requires burial of the pipeline below this depth.

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APPENDIX I-1

List of earthquakes used in seismicity study of the Vancouver Island-Puget Sound Tectonic Province

DEPTH IS IN KILOMETERS. UNKNOWN DEPTH IS DESIGNATED BY -16.
MAG IS THE MAXIMUM OF THE FOUR PRECEDING VALUES (BODY WAVE, SURFACE WAVE, OTHER, AND LOCAL MAGNITUDES). MAGNITUDES ARE RICHTER SCALE.
INT IS MAXIMUM INTENSITY (MODIFIED MERCALLI SCALE, NEGATIVE IS ROSSI-FOREL).

DATE	GMT	LONG-LAT		DEPTH	MB	MS	OTHER	ML	MAG	INT
4 2 1859	103000.0	-123.000	47.000	-16.0	0.00	0.00	0.00	0.00	0.00	5
10 30 1864	21000.0	-123.500	48.500	-16.0	0.00	0.00	0.00	0.00	0.00	6
8 26 1865	50000.0	-123.500	48.500	-16.0	0.00	0.00	0.00	0.00	0.00	6
12 14 1872	-214000.0	-121.000	49.167	0.0	0.00	0.00	7.50	0.00	7.50	9
12 16 1872	-91700.0	-123.500	48.500	0.0	0.00	0.00	0.00	0.00	0.00	6
12 13 1880	44000.0	-122.500	47.500	0.0	0.00	0.00	0.00	0.00	0.00	7
4 30 1882	-223500.0	-123.367	48.417	0.0	0.00	0.00	0.00	0.00	0.00	5
10 9 1885	160000.0	-123.000	47.000	-16.0	0.00	0.00	0.00	0.00	0.00	5
12 8 1885	-221200.0	-122.500	47.500	0.0	0.00	0.00	0.00	0.00	0.00	5
3 8 1891	33000.0	-122.800	48.300	0.0	0.00	0.00	0.00	0.00	0.00	5
9 19 1891	-90000.0	-122.330	47.597	0.0	0.00	0.00	0.00	0.00	0.00	5
9 22 1891	114000.0	-123.500	48.000	-16.0	0.00	0.00	0.00	0.00	0.00	5
11 29 1891	232100.0	-123.000	47.700	0.0	0.00	0.00	0.00	0.00	0.00	7
3 5 1892	0.0	-120.500	46.600	0.0	0.00	0.00	0.00	0.00	0.00	6
4 17 1892	225000.0	-123.000	47.000	-16.0	0.00	0.00	0.00	0.00	0.00	6
2 25 1895	124700.0	-122.400	46.500	-16.0	0.00	0.00	0.00	0.00	0.00	5
4 16 1895	80200.0	-123.000	48.000	-16.0	0.00	0.00	0.00	0.00	0.00	6
1 4 1896	61500.0	-123.300	48.400	0.0	0.00	0.00	0.00	0.00	0.00	7
2 7 1896	55500.0	-124.300	48.300	-16.0	0.00	0.00	0.00	0.00	0.00	6
3 14 1903	21500.0	-122.200	47.700	-16.0	0.00	0.00	0.00	4.30	4.30	5
3 17 1904	42100.0	-124.000	47.500	0.0	0.00	0.00	6.00	0.00	6.00	8
3 17 1904	42000.0	-122.600	48.500	-16.0	0.00	0.00	0.00	0.00	0.00	5
10 18 1905	-110000.0	-120.200	47.800	0.0	0.00	0.00	0.00	0.00	0.00	5
10 18 1905	-230000.0	-122.013	47.842	0.0	0.00	0.00	0.00	0.00	0.00	5
10 18 1905	-230000.0	-122.013	47.842	0.0	0.00	0.00	0.00	0.00	0.00	5
1 2 1906	134500.0	-120.000	47.700	0.0	0.00	0.00	0.00	0.00	0.00	6
6 1 1906	125500.0	-122.330	47.597	0.0	0.00	0.00	0.00	0.00	0.00	5
2 18 1907	-242000.0	-122.013	47.842	0.0	0.00	0.00	0.00	0.00	0.00	5
7 28 1907	102000.0	-123.350	48.450	0.0	0.00	0.00	0.00	0.00	0.00	5
1 11 1909	234900.0	-122.720	49.000	-16.0	0.00	0.00	0.00	5.60	5.60	7
5 24 1909	172000.0	-120.000	47.600	0.0	0.00	0.00	0.00	4.00	4.00	5
9 29 1911	23900.0	-122.700	48.800	-16.0	0.00	0.00	0.00	4.30	4.30	6
7 29 1913	161500.0	-122.000	47.000	-16.0	0.00	0.00	0.00	4.30	4.30	5
12 25 1913	104500.0	-122.500	47.700	0.0	0.00	0.00	0.00	0.00	0.00	5
12 25 1913	144000.0	-122.500	47.700	-16.0	0.00	0.00	0.00	4.30	4.30	5
9 5 1914	93500.0	-123.000	47.000	-16.0	0.00	0.00	0.00	4.30	4.30	5
8 18 1915	140500.0	-121.400	48.500	0.0	0.00	0.00	0.00	5.50	5.50	5
1 2 1916	5200.0	-122.300	47.300	-16.0	0.00	0.00	0.00	4.30	4.30	5
2 22 1916	114500.0	-122.600	48.800	-16.0	0.00	0.00	0.00	4.30	4.30	5
3 28 1917	170500.0	-122.000	46.800	0.0	0.00	0.00	4.30	4.30	4.30	5
6 9 1917	143000.0	-122.000	46.800	0.0	0.00	0.00	0.00	4.30	4.30	5
11 12 1917	104700.0	-121.800	46.800	-16.0	0.00	0.00	0.00	4.30	4.30	6
11 14 1917	5700.0	-121.800	46.800	0.0	0.00	0.00	4.30	0.00	4.30	5
2 28 1918	234500.0	-120.500	46.500	-16.0	0.00	0.00	0.00	4.30	4.30	5
2 28 1918	231500.0	-120.500	46.500	0.0	0.00	0.00	0.00	0.00	0.00	5
6 21 1918	64700.0	-121.700	46.500	0.0	0.00	0.00	0.00	4.30	4.30	5
12 6 1918	84500.0	-123.000	49.300	0.0	0.00	0.00	0.00	0.00	0.00	5
10 10 1919	10720.0	-124.300	48.300	0.0	0.00	0.00	5.50	5.50	5.50	0
1 24 1920	70900.0	-122.700	49.000	-16.0	0.00	0.00	0.00	0.00	0.00	7

DATE			GMT	LONG-LAT		DEPTH	MB	MS	OTHER	ML	MAG	INT
10	7	1920	-20000.0	-120.067	47.633	0.0	0.00	0.00	0.00	0.00	0.00	5
2	12	1923	183000.0	-122.700	49.000	-16.0	0.00	0.00	4.30	4.30	4.30	5
9	7	1926	221436.0	-124.000	49.000	0.0	0.00	0.00	0.00	5.50	5.50	0
9	17	1926	221436.0	-124.000	49.000	0.0	0.00	0.00	5.50	0.00	5.50	0
12	4	1926	135500.0	-123.500	48.500	-16.0	0.00	0.00	0.00	4.30	4.30	5
12	30	1926	175700.0	-120.000	47.000	0.0	0.00	0.00	0.00	0.00	0.00	6
1	3	1927	45800.0	-120.658	47.593	0.0	0.00	0.00	0.00	0.00	0.00	5
5	8	1927	140000.0	-124.000	49.000	0.0	0.00	0.00	0.00	5.50	5.50	0
5	18	1927	215652.0	-124.000	49.000	0.0	0.00	0.00	5.00	0.00	5.00	0
2	2	1928	125200.0	-121.700	47.300	0.0	0.00	0.00	0.00	3.50	3.50	6
4	18	1931	40000.0	-122.250	48.750	-16.0	0.00	0.00	0.00	4.30	4.30	5
12	31	1931	152500.0	-123.300	47.500	-16.0	0.00	0.00	0.00	0.00	0.00	6
1	5	1932	231300.0	-121.800	48.000	0.0	0.00	0.00	0.00	4.30	4.30	5
7	18	1932	60300.0	-121.800	48.000	0.0	0.00	0.00	0.00	4.30	4.30	6
8	6	1932	221600.0	-122.300	47.700	0.0	0.00	0.00	0.00	5.00	5.00	6
8	7	1932	60000.0	-121.900	48.000	0.0	0.00	0.00	0.00	0.00	0.00	5
5	5	1934	40600.0	-123.000	48.000	0.0	0.00	0.00	0.00	4.30	4.30	5
9	18	1934	80000.0	-121.000	47.000	0.0	0.00	0.00	4.30	4.30	4.30	5
9	26	1934	1500.0	-120.540	46.998	0.0	0.00	0.00	0.00	0.00	0.00	5
10	19	1934	233100.0	-120.540	46.998	0.0	0.00	0.00	0.00	0.00	0.00	5
11	1	1934	152800.0	-120.540	46.998	0.0	0.00	0.00	0.00	0.00	0.00	5
11	2	1934	231700.0	-120.540	46.998	0.0	0.00	0.00	0.00	0.00	0.00	5
11	3	1934	145000.0	-123.000	48.000	0.0	0.00	0.00	0.00	4.00	4.00	5
7	9	1935	224500.0	-120.000	47.700	0.0	0.00	0.00	4.30	0.00	4.30	5
10	12	1935	10300.0	-120.223	47.662	0.0	0.00	0.00	0.00	0.00	0.00	5
1	6	1938	131100.0	-122.400	47.800	0.0	0.00	0.00	4.30	4.30	4.30	0
2	19	1938	141000.0	-123.117	49.267	0.0	0.00	0.00	0.00	0.00	0.00	6
11	13	1939	74554.0	-123.000	47.200	-16.0	0.00	0.00	5.75	5.70	5.75	7
10	27	1940	222918.0	-123.400	47.200	-16.0	0.00	0.00	4.60	4.60	4.60	5
1	31	1942	64907.0	-124.000	51.000	0.0	0.00	0.00	5.50	5.50	5.50	0
2	23	1942	150300.0	-120.200	47.600	0.0	0.00	0.00	0.00	0.00	0.00	5
10	14	1942	123000.0	-120.652	48.310	0.0	0.00	0.00	0.00	0.00	0.00	5
4	24	1943	1046.0	-120.600	47.300	0.0	0.00	0.00	4.30	4.30	4.30	6
10	6	1943	150900.0	-121.815	47.522	0.0	0.00	0.00	0.00	0.00	0.00	5
11	29	1943	14300.0	-122.900	48.400	0.0	0.00	0.00	5.00	5.00	5.00	6
3	31	1944	221500.0	-123.000	47.000	0.0	0.00	0.00	4.30	4.30	4.30	0
10	31	1944	123400.0	-120.600	47.800	0.0	0.00	0.00	4.30	4.30	4.30	0
12	7	1944	44800.0	-123.830	46.977	0.0	0.00	0.00	0.00	0.00	0.00	6
1	4	1945	23448.7	-120.223	47.662	0.0	0.00	0.00	0.00	0.00	0.00	5
1	23	1945	50608.1	-122.377	48.242	0.0	0.00	0.00	0.00	0.00	0.00	6
4	29	1945	201617.0	-121.700	47.400	-16.0	0.00	0.00	5.50	5.50	5.50	7
4	30	1945	84600.0	-121.700	47.400	0.0	0.00	0.00	5.00	5.00	5.00	6
5	1	1945	204600.0	-121.700	47.400	0.0	0.00	0.00	4.30	4.30	4.30	0
6	15	1945	222421.0	-123.000	48.000	0.0	0.00	0.00	4.20	4.20	4.20	0
11	12	1945	50500.0	-122.500	48.000	0.0	0.00	0.00	0.00	0.00	0.00	6
2	15	1946	31730.0	-122.500	47.500	-16.0	0.00	0.00	5.75	0.00	5.75	7
2	15	1946	121715.0	-122.268	46.870	0.0	0.00	0.00	0.00	0.00	0.00	6
2	23	1946	85453.0	-122.390	47.045	0.0	0.00	0.00	0.00	0.00	0.00	6
3	20	1946	42700.0	-122.000	47.500	0.0	0.00	0.00	0.00	0.00	0.00	5
6	23	1946	171312.0	-125.300	49.900	-16.0	0.00	0.00	7.30	7.30	7.30	8

DATE	GMT	LONG-LAT		DEPTH	MB	MS	OTHER	ML	MAG	INT
7 5 1946	24116.0	-124.900	49.900	0.0	0.00	0.00	4.50	4.50	4.50	0
1 12 1947	94000.0	-121.810	47.537	0.0	0.00	0.00	0.00	0.00	0.00	5
4 2 1947	5600.0	-122.900	47.400	0.0	0.00	0.00	0.00	0.00	0.00	5
9 20 1947	103000.0	-122.400	47.200	0.0	0.00	0.00	0.00	0.00	0.00	5
1 13 1948	65500.0	-120.300	47.900	0.0	0.00	0.00	0.00	0.00	0.00	5
8 3 1948	120000.0	-121.810	47.537	0.0	0.00	0.00	0.00	0.00	0.00	5
9 24 1949	143500.0	-122.600	47.800	0.0	0.00	0.00	0.00	4.30	4.30	0
9 24 1949	223500.0	-122.587	47.855	0.0	0.00	0.00	0.00	0.00	0.00	6
4 13 1949	195543.0	-122.500	47.250	-16.0	0.00	0.00	7.00	7.10	7.10	8
6 1 1949	82315.0	-124.500	47.500	0.0	0.00	0.00	4.00	4.00	4.00	0
4 14 1950	110346.0	-123.000	48.000	-16.0	0.00	0.00	4.50	4.50	4.50	6
12 3 1950	15700.0	-122.300	47.947	0.0	0.00	0.00	0.00	0.00	0.00	5
1 7 1951	134500.0	-120.000	47.700	0.0	0.00	0.00	0.00	0.00	0.00	5
2 22 1952	93931.2	-123.100	48.600	0.0	0.00	0.00	3.00	3.00	3.00	5
8 6 1952	173100.0	-122.400	47.500	0.0	0.00	0.00	0.00	0.00	0.00	5
3 16 1954	155609.0	-121.800	47.100	-16.0	0.00	0.00	4.30	4.30	4.30	5
5 5 1954	14229.0	-122.416	47.316	-16.0	0.00	0.00	0.00	0.00	0.00	5
5 15 1954	130214.0	-122.500	47.400	-16.0	0.00	0.00	4.10	0.00	4.10	6
5 23 1954	134142.0	-120.137	48.342	0.0	0.00	0.00	0.00	0.00	0.00	5
1 11 1955	102008.0	-124.016	47.816	-16.0	0.00	0.00	3.10	3.10	3.10	5
3 26 1955	65550.0	-122.033	48.050	-16.0	0.00	0.00	3.70	3.70	3.70	6
9 11 1955	5245.0	-124.600	48.400	68.0	0.00	0.00	0.00	3.00	3.00	5
11 3 1955	14029.0	-121.750	48.100	-16.0	0.00	0.00	0.00	2.00	2.00	5
1 7 1956	42935.0	-122.416	47.316	-16.0	0.00	0.00	0.00	0.00	0.00	5
1 26 1956	11616.0	-122.430	48.330	0.0	0.00	0.00	5.00	5.00	5.00	0
2 9 1956	5712.0	-122.650	48.350	-16.0	0.00	0.00	3.10	3.10	3.10	5
1 25 1957	11606.0	-122.433	48.333	26.0	0.00	0.00	3.50	3.50	3.50	6
2 11 1957	170555.6	-121.733	47.533	30.0	0.00	0.00	4.00	4.00	4.00	6
5 4 1957	210925.0	-122.383	47.350	-16.0	0.00	0.00	0.00	3.40	3.40	5
11 1 1957	101200.2	-121.200	46.900	0.0	0.00	0.00	4.70	0.00	4.70	5
4 12 1958	223711.0	-120.000	48.000	-16.0	0.00	0.00	0.00	4.10	4.10	6
5 22 1958	201301.0	-121.600	48.020	0.0	0.00	0.00	4.20	4.20	4.20	0
8 23 1958	50000.0	-122.912	48.692	0.0	0.00	0.00	0.00	0.00	0.00	5
10 7 1958	50752.0	-124.033	46.716	-16.0	0.00	0.00	0.00	3.30	3.30	6
8 6 1959	30435.0	-120.000	47.817	-16.0	0.00	0.00	4.40	4.40	4.40	6
10 14 1959	213539.0	-121.967	47.850	-16.0	0.00	0.00	3.90	3.90	3.90	5
11 23 1959	181525.0	-121.750	46.667	-16.0	0.00	0.00	4.80	4.80	4.50	5
12 12 1959	62417.0	-123.250	48.733	-16.0	0.00	0.00	4.50	0.00	4.50	5
1 7 1960	91600.0	-122.670	46.750	0.0	0.00	0.00	4.90	3.60	4.90	6
4 11 1960	64735.0	-122.250	47.567	-16.0	0.00	0.00	3.30	3.30	3.30	6
9 10 1960	150634.0	-123.150	47.700	-16.0	0.00	0.00	0.00	4.90	4.90	6
1 4 1961	72601.0	-122.083	46.000	33.0	0.00	0.00	0.00	0.00	0.00	5
2 2 1961	55018.4	-121.500	47.000	40.0	0.00	0.00	3.10	3.10	3.10	5
9 16 1961	32456.6	-122.020	46.070	8.0	0.00	0.00	0.00	4.30	4.30	7
9 17 1961	155558.8	-122.000	46.000	3.0	0.00	0.00	0.00	0.00	0.00	6
10 31 1961	33429.8	-120.000	48.400	0.0	0.00	0.00	0.00	0.00	0.00	5
1 15 1962	52913.0	-120.217	47.833	-16.0	0.00	0.00	0.00	0.00	0.00	6
8 11 1962	165300.0	-123.500	46.000	0.0	0.00	0.00	0.00	0.00	0.00	6

DATE	GMT	LONG-LAT		DEPTH	MB	MS	OTHER	ML	MAG	INT
12 31 1962	204935.3	-122.000	47.100	2.0	0.00	0.00	0.00	5.00	5.00	6
1 24 1963	214311.8	-122.100	47.600	17.0	0.00	0.00	0.00	5.00	5.00	6
1 26 1964	210043.2	-122.400	46.010	33.0	0.00	0.00	0.00	0.00	0.00	5
7 14 1964	155003.3	-122.500	48.900	33.0	0.00	0.00	5.00	5.00	5.00	6
7 30 1964	124515.4	-122.300	49.200	33.0	0.00	0.00	4.30	3.60	4.30	5
7 30 1964	153314.7	-122.100	47.700	33.0	0.00	0.00	0.00	0.00	0.00	5
10 14 1964	63300.0	-122.100	47.700	0.0	0.00	0.00	0.00	4.30	4.30	0
10 15 1964	143237.5	-122.100	47.700	23.0	4.10	0.00	4.10	0.00	4.10	5
4 29 1965	152844.0	-122.300	47.400	0.0	6.50	0.00	6.88	6.50	6.88	8
10 23 1965	162759.3	-122.400	47.500	0.0	4.80	0.00	4.80	0.00	4.80	5
3 7 1967	35108.0	-122.700	47.700	0.0	4.20	0.00	4.20	4.10	4.20	0
5 25 1967	232239.0	-122.800	48.700	0.0	4.30	0.00	4.30	4.10	4.30	0
6 19 1968	55143.0	-122.500	47.200	-16.0	4.00	0.00	4.70	0.00	4.70	4
9 6 1968	121632.7	-122.300	47.800	38.0	3.90	0.00	4.30	3.90	4.30	5
11 1 1968	102459.0	-124.159	50.968	33.0	4.50	0.00	0.00	0.00	4.50	0
11 30 1968	144008.8	-122.400	46.500	13.0	4.30	0.00	4.30	0.00	4.30	5
2 14 1969	83337.5	-123.085	48.718	52.0	4.30	0.00	4.50	0.00	4.50	5
10 9 1969	170755.0	-121.716	46.766	-16.0	4.40	0.00	4.40	0.00	4.40	5
11 1 1969	154424.3	-121.950	47.916	5.0	4.10	0.00	4.10	0.00	4.10	5
11 10 1969	73840.8	-121.400	48.516	33.0	0.00	0.00	4.70	0.00	4.70	5
2 10 1970	202111.8	-122.300	47.700	33.0	0.00	0.00	3.90	3.90	3.90	5
5 18 1970	52954.0	-122.700	48.600	11.0	4.00	0.00	4.00	4.00	4.00	0
10 24 1970	223207.9	-122.373	47.334	15.5	0.00	0.00	0.00	4.20	4.20	0
11 23 1971	21214.5	-121.192	48.269	17.4	0.00	0.00	0.00	4.14	4.14	0
12 28 1971	75000.3	-122.214	47.572	22.5	0.00	0.00	0.00	4.38	4.38	0
11 9 1972	41918.4	-123.334	48.449	51.8	0.00	0.00	0.00	4.12	4.12	0
4 20 1974	30010.5	-121.611	46.813	2.2	0.00	0.00	0.00	4.65	4.65	0
5 16 1974	130436.4	-122.984	48.104	52.6	3.80	0.00	0.00	4.17	4.17	5
12 15 1974	175806.1	-122.058	48.504	1.2	0.00	0.00	3.10	2.82	3.10	5
3 31 1975	54838.0	-125.600	49.400	33.0	5.30	0.00	0.00	5.40	5.40	0
4 10 1975	105723.5	-120.978	46.839	1.7	0.00	0.00	0.00	4.01	4.01	0
4 16 1975	190929.2	-122.908	47.557	43.8	0.00	0.00	0.00	4.01	4.01	5
4 23 1975	10400.4	-120.821	46.823	44.8	4.00	0.00	0.00	4.12	4.12	6
7 14 1975	55034.6	-122.407	47.324	6.4	0.00	0.00	0.00	3.45	3.45	5
7 24 1975	114211.3	-122.403	47.321	6.0	0.00	0.00	0.00	3.40	3.40	5
11 30 1975	104821.0	-123.620	49.230	10.0	4.70	3.50	0.00	4.90	4.90	0
5 16 1976	83513.8	-123.441	48.849	67.4	0.00	0.00	0.00	5.10	5.10	6
9 2 1976	133611.0	-122.776	48.179	23.6	0.00	0.00	0.00	4.71	4.71	0
9 8 1976	82101.6	-123.099	47.376	49.6	4.60	3.90	4.80	5.02	5.02	6
11 17 1976	232431.0	-125.797	49.532	10.0	4.20	0.00	0.00	0.00	4.20	0
6 17 1977	61602.1	-122.715	47.759	19.8	0.00	0.00	0.00	4.00	4.00	0
7 13 1977	71506.2	-120.952	47.040	0.1	0.00	0.00	0.00	3.83	3.83	5
10 15 1977	42407.2	-123.795	48.243	49.3	0.00	0.00	0.00	5.22	5.22	0
3 5 1978	181334.9	-123.078	48.061	3.0	0.00	0.00	0.00	4.09	4.09	0
3 11 1978	155312.5	-122.928	47.463	40.0	0.00	0.00	0.00	4.98	4.98	0
3 31 1978	80305.5	-122.451	47.357	40.0	0.00	0.00	0.00	4.44	4.44	0

APPENDIX I-2

Data from Boore (1978) used
to show acceleration, velocity and
displacement of certain magnitude earthquakes.

x is a rock site

☐ is a soil site

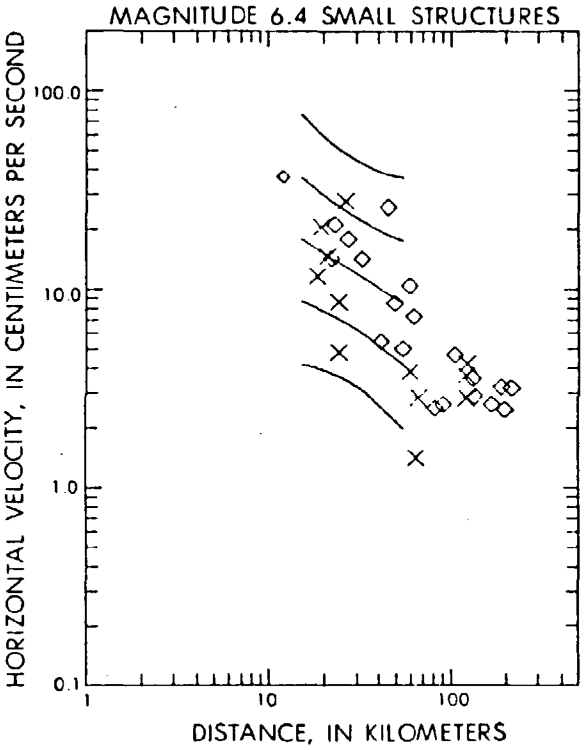

Figure Peak horizontal velocity versus distance to slipped fault for magnitude 6.4 recorded at base of small structures.

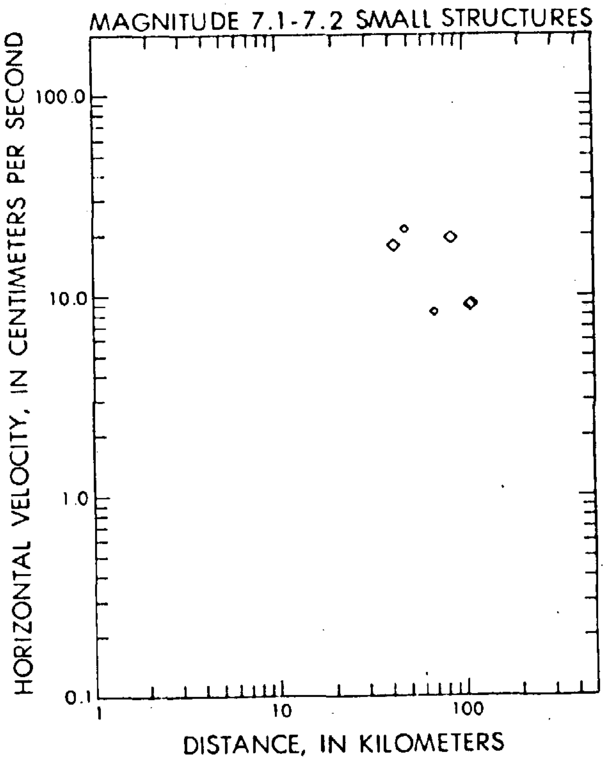

Figure Peak horizontal velocity versus distance to slipped fault for magnitude range 7.1-7.2 recorded at base of small structures.

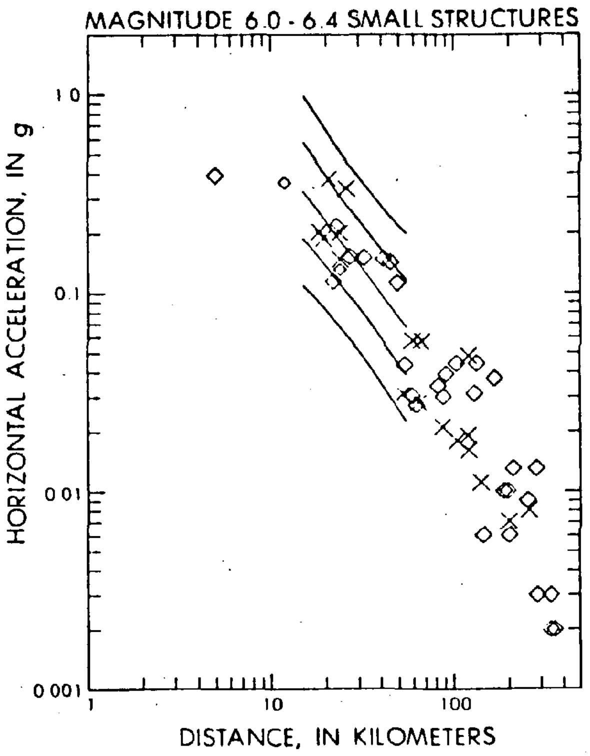

Figure Peak horizontal acceleration versus distance to slipped fault for magnitude range 6.0-6.4 recorded at base of small structures.

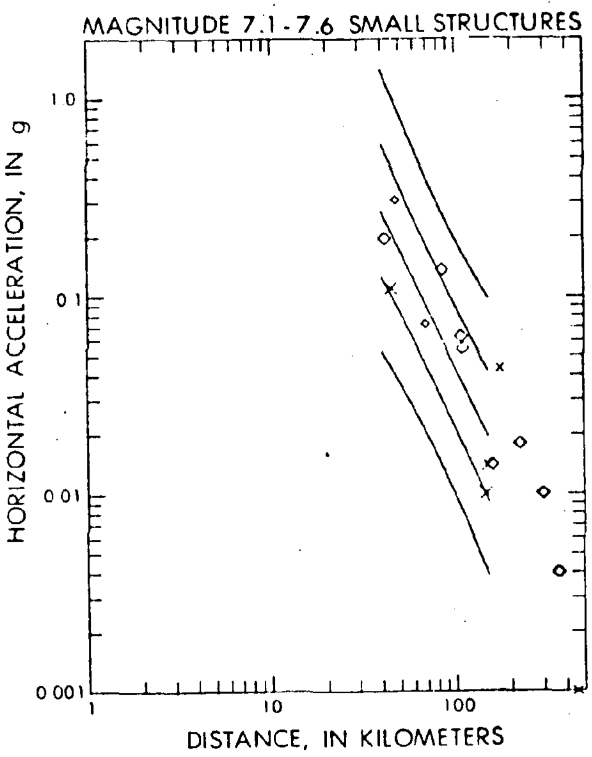

Figure Peak horizontal acceleration versus distance to slipped fault for magnitude range 7.1-7.6 recorded at base of small structures.

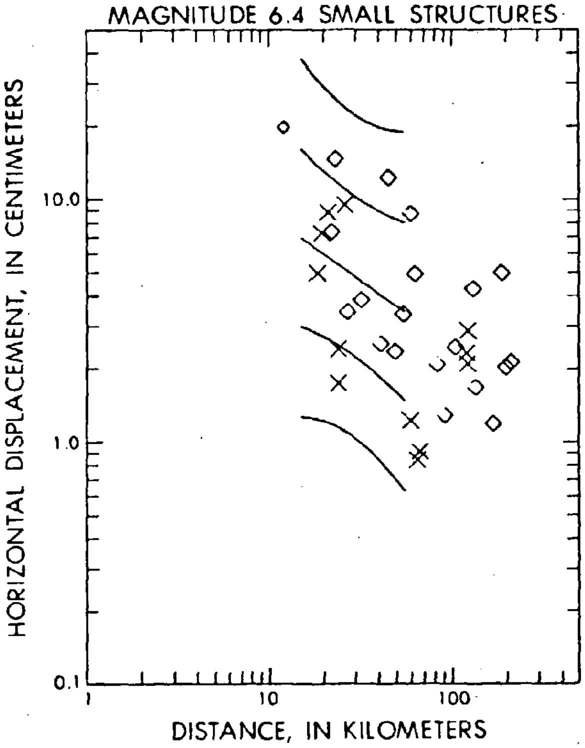

Figure Peak horizontal displacement versus distance to slipped fault for magnitude 6.4 recorded at base of small structures.

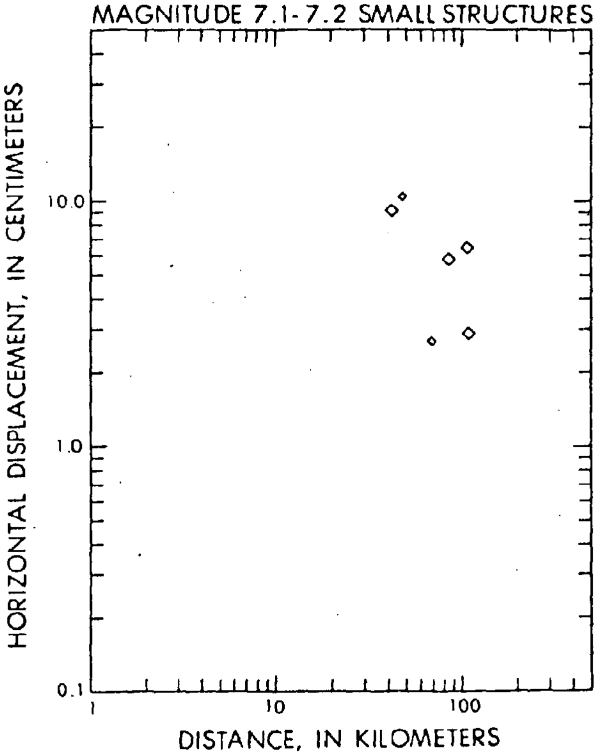

Figure Peak horizontal displacement versus distance to slipped fault for magnitude range 7.1-7.2 recorded at base of small structures.

APPENDIX II-1

U. S. Geological Survey computer printout of water well data used in this report. This is all preliminary data and is subject to revision.

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
--	~~HENDRICKSON, O M~~	~~03/27/1979~~	~~H~~	~~78~~	~~78~~	~~34.00~~		~~73~~	~~S~~
~~21N/01E-02001~~	~~CALDWELL, AUDLEY F~~	~~--~~	~~--~~	~~122~~	~~122~~	~~62.00~~		~~--~~	~~--~~
29N/03W-02K02	TYLER	04/26/1974	H	--	--	50.00		73	P
29N/03W-02C01	SEQUIM BAY PARK	02/ /1947	R	492	492	--		78	P
29N/03W-02J01	RIVELAND ET.AL., DALE	--	H	--	22	14.34		--	--
29N/03W-02K01	ERICKSON, RODNEY	1964	H	--	150	67.95		--	--
29N/03W-02N01	BAIN	01/01/1901	H	215	183	171.00		178	S
29N/03W-02Q01	OLSON, ROY	02/ /1968	U	--	300	29.12		--	--
29N/03W-03Q01	DUNN	10/20/1975	U	185	185		D	--	--
29N/03W-04D01	BUYERS, OTTO H	1960	H	--	121	112.00		--	--
29N/03W-12H01	KAILIN, ELOIS	10/10/1977	H	45	45	9.00+		40	S
29N/03W-12D01	CASCADE POLE CO	1960	H	--	25	--		--	--
29N/03W-12F01	BROWN	05/ /1969	--	31	31	14.00		26	--
29N/03W-12F02	JOPPE	03/09/1965	H	28	28	13.09		--	O
29N/04W-01B01	DENTON	03/12/1975	H	203	203	10.00		53	X
29N/04W-01E01	--	03/31/1978	H	30	30	7.00		--	--
29N/04W-01M01	CHAMROD	02/06/1974	H	21	21	11.00		--	O
29N/04W-02B01	STIRRATT, RALPH	02/24/1978	H	254	229	180.00		211	S
29N/04W-02F01	HOURQUIN	07/24/1975	H	92	92	30.00		--	P
29N/04W-02F02	LAYTON	01/01/1901	H	300	300	100.00		51	X
29N/04W-02F03	LAYTON, D. L	08/21/1978	H	300	300	16.00		39	X
29N/04W-02J01	MARKLEY, TOM	02/13/1975	H	220	220	32.00		20	X
29N/04W-02J02	WANNER, MATT	04/07/1978	H	39	39	10.00		28	P
29N/04W-02R01	RALLS	11/21/1973	H	180	180	10.00		14	X
29N/04W-15A01	PRITTIE	03/ /1968	U	450	0		D	--	--
29N/05W-01G01	BOWER, JAMES	08/04/1978	H	80	80	22.00		75	S
29N/05W-01K04	LAFRENIERE, RALPH	07/31/1978	H	95	95	56.00		90	S
29N/05W-01K05	LAFRENIERE, RALPH	08/08/1978	H	119	119	55.00		114	S
29N/05W-04N01	KOHLMAN, N. C	05/13/1978	H	88	88	69.00		--	O
30N/03W-20N01	NOWELL, FOREST J.	06/09/1976	H	156	156	80.00		--	S
30N/02W-17G01	WASH. STATE, DOE	07/01/1977	U	1015	280	241.00		245	P
30N/03W-18N01	HENDRICKSON, O. M	04/27/1976	H	72	72	37.00		67	S
30N/03W-05A01	LOCHOW, PETE	06/20/1977	H	33	33	6.00		--	O
30N/03W-05B01	BIA	1918	P	--	265		F	--	--
30N/03W-05B02	ALTON, WILLIAM T	1960	H	--	10	5.14		--	O
30N/03W-05B03	SUTTON	07/29/1974	H	37	37	5.00		34	S
30N/03W-05B04	BLACK, PETE	01/14/1977	R	40	40	7.50		35	S
30N/03W-05C01	MCINNES	05/15/1974	H	50	50	3.50		47	S
30N/03W-05H01	YOUNG, ALEX	01/01/1901	H	--	30	7.30		--	--
30N/03W-05M01	SWANBERG	05/21/1974	H	75	75	55.00		72	S

i.

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)		SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
--	17		17.0	1.5	G	U
21N/01E-02Q01	40		2.7	--	G	U
29N/03W-02	2		0.0	2.0	G	U
29N/03W-02C01	--		--	--	G	C
29N/03W-02J01	--		--	--		C
29N/03W-02K01	--		--	--		C
29N/03W-02N01	1		1.0	--	G	U
29N/03W-02Q01	--		--	--		C
29N/03W-03Q01	0.00		0.0	--	G	C
29N/03W-04D01	8		2.3	--	G	C
29N/03W-12-1	20		1.4	--	G	U
29N/03W-12D01	--		--	--		C
29N/03W-12F01	14		0.8	--	G	U
29N/03W-12F02	3		0.3	1.2	G	C
29N/04W-01	2		0.0	2.0	G	U
29N/04W-01-2	--		--	--		U
29N/04W-01M01	8		8.0	1.0	G	C
29N/04W-02-1	2		0.1	16.0	G	U
29N/04W-02F01	2		0.0	0.5	G	U
29N/04W-02F02	1		0.0	2.0	G	U
29N/04W-02F03	2		--	--	G	U
29N/04W-02J01	5		0.0	2.0	G	U
29N/04W-02J02	30		--	--	G	U
29N/04W-02R01	0.5		0.0	1.0	G	U
29N/04W-15A01	0.00		0.0	--	G	U
29N/05W-01G01	45		--	--	G	U
29N/05W-01K04	5		0.2	3.0	G	U
29N/05W-01K05	20		--	--	G	U
29N/05W-04N01	6		0.8	1.5	G	U
30/03W-20N01	20		4.0	1.5	G	C
30N/02W-17G01	--		--	--	G	C
30N/03-18SWQ-2	30		7.5	1.0	G	U
30N/03W-05A	45		6.4	--	G	U
30N/03W-05B01	64	F	--	--		C
30N/03W-05B02	--		--	--		C
30N/03W-05B03	20		--	--	G	U
30N/03W-05B04	16		1.5	1.5	G	U
30N/03W-05C01	30		--	--	G	U
30N/03W-05H01	--		--	--		C
30N/03W-05M01	20		--	--	G	C

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-05N01	SUNLAND ASSOC	11/13/1974	U	22	22	13.30	19	P
30N/03W-05N02	SUN LAND ASSOC	11/13/1974	U	20	20	15.30	17	P
30N/03W-05Q01	SUN LAND SHORES	07/13/1979	N	58	58	3.00	48	S
30N/03W-05R01	REED	06/08/1965	I	--	40	6.00	20	P
30N/03W-05R02	PEDERSEN ET AL, SOREN	05/03/1970	H	238	238	--	--	O
30N/03W-06C01	EVANS, FRANK	--	H	--	7	3.44	--	--
30N/03W-06D01	GAMLEN, V A	02/24/1978	H	151	151	115.00	145	S
30N/03W-06E01	HENNING, DENNIS	07/30/1979	H	144	144	11.00	--	O
30N/03W-06G01	TOWNSEND, GEORGE L	05/30/1967	P	122	122	60.00	--	O
30N/03W-06G02	MOSEBAR	04/29/1974	H	85	85	44.00	--	S
30N/03W-06G03	PETERSON	05/05/1975	H	141	141	114.00	--	O
30N/03W-06G04	INGLIS, D	11/17/1976	H	79	79	50.00	--	S
30N/03W-06G05	SMITH, CHARLIE	05/25/1978	H	157	157	93.00	152	S
30N/03W-06G06	--	05/15/1975	H	85	85	59.00	82	S
30N/03W-06G07	BOARDMAN, W C	03/25/1976	H	123	123	97.00	--	O
30N/03W-06G08	ARMSTRONG, JIM	10/21/1977	H	139	139	111.00	--	O
30N/03W-06H01	OLYMPICSTRAITS	10/18/1974	P	94	94	22.00	86	S
30N/03W-06H02	DAILEY, JERRY	06/23/1979	H	144	144	F	--	O
30N/03W-06H03	WAJDA, FRANK	03/19/1979	H	45	45	1.00+	--	O
30N/03W-06J01	OLYMPIC STRAITS	09/11/1974	U	105	0	--	--	--
30N/03W-06J02	OLYMPIC STRAITS	09/23/1974	--	329	0	--	--	--
30N/03W-06J03	OLYMPIC STRAITS	12/05/1974	H	--	92	21.30	87	S
30N/03W-06K01	PURVIS, ED	06/13/1978	H	96	96	70.00	--	O
30N/03W-06K02	CAMPBELL, ROBERT	07/09/1979	H	118	118	90.00	--	O
30N/03W-06L01	BRADY, TOM	04/05/1979	H	73	73	57.00	--	O
30N/03W-06L01	HENDRICKSON, JERRY	06/27/1977	H	109	109	78.00	102	S
30N/03W-06L02	MEAD, JOHN	04/09/1977	H	118	118	82.00	112	S
30N/03W-06M01	PARKINSON, C. D	03/07/1978	H	105	105	83.00	--	O
30N/03W-06M02	MILLMAN, BOB	01/19/1978	H	139	139	109.00	130	S
30N/03W-06M03	MCCOLL, GORDON	02/09/1978	H	120	120	99.00	--	O
30N/03W-06M05	BEST, RICK	04/03/1979	H	149	149	118.00	144	S
30N/03W-06N01	KIRNER, CONRAD	--	H	--	84	63.69	--	O
30N/03W-06N02	THOMAS, BILL T	12/09/1976	H	100	97	74.00	91	S
30N/03W-06R01	ANGINLI	1930	H	--	22	19.00	--	--
30N/03W-07A01	STILL, CHARLES	--	H	--	32	19.19	--	--
30N/03W-07D01	GASKELL, ROBERT	10/ /1958	H,S	--	130	75.00	--	O
30N/03W-07F01	RUTLEDGE, DICK	01/27/1979	H	66	66	30.00	61	S
30N/03W-07L01	GRIFFITH, JOHN T	1960	H	--	46	26.69	--	--
30N/03W-07L02	TREVILLION, & FARLEY	08/03/1978	H	31	31	9.00	--	O
30N/03W-07M01	SHOLAR, NORMAN	08/18/1977	H	43	43	4.00	37	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-05N01	--	--	--	G	C
30N/03W-05N02	--	--	--	G	C
30N/03W-05Q01	180	19.5	4.0	G	U
30N/03W-05R01	600	67.0	8.0	G	C
30N/03W-05R02	40	--	--	G	U
30N/03W-06C01	--	--	--		C
30N/03W-06D01	30	30.0	--	G	U
30N/03W-06E01	20	0.7	1.5	G	U
30N/03W-06G01	100	33.0	4.0	G	U
30N/03W-06G02	40	40.0	1.0	G	U
30N/03W-06G03	20	10.0	1.0	G	U
30N/03W-06G04	30	30.0	3.0	G	U
30N/03W-06G05	17	0.8	1.5	G	U
30N/03W-06G06	30	30.0	1.0	G	U
30N/03W-06G07	20	4.0	1.0	G	U
30N/03W-06G08	25	--	--	G	U
30N/03W-06H01	168	52.0	--	G	U
30N/03W-06H02	36	4.5	2.0	G	U
30N/03W-06H03	12	0.4	1.5	G	U
30N/03W-06J01	--	--	--	G	U
30N/03W-06J02	--	--	--	G	U
30N/03W-06J03	225	8.2	5.0	G	U
30N/03W-06K01	25	--	--	G	U
30N/03W-06K02	30	3.0	--	G	U
30N/03W-06L01	15	3.0	1.5	G	U
30N/03W-06L01	20	--	2.0	G	C
30N/03W-06L02	22	2.2	1.5	G	U
30N/03W-06M01	30	30.0	3.0	G	C
30N/03W-06M02	20	20.0	3.0	G	U
30N/03W-06M03	15	--	--	G	C
30N/03W-06M05	20	20.0	1.5	G	U
30N/03W-06N01	--	--	--		C
30N/03W-06N02	22	22.0	2.0	G	U
30N/03W-06R01	--	--	--	G	C
30N/03W-07A01	--	--	--		C
30N/03W-07D01	20	2.0	--	G	C
30N/03W-07F01	18	1.8	1.5	G	U
30N/03W-07L01	200	100.0	2.0	G	C
30N/03W-07L02	30	2.5	--	G	U
30N/03W-07M01	35	2.3	2.0	G	C

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-07N01	DEVINE	06/06/1977	H	90	41	8.00	22	P
30N/03W-07N02	STEVENS	09/10/1975	H	38	38	7.42	--	0
30N/03W-07N03	MARTIN, LARRY	05/08/1978	H	53	48	12.00	45	S
30N/03W-07N04	MATHIS, LEWIS	12/15/1976	H	24	24	5.00	--	0
30N/03W-07N05	ROBERTS, GARY+PAT	05/01/1978	H	66	66	7.50	--	0
30N/03W-07P01	STRYKER, CECIL	03/15/1978	H	44	44	13.00	--	0
30N/03W-07P02	GRIFFITH, BETTY F	05/18/1978	H	52	52	41.00	--	0
30N/03W-07P03	BILLINGSLEY, PAUL	05/09/1978	H	90	74	19.00	--	0
30N/03W-07P04	CHINNER, JOHN	01/08/1975	H	43	43	-6.00	38	S
30N/03W-07P05	BERGERON	04/01/1975	H	90	86	19.00	81	S
30N/03W-07P06	EPPICK, FRANK	03/20/1975	H	50	50	7.00	45	S
30N/03W-07P07	NIENKARK	01/31/1979	H	194	194	4.00	--	0
30N/03W-07R01	SEQUIM VIEW CEM	--	I	--	35	16.92	--	--
30N/03W-08B01	SUNLAND ASSOC	01/27/1975	I	58	52	6.20	42	S
30N/03W-08C01	CASSALERY, MOE	--	H,S	--	30	13.00	--	--
30N/03W-08C02	SUNLAND ASSOC	08/06/1979	P	124	124	11.80	109	S
30N/03W-08J01	STONE, STACY	02/23/1976	I,H	342	342	79.42	303	P
30N/03W-08M01	SUN LAND ASSOC	04/15/1963	P	250	250	78.00	160	S
30N/03W-08P02	FRICK, DORA L	06/22/1978	H	117	117	87.00	--	0
30N/03W-08R01	STARES	01/01/1901	H,S	--	84	76.00	--	--
30N/03W-08~~S[illegible]~~M02	ANGIULI, NATHALIE	05/22/1978	H	118	118	71.00	113	S
30N/03W-09K01	GRAYS MARSH FRM	--	H,S	--	40	--	--	--
30N/03W-10N01	GATES, JAMES	1952	H	--	310	7.00	--	S
30N/03W-15G01	SEQUIM VALLEY	04/13/1951	H	574	574	F	--	--
30N/03W-16B01	SNIDER	01/01/1901	H	--	39	19.00	--	--
30N/03W-16B02	SMITH	01/01/1901	U	--	28	26.04	--	--
30N/03W-16B03	LANCASTER, LESTER	05/05/1976	H	113	113	73.00	--	0
30N/03W-16C01	WOODMAN	06/01/1974	H	184	184	77.00	177	S
30N/03W-16C02	PETERSON	11/26/1974	H	90	58	25.00	51	S
30N/03W-16C03	MATTMAN, CHARLES	02/17/1978	H	50	50	--	45	S
30N/03W-16D01	WILLEY	06/08/1975	H	152	152	75.00	--	0
30N/03W-16D02	LILLEY, GORDON	07/26/1979	H	90	89	73.00	--	0
30N/03W-16F01	MATTMAN, CHUCK	06/12/1977	H	55	52	--	47	S
30N/03W-16F02	FRYER, DAN	08/24/1978	H	62	62	43.00	59	S
30N/03W-16K01	RUTLEDGE, DICK	04/30/1979	H	75	75	52.00	70	S
30N/03W-16L01	BELENSKI, BILL	11/08/1978	H	98	98	81.00	93	S
30N/03W-17~~1~~K01	BERMAN, STANTON	11/25/1977	H	41	41	14.00	--	0
30N/03W-17A01	EGGERS	12/06/1974	H	157	157	75.00	--	0
30N/03W-17B01	BENT, BOB	01/03/1977	H	79	79	59.00	--	0
30N/03W-17B02	BAILEY, ED	04/06/1978	H,I	158	156	76.00	145	S

V.

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-07N01	50	10.0	--	G	C
30N/03W-07N02	30	7.5	--	G	C
30N/03W-07N03	20	4.0	2.0	G	C
30N/03W-07N04	50	50.0	--	G	U
30N/03W-07N05	60	60.0	1.0	G	U
30N/03W-07P01	10	0.3	1.5	G	U
30N/03W-07P02	9	9.0	1.0	G	C
30N/03W-07P03	20	0.3	2.0	G	C
30N/03W-07P04	20	20.0	3.0	G	U
30N/03W-07P05	12	0.2	10.0	G	U
30N/03W-07P06	80	80.0	2.0	G	U
30N/03W-07P07	25	2.5	--	G	U
30N/03W-07R01	--	--	--		C
30N/03W-08B01	250	15.6	3.8	G	C
30N/03W-08C01	--	--	--		C
30N/03W-08C02	705	46.2	1.1	G	U
30N/03W-08J01	170	1.0	8.0	G	C
30N/03W-08M01	600	18.0	2.5	G	C
30N/03W-08P02	15	1.9	4.0	G	U
30N/03W-08R01	5	--	--		C
30N/03W-08SWQ-1	30	--	--	G	U
30N/03W-09K01	--	--	--		C
30N/03W-10N01	--	--	--		U
30N/03W-15G01	100 F	--	--	G	C
30N/03W-16B01	--	--	--		C
30N/03W-16B02	--	--	--		C
30N/03W-16B03	15	0.5	--	G	C
30N/03W-16C01	36	1.3	3.0	G	C
30N/03W-16C02	20	0.6	2.0	G	U
30N/03W-16C03	6	--	--	G	U
30N/03W-16D01	--	--	--	G	U
30N/03W-16D02	20	2.0	1.5	G	U
30N/03W-16F01	25	12.5	2.0	G	U
30N/03W-16F02	25	3.6	1.0	G	U
30N/03W-16K01	12	2.4	1.5	G	U
30N/03W-16L01	10	10.0	1.5	G	U
30N/03W-17-1	40	40.0	--	G	U
30N/03W-17A01	25	--	--	G	C
30N/03W-17B	10	--	1.5	G	U
30N/03W-17B02	55	--	--	G	C

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-17D01	ILLSLEY, HARRY	04/11/1978	H	79	79	22.20	74	S
30N/03W-17D02	THAYNE, WALTER	06/06/1978	H	76	74	17.50	69	S
30N/03W-17D03	WHITESIDE, RAY	07/19/1978	H	78	78	16.50	73	S
30N/03W-17D04	MC GARR, C H	04/21/1979	H	80	79	23.00	74	S
30N/03W-17D05	TAYLOR, RAYMOND E	05/05/1979	H	80	80	24.00	75	S
30N/03W-17E01	LAWRENCE, KETTEL	04/17/1976	H	35	35	12.00	--	O
30N/03W-17F01	STONE, STACEY	--	H,S	--	32	7.00	--	--
30N/03W-17L01	EKSE	11/21/1974	H	54	54	29.00	--	O
30N/03W-17L02	ARTS BARBERSHOP	--	--	--	--	--	--	--
30N/03W-17L03	OLSON, M. A	12/21/1976	H	37	37	10.00	--	O
30N/03W-17N01	GUSTAFSON	07/15/1974	H	68	68	14.70	64	--
30N/03W-17N02	WEATHERBY	10/28/1974	H	539	53	14.60	--	O
30N/03W-17N03	MAURER-2, STEVE	02/11/1977	H	49	49	24.00	--	O
30N/03W-18~~1~~F10	STONE, GREGG	04/09/1976	H	56	56	20.50	48	S
30N/03W-18A01	ADVENTIST CH	09/04/1975	H	60	60	12.75	--	S
30N/03W-18A02	SANFORD, NEUMAN	09/02/1977	H	31	31	14.00	--	O
30N/03W-18A03	SEQUIM BAPT. CH	06/08/1978	H	96	96	22.00	91	S
30N/03W-18B01	ALFRONE, JENE	08/31/1979	H	79	79	21.00	--	O
30N/03W-18B02	WRIGHT, GAYLORD	03/29/1979	H	89	88	39.00	--	O
30N/03W-18C01	NEUBAUER	02/06/1974	H	46	46	15.00	--	O
30N/03W-18C02	BURKS, SHIRD	12/13/1977	H	--	--	8.00	--	O
30N/03W-18D01	CAYS	03/05/1975	H	68	68	11.00	65	S
30N/03W-18D02	GILKISON	09/19/1974	H	37	37	2.00	--	O
30N/03W-18D03	WEHORG, WILLIAM H	09/19/1974	H	45	45	9.00	40	--
30N/03W-18D04	ROACH, NOLAN	01/10/1978	H	59	59	3.58	54	S
30N/03W-18D05	ANDERSON, E.	03/01/1978	H	72	72	12.00	59	S
30N/03W-18E01	LOVEGREN	09/17/1974	H	44	44	4.00	40	S
30N/03W-18E02	SHARP	07/23/1974	H	55	55	2.50	51	S
30N/03W-18E03	HAMMOND	10/27/1975	H	40	40	6.00	37	S
30N/03W-18E04	TELFORD	12/20/1974	H	39	39	9.75	36	P
30N/03W-18E05	BIRD, JAY	04/23/1976	H	66	66	27.00	--	O
30N/03W-18E06	SHAY, JIM	05/10/1976	H	41	41	7.00	38	S
30N/03W-18E07	CHURCHILL, C C	05/16/1977	H	51	48	6.00	44	S
30N/03W-18E08	G&H CONTRACTORS	03/07/1974	H	89	89	6.00	86	S
30N/03W-18F01	MUELLER, DAVID	02/08/1978	H	49	49	18.00	--	O
30N/03W-18F02	TRAVELLION, WALT	03/02/1977	H	38	39	15.60	33	S
30N/03W-18F03	MCNUTT, RALPH	06/08/1977	H	38	38	14.00	--	O
30N/03W-18F04	OLIPHANT, LEONARD D	12/09/1976	H	42	42	6.50	--	O
30N/03W-18F05	PARSON, DON	12/13/1976	H	40	40	12.00	--	O
30N/03W-18F06	KELSAY, MERRITT	06/10/1977	H	43	43	7.50	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-17D01	50	--	--	G	C
30N/03W-17D02	30	--	--	G	C
30N/03W-17D03	25	0.8	3.0	G	U
30N/03W-17D04	25	1.3	2.0	G	U
30N/03W-17D05	20	0.5	2.0	G	U
30N/03W-17E-1	40	20.0	--	G	U
30N/03W-17F01	--	--	--		C
30N/03W-17L01	45	2.0	--	G	U
30N/03W-17L02	--	--	--		C
30N/03W-17L03	25	1.9	--	G	U
30N/03W-17N01	40	2.7	--	G	U
30N/03W-17N02	45	2.4	--	G	U
30N/03W-17N03	40	8.0	--	G	U
30N/03W-18-1	50	12.5	2.0	G	U
30N/03W-18A01	30	--	--	G	U
30N/03W-18A02	30	--	--	G	U
30N/03W-18A03	45	--	--	G	C
30N/03W-18B01	20	--	1.5	G	U
30N/03W-18B02	50	--	1.0	G	U
30N/03W-18C01	16	--	--	G	U
30N/03W-18C02	35	1.8	--	G	U
30N/03W-18D01	20	0.5	--	G	U
30N/03W-18D02	--	--	--	G	U
30N/03W-18D03	16	0.6	--	G	U
30N/03W-18D04	30	2.3	0.5	G	U
30N/03W-18D05	60	10.0	2.2	G	U
30N/03W-18E01	40	--	--	G	U
30N/03W-18E02	45	3.0	--	G	U
30N/03W-18E03	25	1.8	--	G	U
30N/03W-18E04	40	--	--	G	U
30N/03W-18E05	26	1.2	--	G	U
30N/03W-18E06	50	5.0	--	G	U
30N/03W-18E07	30	7.5	2.0	G	U
30N/03W-18E08	17	--	--	G	U
30N/03W-18F01	12	0.8	--	G	U
30N/03W-18F02	20	2.9	1.5	G	U
30N/03W-18F03	40	6.7	--	G	C
30N/03W-18F04	50	5.0	--	G	C
30N/03W-18F05	25	2.5	--	G	U
30N/03W-18F06	50	5.0	--	G	U

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-18F07	LACCINOLE, JIM	06/16/1977	H	44	44	10.50	--	O
30N/03W-18F08	ARNOLD, WILLIS R	12/12/1975	H	36	36	8.00	32	S
30N/03W-18F09	HANSEN, DON	07/03/1979	H	36	36	16.00	--	O
30N/03W-18G 02	BRIDGE, CHARLES	12/17/1976	H	30	30	13.00	--	O
30N/03W-18G01	HOLLECK, JOSEPH	11/04/1977	H	59	59	14.83	45	P
30N/03W-18H01	WOOD, ROBERT	05/24/1977	H	85	83	13.75	--	P
30N/03W-18H02	MARTIM, DON	05/08/1978	H	59	59	24.20	--	O
30N/03W-18J01	GASCHK, MEL	03/25/1976	H	41	41	--	36	S
30N/03W-18J02	SANDS+KRAFT	03/15/1978	H	91	80	43.00	--	O
30N/03W-18J03	FORD, LUCILLE	10/24/1978	H	45	45	11.00	--	O
30N/03W-18M01	BOSTON	03/01/1975	H	44	44	22.00	--	O
30N/03W-18M02	FISHER	10/16/1973	H	49	49	10.00	--	O
30N/03W-18M03	STURDEVENT	10/23/1975	H	50	50	13.67	--	O
30N/03W-18M04	HEDAHL, VERN	02/02/1978	H	47	47	18.00	41	S
30N/03W-18M05	SHEPHARD, WILLIAM C	01/04/1978	H	47	47	20.00	--	O
30N/03W-18Q01	SORENSEN, DON	05/12/1977	H	51	44	20.00	--	S
30N/03W-18Q02	HARRIS, LORRAINE C	03/14/1979	H	59	59	22.00	--	O
30N/03W-18Q03	BROWN, RICK	10/19/1978	H	46	46	15.00	--	O
30N/03W-18R01	SEQUIM BIBLE CH	11/28/1969	H,I	51	51	7.00	--	O
30N/03W-18R02	GOLLEHON	09/22/1975	H	28	28	8.00	--	O
30N/03W-18R03	SEQUIM VIEW LND	04/14/1972	H	85	85	20.00	55	S
30N/03W-18~~6~~ M06	TURNER, WINSTON	10/26/1977	H	55	55	18.50	--	O
30N/03W-19D01	CAMERON	10/11/1972	H	67	49	32.00	--	O
30N/03W-20A01	BLAKE, ED	1956	H,S	34	34	11.56	--	--
30N/03W-20B01	BUCHER	01/ /1949	S,I	--	23	0.00	--	--
30N/03W-20C01	CLAYTON	1900	H,S,I	--	50	9.00	--	--
30N/03W-20C02	PEDLAR	05/08/1971	H	36	36	9.50	--	O
30N/03W-20C03	FOSTER, J. C	08/14/1978	H	75	75	40.00	70	S
30N/03W-20E01	MACEDO, STANLEY T	10/11/1977	I	71	71	26.00	66	S
30N/03W-20M01	KRISTOFERSON	--	P	--	100	--	--	--
30N/03W-20Q01	BELFIELD	05/20/1966	--	235	236	36.00	--	--
30N/03W-20R01	VALASKE	01/01/1901	H	201	158	82.00	145	S
30N/03W-21A01	SMITH	10/10/1973	H	46	46	1.00	--	O
30N/03W-21D01	HOLGERSON, HILL	10/03/1979	H	230	230	58.00	--	O
30N/03W-21H01	BAYWOOD VILLAGE	02/10/1970	P	298	298	95.00	--	O
30N/03W-21H02	DOWNIE	05/21/1974	H	265	265	113.00	--	O
30N/03W-21K01	BOSTROM, DON	01/01/1901	H	--	117	99.00	103	P
30N/03W-21K02	CABBAGE	11/21/1975	H	162	162	60.00	--	S
30N/03W-21K03	NELSON, ART	07/15/1976	H	280	280	107.50	--	O
30N/03W-21M01	BAKER	10/06/1975	H	69	68	13.00	65	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-18F07	20	1.0	--	G	U
30N/03W-18F08	50	10.0	--	G	U
30N/03W-18F09	15	15.0	1.5	G	U
30N/03W-18GH-1	20	6.7	--		U
30N/03W-18G01	100	--	--	G	U
30N/03W-18H01	60	8.3	6.0	G	U
30N/03W-18H02	40	--	--	G	U
30N/03W-18J01	--	--	--	G	U
30N/03W-18J02	40	2.0	2.0	G	U
30N/03W-18J03	20	0.8	--	G	U
30N/03W-18M01	12	1.2	--	G	U
30N/03W-18M02	40	2.7	1.0	G	U
30N/03W-18M03	40	2.4	--	G	U
30N/03W-18M04	30	15.0	1.5	G	U
30N/03W-18M05	24	12.0	1.0	G	U
30N/03W-18Q01	20	--	1.0	G	U
30N/03W-18Q02	40	--	1.0	G	U
30N/03W-18003	40	3.3	--	G	U
30N/03W-18R01	40	5.0	1.0	G	U
30N/03W-18R02	15	1.2	--	G	U
30N/03W-18R03	72	33.2	4.0	G	U
30N/03W-18SWQ-1	30	--	--	G	U
30N/03W-19D01	35	2.3	2.0	G	C
30N/03W-20A01	10	--	--	G	C
30N/03W-20B01	--	--	--		C
30N/03W-20C01	300	29.0	4.0	G	C
30N/03W-20C02	60	20.0	2.0	G	U
30N/03W-20C03	30	2.3	3.0	G	U
30N/03W-20E01	60	--	2.0	G	C
30N/03W-20M01	--	--	--		C
30N/03W-20Q01	30	0.3	2.0	G	C
30N/03W-20R01	30	1.4	47.0	G	U
30N/03W-21A01	20	2.0	2.0	G	C
30N/03W-21D01	60	15.0	3.0	G	U
30N/03W-21H01	19	0.5	1.5	G	C
30N/03W-21H02	9	0.2	--	G	C
30N/03W-21K01	17	17.0	4.0	G	C
30N/03W-21K02	20	0.3	--	G	U
30N/03W-21K03	6	0.1	3.0	G	C
30N/03W-21M01	6	0.1	--	G	U

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-22K01	BATELLE NW LABS	1900	H	634	355	4.00+	--	--
30N/03W-22M01	ZAHN	04/25/1969	H,I	333	333	137.00	327	S
30N/03W-22M02	DILTZ, DARLENE	02/23/1979	H	235	232	134.00	227	S
30N/03W-22N01	EBERLY	1959	--	--	179	150.00	--	--
30N/03W-27G01	MURRAY	04/15/1974	H	40	40	16.00	--	O
30N/03W-27F01	AKERS	01/10/1975	H	300	300	40.00	90	P
30N/03W-27B01	WHITFIELD	05/ /1955	H	66	66	35.00	--	O
30N/03W-27B02	SPATH, L. M	--	H	--	64	25.30	--	--
30N/03W-27B03	EVANS, FRED G	--	H	--	8	2.99	--	--
30N/03W-27B04	FULLERTON, LEE	09/07/1977	H	65	65	40.00	62	S
30N/03W-27C01	MCCORIE	--	H,S	--	35	--	--	--
30N/03W-27K01	STANDARD, JAMES F	11/02/1978	U	180	0	0	--	--
30N/03W-27B05	HEBERT, ED	05/18/1978	H	68	68	39.00	--	O
30N/03W-27Q01	SCHENCK, PHIL	--	H	--	15	4.00	--	O
30N/03W-28M01	TRIPP	1948	H,S	--	400	189.30	--	--
30N/03W-28K01	MARTIN	11/18/1974	H	145	145	6.50	36	P
30N/03W-28M01	WALLA-1, DONALD	07/12/1977	--	200	200	0	--	X
30N/03W-28M02	WALLA-2, DONALD	09/02/1977	--	130	130	0	17	P
30N/03W-29A01	HERRETT	08/29/1970	P	113	113	90.00-	109	S
30N/03W-30D01	SOUTHERLUND	05/30/1974	H	172	172	47.00	169	S
30N/03W-30D02	LURENSON	03/ /1947	H,I	265	0	--	--	--
30N/03W-30D03	REVARD, CARL	04/02/1976	H	99	100	47.00	92	S
30N/03W-30D04	FLEGEL, FRITZ	10/05/1978	H	120	119	46.00	114	S
30N/03W-30D05	PETERSON, JON C	04/13/1979	H	185	185	125.00	180	S
30N/03W-30D06	BURR, TED	01/17/1979	H	90	90	50.00	85	S
30N/03W-30H02	GERHARDT	02/20/1975	H	66	66	4.00+	--	O
30N/03W-30J02	LILE, AUDREY N	08/12/1977	H	110	110	34.00	105	S
30N/03W-30L01	ARMSTRONG	11/25/1974	H	64	64	35.00	--	O
30N/03W-30Q01	KING	10/16/1974	H	--	--	44.00	113	X
30N/03W-30R01	WILLIS	1948	H,I	65	65	50.00	50	S
30N/03W-30R02	LIDDLE	07/12/1974	H	93	93	19.00	90	S
30N/03W-31C01	BERGER	08/10/1961	H	54	48	3.00	49	S
30N/03W-31K06	KNIGHT	10/03/1974	H	137	137	29.00	134	S
30N/03W-31Q01	SCOTT	06/20/1974	H	126	126	10.75	35	P
30N/03W-31C02	SILVERTHORN, WILLIAM	07/15/1975	H	41	41	4.00	--	O
30N/03W-31B01	JOHNSTON, RICHARD L	03/08/1978	H	185	28	--	--	O
30N/03W-31D01	PINSON	06/12/1974	H	51	51	2.60	44	S
30N/03W-31D02	COCCIA	06/14/1974	H	41	41	5.00	--	O
30N/03W-31E01	FULLER	01/30/1974	H	34	84	9.00	--	O
30N/03W-31G01	MCCLESS	10/25/1974	H	61	61	11.50	56	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-22K01	20	0.5	--		C
30N/03W-22M01	18	1.4	0.5	G	U
30N/03W-22M02	10	0.1	4.0	G	U
30N/03W-22N01	5	0.3	2.0	G	C
30N/03W-27-1	20	3.3	1.0	G	U
30N/03W-27-3	--	--	--	G	U
30N/03W-27B01	9	0.8	--	G	C
30N/03W-27B02	--	--	--		C
30N/03W-27B03	--	--	--		C
30N/03W-27B04	3	3.0	1.5	G	C
30N/03W-27C01	--	--	--		C
30N/03W-27K01	0.00	0.0	--	G	U
30N/03W-27NEQ-1	8	0.4	--	G	U
30N/03W-27Q01	--	--	--		C
30N/03W-28H01	--	--	--		C
30N/03W-28K01	7	0.1	--	G	U
30N/03W-28M01	--	--	--	G	U
30N/03W-28M02	--	--	--	G	U
30N/03W-29A01	10	0.4	1.0	G	C
30N/03W-30D01	20	0.3	--	G	C
30N/03W-30D02	--	--	--		U
30N/03W-30D03	8	0.2	1.5	G	C
30N/03W-30D04	65	--	1.5	G	U
30N/03W-30D05	50	2.8	3.2	G	U
30N/03W-30D06	12	0.6	1.5	G	U
30N/03W-30H02	1	0.0	--	G	C
30N/03W-30J02	12	--	--		U
30N/03W-30L01	13	--	--	G	C
30N/03W-30Q01	2	0.0	--	G	U
30N/03W-30R01	38	460.0	3.0		U
30N/03W-30R02	30	1.2	--	G	U
30N/03W-31-1	25	1.4	2.0	G	U
30N/03W-31-3	12	0.1	--	G	U
30N/03W-31-4	9	0.5	2.0	G	U
30N/03W-31-5	20	2.9	--	G	U
30N/03W-31B01	2	--	--	G	U
30N/03W-31D01	12	0.4	--	G	U
30N/03W-31D02	40	2.7	--	G	U
30N/03W-31E01	20	1.5	3.0	G	U
30N/03W-31G01	36	1.6	--	G	U

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-01J06	WILLIS, JOHN	09/08/1976	H	68	68	38.00	63	S
30N/04W-01J02	ZBARASCHUK	08/04/1975	H	140	140	105.00	135	S
30N/04W-01J03	GINGRICH, INEL	06/08/1977	H	141	141	110.00	137	S
30N/04W-01J04	FRITZ, S. A	07/04/1974	H	153	153	118.00	--	O
30N/04W-01J05	BALKAN, MIKE	08/12/1976	H	151	151	113.67	146	S
30N/04W-01J07	WALKER, FRED	06/07/1979	H	87	87	71.00	--	O
30N/04W-01K01	LEWIS, CHARLES D	12/11/1953	--	143	142	99.00	--	O
30N/04W-01K02	FOREST RIDGE	10/04/1978	P	139	139	99.00	129	S
30N/04W-01K03	ALDRICH, KIRK	06/29/1977	H	93	93	71.00	--	--
30N/04W-01K04	HANKES, WILLARD	05/26/1978	H	130	130	116.00	124	S
30N/04W-01L01	MADRONA HEIGHTS, FIANDER	--	P	--	70	24.15	65	S
30N/04W-01L02	FIANDER	10/27/1969	P	300	162	60.00	--	S
30N/04W-01M01	WASH. STATE, DPT.FISHRS	07/31/1975	Z	130	118	6.50	37	S
30N/04W-01M02	WASH.STAT, DPT.FISHRS	09/05/1975	Z	133	130	14.40	--	O
30N/04W-01M03	MACDONALD, BOB	1969	H	--	--	10.20	--	--
30N/04W-01M04	WASH.STATE, DPT.FISHRS	1974	U	134	134	6.00	--	--
30N/04W-01N01	HURD	--	H	--	39	10.64	--	O
30N/04W-01N02	GAULT	--	H	--	18	11.15	--	--
30N/04W-01P01	STRUMBAUGH, RICHARD	05/18/1978	H	110	110	58.00	--	O
30N/04W-01Q01	ONEILL	01/29/1974	H	88	88	57.50	--	O
30N/04W-01Q02	MEYER I	02/03/1978	H	89	89	69.00	--	O
30N/04W-01Q03	ANDERSON, TERRY	12/30/1976	H	92	92	63.00	--	O
30N/04W-02G01	GLOVER, MILTON F	10/29/1976	H	52	52	17.00	48	S
30N/04W-02M01	SCHMUCK, HANS	--	H,S	--	51	8.64	--	--
30N/04W-02M02	MILLS, DONALD F	09/27/1978	H	180	180	F	175	S
30N/04W-02M03	MAHAN	09/17/1975	H	239	239	15.00+	232	S
30N/04W-02P01	MANTLE, REX J	--	H,S	10	10	5.16	--	--
30N/04W-02R01	WHEELER	04/22/1969	I	62	62	9.00	25	P
30N/04W-03C01	LEMCKE	11/06/1975	H	69	69	46.00	--	O
30N/04W-03D01	MICHAEL, RUSSELL	03/29/1978	H	56	56	24.50	51	S
30N/04W-03D02	WILCH, HOWARD	12/20/1978	H	73	73	39.00	--	O
30N/04W-03H01	SCHREINER, JAMES	--	H	--	40	3.20	--	--
30N/04W-03H03	LOWICKI, ED	03/02/1978	H	61	61	25.00	58	S
30N/04W-03H04	COFFEL, TOM	08/03/1978	H	56	56	27.00	51	S
30N/04W-03H05	LAVENDER	03/12/1969	H,I,S	65	65	5.00	--	--
30N/04W-03H06	COFFEL, TOM	02/22/1979	H	63	63	24.00	58	S
30N/04W-03J01	HARTMAN, LAVERNE	05/20/1978	H	178	178	2.00	173	S
30N/04W-03N01	NOMBALAIS, FRANK	06/29/1977	H	66	66	23.00	61	S
30N/04W-03Q01	MT VISTA COUNTRY CLUB, COUNTRY	05/18/1973	P	265	249	5.00	234	S
30N/04W-04~~1~~L03	ROBERTS, GUY	01/30/1976	H	108	108	70.50	103	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-01J	15	5.0	2.0	G	U
30N/04W-01J02	20	20.0	2.0	G	U
30N/04W-01J03	20	--	1.5	G	U
30N/04W-01J04	20	1.7	--	G	U
30N/04W-01J05	20	--	1.5	G	U
30N/04W-01J07	12	12.0	1.5	G	U
30N/04W-01K01	40	4.0	--	G	C
30N/04W-01K02	76	9.0	3.2	G	U
30N/04W-01K03	25	2.5	--	G	C
30N/04W-01K04	12	--	--	G	U
30N/04W-01L01	--	--	--		C
30N/04W-01L02	20	--	--	G	U
30N/04W-01M01	1147	34.7	6.0	G	C
30N/04W-01M02	--	--	--	G	C
30N/04W-01M03	--	--	--		C
30N/04W-01M04	--	--	--	G	C
30N/04W-01N01	--	--	--		C
30N/04W-01N02	--	--	--		C
30N/04W-01P01	20	6.7	3.0	G	U
30N/04W-01Q01	18	--	--	G	U
30N/04W-01Q02	15	2.5	--	G	U
30N/04W-01Q03	12	--	2.0	G	U
30N/04W-02G01	7	2.9	3.0	G	U
30N/04W-02M01	--	--	--		C
30N/04W-02M02	30	1.0	3.0	G	U
30N/04W-02M03	20	0.1	--	G	C
30N/04W-02P01	50	12.5	--	G	C
30N/04W-02R01	500	45.0	1.0	G	C
30N/04W-03C01	40	13.0	--	G	U
30N/04W-03D01	30	--	--	G	U
30N/04W-03D02	45	--	--	G	U
30N/04W-03H01	--	--	--		C
30N/04W-03H03	25	6.2	1.5	G	C
30N/04W-03H04	10	10.0	1.5	G	C
30N/04W-03H05	60	30.0	--	G	C
30N/04W-03H06	12	0.5	2.0	G	U
30N/04W-03J01	6	--	4.0	G	U
30N/04W-03N01	11	0.4	2.0	G	U
30N/04W-03Q01	40	2.0	--	G	C
30N/04W-04-1	30	6.0	--	G	U

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-04H01	HALL, PHILLIP	12/18/1976	H	111	111	63.00	106	S
30N/04W-04L01	WICKMAN, JAMES A	02/28/1969	H,I	79	76	48.50	72	S
30N/04W-04L02	STRANDSKOV, HERB	04/12/1974	H	72	56	38.00	54	S
30N/04W-04 M03	MCHUGH	05/08/1974	H	99	114	83.60	--	0
30N/04W-04M01	BROOKE	04/21/1975	H	105	105	52.00	100	S
30N/04W-04M02	EVANS	08/08/1974	H	108	108	42.00	101	S
30N/04W-04N01	OLSTEAD, HAROLD L	--	H	--	51	27.89	--	--
30N/04W-04N02	ANDERSON, PAUL	11/08/1978	H	57	57	33.00	52	S
30N/04W-04P01	OLSON	01/01/1901	S	--	48	32.92	--	--
30N/04W-05 L03	LEJEUNE, A. J	04/20/1976	H	109	110	68.00	105	S
30N/04W-05 L04	SPICKERMAN, CLARENCE	07/19/1976	H	118	118	44.00	112	S
30N/04W-05 L05	SMITH, MIKE	05/11/1978	H	60	60	28.00	55	S
30N/04W-05G01	NEWELL	04/18/1962	H	125	125	94.00	--	S
30N/04W-05G02	FRENCH, MILTON	11/04/1976	--	114	114	82.00	109	S
30N/04W-05J01	OLSON, EDGAR H	05/29/1973	H	117	117	73.66	--	S
30N/04W-05K 3	CRAMER	01/18/1974	H	110	110	76.50	105	S
30N/04W-05K01	NEWELL	07/01/1969	H	125	125	75.00	--	S
30N/04W-05K02	NEWELL	03/03/1975	H	120	120	95.50	115	S
30N/04W-05L01	STUCKI, B. J	09/ /1964	H	--	126	116.00	--	0
30N/04W-05L02	POST, AUSTIN	1950	H	--	92	72.00	--	S
30N/04W-05M01	HUBER, LOUIS	--	H	--	108	--	--	--
30N/04W-05N01	LEWIS, D.H.W.	--	H,S	--	95	81.00	--	--
30N/04W-05P01	BULL	04/14/1973	P	161	161	126.00	--	--
30N/04W-05Q01	HILLES, A	01/26/1978	H	117	117	--	112	S
30N/04W-05Q01	SIMPSON	01/05/1976	H	152	152	68.33	147	S
30N/04W-05Q02	KOONZ, BOB	10/28/1977	H	110	110	28.00	106	S
30N/04W-05Q04	HIRST, FLOYD	06/08/1979	H	175	158	70.00	152	S
30N/04W-05Q05	KENSEY, S G	11/06/1978	H	127	127	80.00	122	S
30N/04W-06R01	BRYANT, FAYE	05/25/1977	H	142	142	115.00	--	0
30N/04W-06R02	BRYANT, FAYE	01/15/1979	H	151	151	115.00	--	0
30N/04W-07 F02	WRAY, GORDON	03/29/1978	H	108	108	64.00	103	S
30N/04W-07 G02	*MONTERRA 2*	*09/01/1976*	*H*	*221*	*221*	*131.00*	*89*	*P*
30N/04W-07F01	NIEMI, ROY I	--	H	--	71	64.25	--	--
30N/04W-07G01	MONTERRA INC	06/23/1971	H	221	221	103.00	109	P
30N/04W-07J01	SAUER	07/02/1974	H	164	163	90.00	160	S
30N/04W-07J02	NOVICH	09/18/1975	H	93	93	61.00	--	0
30N/04W-07K01	GRIMSLEY, D. K	--	H	--	96	--	--	--
30N/04W-07K02	GOIN, TRESA	09/18/1972	H	117	113	59.00	108	S
30N/04W-07L01	MYERS	07/01/1974	H	92	92	60.60	--	0
30N/04W-07N01	MULLINS	10/27/1975	H	264	281	119.00	266	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-04H01	30	--	1.5	G	U
30N/04W-04L01	25	12.5	1.0	G	U
30N/04W-04L02	10	--	--	G	C
30N/04W-04MN-1	25	--	--	G	U
30N/04W-04M01	35	35.0	2.0	G	U
30N/04W-04M02	40	1.5	5.0	G	U
30N/04W-04N01	--	--	--		C
30N/04W-04N02	35	11.7	--	G	U
30N/04W-04P01	--	--	--		C
30N/04W-05-1	15	--	1.0	G	U
30N/04W-05-2	20	0.7	3.0	G	U
30N/04W-05-3	22	1.6	--	G	U
30N/04W-05G01	25	2.5	1.0	G	U
30N/04W-05G02	15	7.5	2.5	G	U
30N/04W-05J01	30	5.0	--	G	C
30N/04W-05K0-1	22	3.1	2.0	G	U
30N/04W-05K01	25	2.5	1.0	G	U
30N/04W-05K02	15	6.0	1.5	G	U
30N/04W-05L01	5	--	--	G	C
30N/04W-05L02	--	--	--		C
30N/04W-05M01	--	--	--		C
30N/04W-05N01	--	--	--		C
30N/04W-05P01	25	1.3	1.0	G	U
30N/04W-05Q01	16	0.7	--	G	U
30N/04W-05Q01	20	--	--	G	U
30N/04W-05Q02	20	0.3	--	G	U
30N/04W-05Q04	18	0.3	1.5	G	U
30N/04W-05Q05	30	4.3	--	G	U
30N/04W-06R01	15	1.3	--	G	U
30N/04W-06R02	25	1.7	--	G	U
30N/04W-07-1	34	8.5	1.5	G	U
30N/04W-07BG-1	104	2.5	6.0	G	U
30N/04W-07F01	--	--	--		C
30N/04W-07G01	250	3.6	24.0	G	U
30N/04W-07J01	30	1.3	2.0	G	U
30N/04W-07J02	9	0.4	--	G	U
30N/04W-07K01	--	--	--		C
30N/04W-07K02	20	2.5	2.5	G	U
30N/04W-07L01	30	--	--	G	C
30N/04W-07N01	8	0.4	2.0	G	C

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-07Q01	NORRIS, HUGH W	03/07/1978	H	111	111	72.00	--	O
30N/04W-08A01	WALLACKER	03/27/1974	H	108	108	55.00	103	S
30N/04W-08A02	WEYERHAEUSER, RESIDENCE	--	--	--	--	54.70	--	--
30N/04W-08B01	CORWIN, MARGUERITE	06/16/1977	H	134	132	67.00	--	O
30N/04W-08F01	DURCO CONST., GEO.DURHAM	08/16/1978	H	91	91	65.00	86	S
30N/04W-08G01	BURDICK, W. H	1960	H	104	98	59.00	--	O
30N/04W-08G02	CHRISTENSEN	06/27/1974	H	120	120	44.00	117	S
30N/04W-08J01	MAY, BUD	1960	H	56	56	38.00	--	--
30N/04W-08M01	FARNAM	09/10/1974	H	100	100	38.00	--	O
30N/04W-08M02	NETTLES	09/15/1975	H	89	84	35.00	81	S
30N/04W-08M04	FINLEY, SAM	12/29/1978	H	84	84	22.00	79	S
30N/04W-08R01	KEYS, FRANK	03/17/1979	H	69	69	21.00	64	S
30N/04W-09C01	CAMERON	1947	H,S	--	70	--	--	--
30N/04W-09C02	CAMERON, HOWARD	--	I	--	60	--	--	--
30N/04W-09K01	CAMERON, V. W	--	H,S	--	22	9.63	--	--
30N/04W-09L01	WEYERHAEUSER CO	02/27/1974	I	970	842	82.97	794	S
30N/04W-09N02	JOHNSON, LLOYD	11/28/1979	H	75	75	24.00	70	S
30N/04W-10C01	MILES, DAVID	06/22/1976	H	67	60	6.50	56	S
30N/04W-10E01	DREILING, ALVIN	03/30/1977	H	50	50	17.50	47	S
30N/04W-10H01	HEGGENES	02/17/1975	H	38	38	9.00	--	O
30N/04W-10J01	ANDERSEN, WILLIAM T	06/14/1977	H	30	30	11.00	--	O
30N/04W-10J02	PETERSON, JERRY	08/25/1977	H	31	31	8.00	--	O
30N/04W-10K01	MCCUTCHAN	12/13/1965	H,I	31	31	7.00	--	O
30N/04W-10L01	COOK	01/01/1901	H	--	22	2.00	--	--
30N/04W-10M01	SANFORD, JAMES R	01/19/1978	H	42	42	5.00	37	S
30N/04W-10M02	SCHNEIDER, ROBERT	05/08/1978	H	52	52	6.00	--	O
30N/04W-10M03	SWAPP, RICHARD	08/10/1978	H	45	45	5.00	--	O
30N/04W-10P01	HELLER	01/01/1901	H,I	--	10	5.00	--	--
30N/04W-10Q01	SMITH, LLOYD	05/05/1976	H	82	82	11.00	76	S
30N/04W-10R01	STACEY	09/18/1972	H,I	61	61	6.00	56	S
30N/04W-10H02	STREGE	05/02/1974	H	67	67	11.00	60	S
30N/04W-10R02	WHITE	06/20/1974	H	33	33	10.00	--	O
30N/04W-10R04	BORN, GLENN E	09/ /1967	H	38	38	10.00	35	S
30N/04W-11A01	BALTZLY	04/28/1974	H	45	45	12.00	--	O
30N/04W-11A02	SIMONTON	12/01/1974	H	62	62	11.50	--	O
30N/04W-11H01	HARIN, JACK	07/10/1978	H	20	20	10.00	--	O
30N/04W-11J01	GILBERTSON, GIL	04/01/1977	H	76	76	20.00	--	O
30N/04W-11~~[illegible]~~K01	SANDERS, HARRY M	05/31/1978	H	30	30	12.00	--	O
30N/04W-11L01	CAREY, J. J	--	H	--	16	12.00	--	--
30N/04W-11L02	SHADE, C W	04/13/1978	H	36	36	10.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-07Q01	10	0.8	1.0	G	U
30N/04W-08A01	25	8.3	1.5	G	U
30N/04W-08A02	--	--	--		C
30N/04W-08B01	10	1.3	2.0	G	U
30N/04W-08F01	12	12.0	1.5	G	U
30N/04W-08G01	--	--	--	G	C
30N/04W-08G02	25	--	--	G	U
30N/04W-08J01	17	1.3	--	G	C
30N/04W-08M01	14	0.6	--	G	U
30N/04W-08M02	35	1.2	--	G	U
30N/04W-08M04	18	0.4	1.5	G	U
30N/04W-08R01	30	2.5	1.5	G	U
30N/04W-09C01	25	--	5.0		C
30N/04W-09C02	--	--	--		C
30N/04W-09K01	--	--	--		C
30N/04W-09L01	715	25.1	6.5	G	C
30N/04W-09N02	35	1.9	3.0	G	U
30N/04W-10C01	25	0.8	--	G	U
30N/04W-10E01	35	2.3	--	G	U
30N/04W-10H01	35	2.1	--	G	C
30N/04W-10J01	10	10.0	1.5	G	U
30N/04W-10J02	15	15.0	1.5	G	U
30N/04W-10K01	18	2.3	1.0	G	U
30N/04W-10L01	--	--	--		C
30N/04W-10M01	13	0.6	3.5	G	U
30N/04W-10M02	20	0.6	--	G	U
30N/04W-10M03	20	1.8	1.5	G	U
30N/04W-10P01	--	--	--		C
30N/04W-10Q01	65	5.4	2.0	G	U
30N/04W-10R01	15	15.0	--	G	U
30N/04W-10R02	40	1.7	1.0	G	U
30N/04W-10R02	25	8.3	0.5	G	U
30N/04W-10R04	20	1.3	--	G	U
30N/04W-11A01	32	2.1	1.0	G	C
30N/04W-11A02	25	1.0	5.0	G	U
30N/04W-11H01	24	24.0	1.5	G	U
30N/04W-11J01	20	--	1.5	G	C
30N/04W-11KQ-1	30	--	--	G	U
30N/04W-11L01	--	--	--		C
30N/04W-11L02	35	3.5	--	G	U

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-11P01	TORMALA	09/02/1975	H	55	55	16.00	--	O
30N/04W-11P02	SMITH, RON	06/03/1976	H	38	38	13.00	--	O
30N/04W-11P03	HEBHRENFELD, DOUG	06/01/1977	H	53	53	14.50	--	O
30N/04W-11P04	SMITH, RON	12/09/1977	H	32	32	13.00	--	O
30N/04W-11Q01	NOGASH, HANK	10/06/1978	H	57	57	19.00	--	O
30N/04W-11R01	TRUDY, VICTOR R	07/07/1977	H	81	81	24.00	--	O
30N/04W-11R02	MARCHBANK, ALVIN	12/30/1977	H	66	66	24.00	--	O
30N/04W-11R03	STARRY, FRANK	06/22/1977	H	81	81	21.00	--	O
30N/04W-11R04	WHITMORE, LLOYD	06/23/1977	H	81	81	23.00	--	O
30N/04W-11R05	JEZIK, JOSEPH F	02/14/1978	H	89	89	19.00	84	S
30N/04W-11R06	FIRESIDE HOMES 2	02/18/1977	H	22	22	8.00	--	O
30N/04W-11R07	FIRESIDE HOMES 1	01/16/1977	H	50	50	20.00	--	O
30N/04W-11R08	NELSON, KENNY	07/28/1979	H	26	26	12.00	--	O
30N/04W-11R09	KOTAS, MURRY	12/05/1978	H	81	81	22.00	--	O
30N/04W-12C01	SPENCER	02/02/1974	H	38	38	4.50	35	P
30N/04W-12C02	SPENCER	01/24/1974	H	65	65	19.50	--	O
30N/04W-12C03	TRIPLETT, DAVE	03/29/1978	H	43	43	11.00	--	O
30N/04W-12C04	SMITH, STEVE	03/01/1978	H	24	24	7.00	--	O
30N/04W-12C05	GAULT, TOM	02/28/1978	H	24	24	8.00	--	O
30N/04W-12D01	GAESTEL, STAN	11/02/1977	H	33	33	9.00	--	O
30N/04W-12E01	BOGGS	05/13/1974	H	22	22	3.40	--	P
30N/04W-12F01	TALLEY	11/11/1976	H	82	82	47.00	--	O
30N/04W-12F02	MATLOCK, J G	03/31/1978	H	48	48	9.00	45	S
30N/04W-12F03	TINSLEY, FRED H	03/ /1975	H	15	15	7.00	12	T
30N/04W-12J01	ERNY, R H	04/18/1979	H	108	108	90.00	--	O
30N/04W-12K01	LIVENGOOD, GARY	11/09/1977	H	26	26	6.00	--	O
30N/04W-12N01	BALKAN CONST., MIKE	08/23/1977	H	74	69	11.00	--	O
30N/04W-12Q01	WOOD, DAVE	01/16/1976	H	36	36	11.50	--	O
30N/04W-12Q02	ROBINS, LESTER	--	I	--	25	--	11	P
30N/04W-12R01	LIVENGOOD	03/09/1966	I	27	27	5.70	9	P
30N/04W-13 K9	LOUTHAN, ED	10/31/1974	H	43	43	5.00	--	O
30N/04W-13 K10	BORDEN	01/24/1975	H	--	54	20.00	--	S
30N/04W-13 K11	WALPER	11/04/1974	H	42	42	8.00	--	O
30N/04W-13 K12	HANWAY, FRANK	11/03/1976	H	46	46	8.50	--	O
30N/04W-13 A01	PIKE	04/17/1975	H	43	43	18.00	--	O
30N/04W-13 A02	DENTON	03/14/1974	H	84	84	18.00	--	O
30N/04W-13A03	AIKENS	11/21/1974	H	46	46	2.00	41	S
30N/04W-13A04	HARDGROVE	1925	H,I	--	20	--	--	--
30N/04W-13A05	MALENDA, FRED	07/06/1977	H	36	36	6.00	--	O
30N/04W-13A06	FINK, LOWELL	10/18/1977	H	39	39	9.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-11P01	12	--	--	G	U
30N/04W-11P02	50	6.3	--	G	U
30N/04W-11P03	30	1.3	--	G	U
30N/04W-11P04	45	22.0	--	G	U
30N/04W-11Q01	13	0.5	1.5	G	U
30N/04W-11R01	30	--	--	G	U
30N/04W-11R02	19	1.0	2.0	G	U
30N/04W-11R03	75	--	1.0	G	U
30N/04W-11R04	60	--	1.0	G	U
30N/04W-11R05	20	0.6	3.0	G	U
30N/04W-11R06	40	8.0	1.5	G	U
30N/04W-11R07	10	0.7	2.0	G	U
30N/04W-11R08	25	25.0	1.5	G	U
30N/04W-11R09	80	--	--	G	U
30N/04W-12C01	30	--	--	G	U
30N/04W-12C02	25	--	--	G	U
30N/04W-12C03	25	1.1	--	G	U
30N/04W-12C04	10	10.0	1.5	G	U
30N/04W-12C05	10	10.0	1.5	G	U
30N/04W-12D01	25	1.8	--	G	U
30N/04W-12E01	25	51.0	--	G	U
30N/04W-12F01	30	6.0	--	G	U
30N/04W-12F02	40	2.2	--	G	U
30N/04W-12F03	--	--	--		U
30N/04W-12J01	17	17.0	1.5	G	U
30N/04W-12K01	45	9.0	--	G	C
30N/04W-12N01	30	--	--	G	U
30N/04W-12Q01	25	5.0	--	G	U
30N/04W-12Q02	160	80.0	24.0		C
30N/04W-12R01	325	46.0	1.0	G	U
30N/04W-13-1	45	3.5	--	G	U
30N/04W-13-2$18=60	50	--	--		U
30N/04W-13-3	40	2.5	--	G	U
30N/04W-13-4	40	2.2	--	G	U
30N/04W-13AB-1	12	0.8	--	G	U
30N/04W-13AB-2	30	--	--	G	U
30N/04W-13A03	30	--	--	G	U
30N/04W-13A04	--	--	--		C
30N/04W-13A05	50	5.0	--	G	U
30N/04W-13A06	18	0.9	--	G	U

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LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-13D01	FASOLA, ALFRED	--	H	--	24	8.00	--	--
30N/04W-13E01	PARKER, DICK	12/18/1974	H	39	39	18.60	--	O
30N/04W-13F02	BERG, RUDOLPH V	06/19/1978	H	48	48	8.00	43	S
30N/04W-13F03	LANTZ, KENNETH	06/26/1979	H	30	30	14.00	--	O
30N/04W-13F04	LUNDSTROM, IVAN	06/26/1979	H	30	30	18.00	--	O
30N/04W-13F05	WILLIAMSON, TOM	03/06/1979	H	42	42	26.00	--	O
30N/04W-13G01	SALLEE	02/03/1970	H	68	68	23.00	--	O
30N/04W-13G02	YOUNG	03/11/1974	H	58	58	26.00	--	O
30N/04W-13G03	GOODWIN, ROBERT A	07/21/1977	H	50	50	--	--	O
30N/04W-13G04	CLARK, RONALD	01/02/1979	H	42	42	19.50	--	O
30N/04W-13H01	ROBINSON	01/01/1901	H,S	--	30	25.00	--	--
30N/04W-13H02	LEITH, ROBERT B	04/18/1977	H	58	58	15.00	53	S
30N/04W-13J01	KENDALL	1927	H,I	--	50	10.00	--	--
30N/04W-13J01	BLANTON	05/29/1975	H	62	62	25.00	--	O
30N/04W-13J03	WEHER	05/25/1974	H	49	49	9.00	--	O
30N/04W-13J04	MAYFIELD	07/25/1974	H	45	45	6.50	41	S
30N/04W-13J05	BELLEVUE	10/29/1975	H	71	59	17.50	--	O
30N/04W-13J06	TERRENCE, FLOYD	06/06/1977	H	46	46	15.00	--	O
30N/04W-13J07	SUTHERLIN, DICK	01/18/1978	H	48	48	24.00	--	O
30N/04W-13K03	SCHADEK	11/01/1975	H	61	61	26.75	--	O
30N/04W-13K04	MCHUGH, PAUL	08/08/1977	H	45	45	8.00	--	O
30N/04W-13K05	JUNDY, JENE	05/31/1977	H	61	61	28.17	--	O
30N/04W-13K06	L.B.D.	02/17/1977	H	40	40	14.00	37	S
30N/04W-13L02	ROTHWEILER	07/15/1975	H	37	37	15.00	--	O
30N/04W-13L02	WILLIAMSON	10/12/1968	H	34	34	21.00	31	S
30N/04W-13~~[illegible]~~ No2	ZALEWSKI, VAL	10/28/1977	H	58	58	20.00	52	S
30N/04W-13~~[illegible]~~ No3	PYLES, JIM	04/12/1977	H	45	45	20.00	--	O
30N/04W-~~[illegible]~~ No4	TESSMER, ALVIN H	03/24/1978	H	43	43	21.00	--	O
30N/04W-13~~[illegible]~~ B01	ULRICH	12/03/1975	H	34	32	18.00	--	O
30N/04W-13N01	APPLEGATE, CHARLES M	07/19/1977	H	49	49	19.00	44	S
30N/04W-13P01	CONLEY	01/01/1901	H	48	48	24.00	--	O
30N/04W-13Q01	KRNOULL	01/01/1901	H,I	--	36	--	--	--
30N/04W-13Q02	BERG	01/11/1974	H	64	64	25.00	--	O
30N/04W-13Q03	JANSSEN	04/30/1975	H	61	61	38.00	56	S
30N/04W-13R01	WANEK	06/16/1975	H	53	53	22.00	--	O
30N/04W-13R02	STANGER, J D	09/18/1976	H	64	64	17.00	--	O
30N/04W-13R03	WILHER, L. P	01/09/1978	H	78	78	29.00	--	O
30N/04W-13R04	DILGER, LAURENCE	06/02/1976	H	57	57	23.67	52	S
30N/04W-13R05	PALMER, T. J	09/11/1978	H	55	55	11.00	--	O
30N/04W-13R06	KEYS, FRANK	01/23/1979	H	81	61	30.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-13D01	--	--	--		C
30N/04W-13E01	30	6.0	--	G	U
30N/04W-13F02	40	4.0	--	G	U
30N/04W-13F03	20	20.0	1.5	G	U
30N/04W-13F04	20	20.0	1.5	G	U
30N/04W-13F05	10	1.0	1.5	G	U
30N/04W-13G01	6	0.6	1.0	G	U
30N/04W-13G02	10	--	--	G	U
30N/04W-13G03	13	1.3	1.5	G	U
30N/04W-13G04	20	1.3	--	G	U
30N/04W-13H01	--	--	--		C
30N/04W-13H02	14	0.6	--	G	U
30N/04W-13J01	25	--	--		U
30N/04W-13J01	18	0.7	--	G	U
30N/04W-13J03	50	25.0	--	G	U
30N/04W-13J04	19	--	--	G	U
30N/04W-13J05	40	--	--	G	U
30N/04W-13J06	40	2.7	--	G	U
30N/04W-13J07	24	2.0	--	G	U
30N/04W-13K03	30	2.1	--	G	U
30N/04W-13K04	40	3.3	--		U
30N/04W-13K05	50	--	--	G	U
30N/04W-13K06	20	2.0	--	G	U
30N/04W-13L02	12	0.9	2.0	G	U
30N/04W-13L02	15	1.0	1.0	G	U
30N/04W-13MN-2	25	--	--	G	U
30N/04W-13MN-3	30	3.8	--	G	U
30N/04W-13MN-4	18	1.3	--	G	U
30N/04W-13NH-1	15	30.0	4.0	G	U
30N/04W-13N01	30	20.0	2.0	G	C
30N/04W-13P01	20	5.0	2.0	G	U
30N/04W-13Q01	--	--	--		C
30N/04W-13Q02	30	3.0	1.0	G	U
30N/04W-13Q03	10	--	--	G	U
30N/04W-13R01	35	3.5	--	G	U
30N/04W-13R02	18	1.0	1.0	G	U
30N/04W-13R03	30	2.5	2.0	G	U
30N/04W-13R04	25	--	1.0	G	U
30N/04W-13R05	40	2.1	--	G	U
30N/04W-13R06	30	--	--	G	U

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-13R07	MAXTED, D H	06/04/1979	H	89	89	27.00	--	O
30N/04W-13R08	MAXTED, D H	06/01/1979	H	89	89	27.00	--	O
30N/04W-13R09	MAXTED, A H	01/24/1979	H	89	89	30.00	--	O
30N/04W-13R10	WAAGEN, NORMAN E	09/26/1979	H	80	79	19.00	--	O
30N/04W-13~~S[illegible]~~ J08	BERGERON, MARGOT	03/18/1977	H	50	50	18.00	--	O
30N/04W-14A01	STEVENS	05/29/1964	I	30	30	12.00	19	P
30N/04W-14C01	HEATH, OLIVE	--	H	--	21	12.01	--	--
30N/04W-14C02	TROXEL	08/29/1975	H	60	60	17.00	--	O
30N/04W-14C03	HARDY, SHEILA	09/13/1979	H	81	81	23.20	--	O
30N/04W-14D01	WHITE	05/12/1975	H	66	66	24.00	--	O
30N/04W-14E01	MARPEL	06/03/1974	H	65	65	25.00	--	O
30N/04W-14F02	JENSEN, TOM	04/06/1977	H	82	82	22.33	64	P
30N/04W-14F03	CRANER	06/10/1975	H	57	57	19.00	54	S
30N/04W-14M01	MATSON, VIC	07/10/1976	H	54	44	17.00	39	S
30N/04W-14M02	WRIGHT, T	08/22/1977	H	38	38	11.00	--	O
30N/04W-14P01	NICKERSON	08/12/1975	H	60	38	14.00	35	S
30N/04W-14P02	EMERY	06/14/1973	H	52	52	14.00	--	O
30N/04W-14P03	THOMPSON, RAY	06/16/1976	H	98	98	17.50	--	O
30N/04W-15[illegible] G04	CHILDERS, W.REX	05/13/1977	H	51	51	24.00	--	O
30N/04W-15A01	BRUCE, ELWOOD	--	U	--	--	19.78	--	--
30N/04W-15C01	SMITH	04/08/1975	H	54	44	12.00	42	S
30N/04W-15F01	SONNENFELD, DELBERT	03/06/1979	H	53	53	23.00	48	S
30N/04W-15G01	AVERY	1928	H	--	50	6.00	--	--
30N/04W-15G02	ENGEL	07/24/1975	H	56	56	11.50	--	O
30N/04W-15G03	LEADON, GEORGE	03/26/1977	H	55	55	24.00	--	O
30N/04W-15H01	AVERY	1938	H,I	--	50	6.00	--	--
30N/04W-15H02	AVERY	1938	H,I	--	50	6.00	--	P
30N/04W-15H03	AVERY	1938	H	--	50	6.00	--	P
30N/04W-15K01	SEAMONDS, LARRY	01/03/1979	H	55	55	18.00	50	S
30N/04W-15M01	GILLESPIE, F.	--	U	--	15	5.20	--	--
30N/04W-15M02	GILLESPIE	01/01/1901	H	--	43	12.57	--	--
30N/04W-15M03	CUMMINGS, HILLMAN	09/25/1978	H	39	39	4.00	--	O
30N/04W-15N01	BOYD	03/16/1974	H	34	28	4.00	26	S
30N/04W-15P01	FERGOSON	01/21/1974	H	65	65	29.50	--	O
30N/04W-15P02	MARTIN, ANN	08/02/1977	H	36	36	14.00	--	O
30N/04W-15P03	CRARY, C. W	07/03/1978	H	65	65	19.00	61	S
30N/04W-16C01	RUTLEDGE, DICK	03/07/1979	H	47	45	8.00	43	S
30N/04W-16G01	SAYERS	11/06/1974	H	90	90	28.00	85	S
30N/04W-16G02	KITHCENS INC	10/17/1974	H	40	40	9.00	--	O
30N/04W-16P02	BULL, GERALD	07/04/1977	H	144	144	100.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-13R07	60	--	1.5	G	U
30N/04W-13R08	60	--	1.5	G	U
30N/04W-13R09	40	--	--	G	U
30N/04W-13R10	40	--	1.0	G	U
30N/04W-13SEQ-1	30	3.0	2.0	G	U
30N/04W-14A01	150	50.0	2.0	G	U
30N/04W-14C01	--	--	--		C
30N/04W-14C02	20	--	--	G	U
30N/04W-14C03	70	--	1.0	G	U
30N/04W-14D01	25	0.9	--	G	U
30N/04W-14E01	25	1.3	1.0	G	U
30N/04W-14F02	6	--	2.0	G	U
30N/04W-14F03	25	1.1	--	G	U
30N/04W-14M01	15	3.8	2.0	G	U
30N/04W-14M02	40	--	--	G	U
30N/04W-14P01	15	2.5	4.0	G	C
30N/04W-14P02	20	--	--	G	U
30N/04W-14P03	40	1.3	--	G	U
30N/04W-15-1	10	1.7	1.0	G	U
30N/04W-15A01	--	--	--		C
30N/04W-15C01	120	18.0	2.0	G	U
30N/04W-15F01	25	2.5	1.5	G	U
30N/04W-15G01	5	--	--		C
30N/04W-15G02	50	3.3	--	G	U
30N/04W-15G03	25	1.6	--	G	U
30N/04W-15H01	25	25.0	4.0		U
30N/04W-15H02	25	--	--		C
30N/04W-15H03	25	--	--		C
30N/04W-15K01	20	2.0	1.5	G	U
30N/04W-15M01	--	--	--		C
30N/04W-15M02	--	--	--		C
30N/04W-15M03	40	--	--	G	U
30N/04W-15N01	12	--	--	G	U
30N/04W-15P01	30	--	--	G	U
30N/04W-15P02	8	0.8	1.5	G	U
30N/04W-15P03	48	3.2	--	G	U
30N/04W-16C01	20	4.0	1.5	G	U
30N/04W-16G01	15	0.6	2.0	G	C
30N/04W-16G02	3	--	--	G	C
30N/04W-16P02	25	6.3	1.5	G	U

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-16Q01	KEITH	12/03/1973	H	67	67	34.00	64	S
30N/04W-16Q02	TEAGUE	11/15/1974	H	53	53	26.00	--	O
30N/04W-16Q03	NELSON, GARY	01/30/1976	H	82	82	46.50	79	S
30N/04W-16Q04	RUBENS	08/07/1975	H	125	87	36.00	84	S
30N/04W-16Q05	FRANTZ, JOHN	--	H,S	--	63	60.56	--	--
30N/04W-17B01	EDMONSON	04/24/1974	H	91	91	39.50	85	S
30N/04W-17B02	LEWIS, CARL	10/31/1978	H	105	105	60.00	101	S
30N/04W-17D01	SIMONSON, HENRY	1947	H,S	146	146	65.00	--	--
30N/04W-17D02	OPDAHL	10/15/1974	H	111	111	63.00	108	S
30N/04W-17F01	SOLMAR LAND	08/11/1974	H	137	129	72.00	116	S
30N/04W-17G01	MILLER, W. S	--	H	--	97	65.40	--	--
30N/04W-17N01	PITCH, JOHN H	11/30/1976	H	81	73	49.00	68	S
30N/04W-17N02	TOZIER, LARRY	07/25/1978	H	211	211	180.00	--	O
30N/04W-17P01	PILCH, JOHN	01/26/1978	H	70	66	38.50	61	S
30N/04W-17R01	HIGGINS	07/22/1974	H	91	91	60.00	83	S
30N/04W-18A01	KOVOCH, NICK	--	H,S	--	145	86.82	--	--
30N/04W-18A02	BORRELLI	09/15/1975	H	119	119	89.83	114	S
30N/04W-18B01	WAGGONER, ROBERT B	09/08/1977	H	112	112	68.50	107	S
30N/04W-18G01	WOLFGRAM, HERBERT	1968	H	--	126	86.00	--	--
30N/04W-18H01	SMITH	05/09/1974	H	140	140	101.00	133	S
30N/04W-18H02	KENT, GEORGE	02/25/1977	H	128	128	97.00	123	S
30N/04W-18H03	UHLIG, VANCE	02/21/1976	H	140	140	110.00	135	S
30N/04W-18H04	SMITH, BURREL	12/15/1977	H	150	150	104.00	--	O
30N/04W-18H05	ELLIOTT, REX	03/13/1979	H	127	127	100.00	122	S
30N/04W-18J01	MUELLER, DAVID	--	H	--	12	2.70	--	--
30N/04W-18J02	COLLA, DR	12/02/1978	H	146	146	110.00	141	S
30N/04W-18R01	WEST	03/13/1974	--	61	60	17.00	44	S
30N/04W-18R02	CREASEY, ED	08/15/1978	H	117	116	87.00	111	S
30N/04W-18R03	MAXTED, D H	06/05/1979	H	89	89	27.50	--	O
30N/04W-19F01	ADAMS	06/10/1975	H	--	57	12.00	--	S
30N/04W-19H01	MCINNES	1954	--	98	98	50.00	94	S
30N/04W-19J01	SAMPAIR, J. A	--	H	--	10	5.77	--	--
30N/04W-20B01	SNOHOMISH LUMBER	05/30/1977	H	85	85	43.00	80	S
30N/04W-20B02	BAKER, ODIE	02/14/1979	H	345	345	204.00	209	P
30N/04W-20B03	BAKER, ODIE	02/09/1979	U	130	130	D	--	--
30N/04W-20C01	FOX, H. C	1947	H	108	108	76.00	--	--
30N/04W-20E01	PLAINS, NANCY	02/23/1977	H	80	38	12.00	16	P
30N/04W-20F01	TYLER, GARTH	03/21/1978	H	86	85	37.00	--	O
30N/04W-20H01	KESSLER, PAUL	07/02/1979	H	265	265	225.00	--	O
30N/04W-20M01	BRANT	02/18/1975	H	50	50	3.50	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-16Q01	25	--	--	G	U
30N/04W-16Q02	6	--	--	G	U
30N/04W-16Q03	12	0.5	--	G	U
30N/04W-16Q04	8	0.2	--	G	U
30N/04W-16Q05	--	--	--		C
30N/04W-17B01	40	8.0	2.5	G	C
30N/04W-17B02	30	1.5	--	G	U
30N/04W-17D01	--	--	--	G	C
30N/04W-17D02	25	--	--	G	U
30N/04W-17F01	204	38.0	6.0	G	U
30N/04W-17G01	--	--	--		C
30N/04W-17N01	3	0.2	16.0	G	U
30N/04W-17N02	10	1.0	1.5	G	U
30N/04W-17P01	18	18.0	9.0		U
30N/04W-17R01	10	2.0	--	G	U
30N/04W-18A01	--	--	--		C
30N/04W-18A02	20	12.0	--	G	C
30N/04W-18B01	15	--	--	G	C
30N/04W-18G01	--	--	--		C
30N/04W-18H01	15	3.8	2.0	G	U
30N/04W-18H02	15	--	2.0	G	C
30N/04W-18H03	15	--	--	G	C
30N/04W-18H04	15	1.1	1.5	G	U
30N/04W-18H05	20	5.0	1.0	G	U
30N/04W-18J01	--	--	--		C
30N/04W-18J02	12	0.8	1.5	G	U
30N/04W-18R01	20	3.3	1.0	G	U
30N/04W-18R02	7	0.2	3.0	G	U
30N/04W-18R03	60	--	1.5	G	U
30N/04W-19F01	25	80.0	10.0	G	U
30N/04W-19H01	12	0.4	1.0	G	U
30N/04W-19J01	--	--	--		C
30N/04W-20B01	20	1.7	--	G	C
30N/04W-20B02	5	0.1	4.0	G	U
30N/04W-20B03	0.00	0.0	--	G	U
30N/04W-20C01	--	--	--	G	C
30N/04W-20E01	20	4.0	2.5	G	U
30N/04W-20F01	6	0.2	1.5	G	U
30N/04W-20H01	17	1.7	1.5	G	U
30N/04W-20M01	25	0.8	--	G	U

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-20M02	BRANDT, MIKE	11/01/1977	H	161	161	40.00	--	X
30N/04W-20N01	WALLACE	04/04/1974	H	35	35	6.00	31	S
30N/04W-20N02	WAGNER, ROBERT	09/30/1976	--	50	--	D	--	--
30N/04W-20P01	MILLER, KEN	09/12/1978	H	70	70	25.00	--	O
30N/04W-20Q01	FLYUM	07/02/1974	H	70	50	6.50	20	P
30N/04W-21~~[illegible]~~ G04	LEACH, ARTHUR	12/29/1975	H	384	327	267.00	322	S
30N/04W-21B01	SPENCER, CHARLES	--	H	--	38	0.80+	--	--
30N/04W-21C01	HOFFMAN	11/08/1965	P	160	160	120.00	156	S
30N/04W-21C02	KITCHEN, GEORGIE	10/07/1977	H	110	110	70.00	--	--
30N/04W-21G01	SCHOEPPE	06/27/1975	H	42	41	16.00	36	S
30N/04W-21G02	LEBLANC, RICHARD	03/31/1978	H	46	45	18.00	40	S
30N/04W-21G03	--	07/01/1978	H	54	54	21.00	50	S
30N/04W-21J01	PEDLAR, JIM	11/08/1976	H	100	100	42.00	--	O
30N/04W-21J02	FLEISHER, SKIP	04/05/1978	H	139	139	78.00	134	S
30N/04W-21K01	MESSICK	10/01/1974	H	267	267	192.00	258	S
30N/04W-21K02	REEKIE, ARTHUR	11/16/1978	H	44	44	13.00	40	S
30N/04W-21L01	LUCE, SCHULER	01/05/1977	H	326	326	275.00	--	S
30N/04W-22A01	KAMPRUD, ROBERT	06/21/1977	H	95	91	28.00	81	P
30N/04W-22A02	SEWELL, O.	06/21/1977	H	49	49	16.50	--	O
30N/04W-22D01	SWARD, CARL	07/22/1976	H	57	57	37.00	--	O
30N/04W-22D02	THOMPSON, F W	11/04/1977	H	38	38	24.00	--	O
30N/04W-22E01	SPENCER	08/24/1971	P	70	68	55.00	--	O
30N/04W-22E02	BURTON	01/07/1976	H	37	37	14.00	--	O
30N/04W-22E02	SPENCER	06/19/1970	H	117	117	49.58	111	S
30N/04W-22H01	ARVIE SMITH	1965	H	163	163	93.68	158	S
30N/04W-22H02	SMITH-2, ARNIE	02/24/1978	P	298	298	102.00	160	P
30N/04W-22J01	LOCHOW, F. A	--	H	--	109	93.78	--	--
30N/04W-22J02	STOICAN DRLG CO	1959	H	--	118	94.00	--	--
30N/04W-22N01	PHILLIPS	12/20/1973	H	275	275	220.00	269	S
30N/04W-22N02	LOHR, BILL M	11/11/1976	U	416	409	242.00	--	O
30N/04W-22N03	SLATER, DON	02/28/1979	U	237	237	D	--	--
30N/04W-22Q01	ROSCHE, WILLIAM	05/31/1976	H	108	107	76.50	--	O
30N/04W-22R01	TOZZER	08/17/1974	H	270	270	150.00	155	P
30N/04W-22R02	SCHMIDT, MIKE	06/01/1977	H	60	60	20.00	55	S
30N/04W-22R03	LASSITER, JOSEPH C	06/14/1979	H	101	100	74.00	--	O
30N/04W-22R04	SMITH, BURREL	04/14/1979	H	99	99	60.00	--	O
30N/04W-23~~2~~ K01	READER, PAUL	05/03/1976	H	46	46	25.00	--	O
30N/04W-23~~2~~ K02	PARKER, SHANNON	03/03/1977	H	88	88	21.00	--	O
30N/04W-23C01	HUTCHINSON, HUGH R	03/08/1962	--	66	66	27.00	33	P
30N/04W-23E01	BURTON, CLARENCE N	04/15/1952	I	--	16	7.50	--	--

xxvii.

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/04W-20M02	2	--	1.5	G	U
30N/04W-20N01	12	--	--	G	U
30N/04W-20N02	--	--	--	G	U
30N/04W-20P01	6	6.0	1.5	G	U
30N/04W-20Q01	3	--	--	G	U
30N/04W-21-1	5	0.1	6.0	G	U
30N/04W-21B01	--	--	--		C
30N/04W-21C01	15	0.5	0.5	G	U
30N/04W-21C02	7	0.2	--	G	U
30N/04W-21G01	15	3.8	2.0	G	U
30N/04W-21G02	12	0.6	1.5	G	C
30N/04W-21G03	18	1.0	1.5	G	C
30N/04W-21J01	10	0.2	--	G	U
30N/04W-21J02	20	2.0	3.0	G	U
30N/04W-21K01	18	0.6	2.0	G	C
30N/04W-21K02	10	10.0	1.5	G	U
30N/04W-21L01	15	0.8	5.5	G	C
30N/04W-22A01	30	0.6	2.0	G	U
30N/04W-22A02	17	0.7	--	G	U
30N/04W-22D01	25	3.1	--	G	U
30N/04W-22D02	12	1.5	--	G	U
30N/04W-22E01	25	12.0	--	G	U
30N/04W-22E02	8	--	--	G	U
30N/04W-22E02	25	0.5	--	G	U
30N/04W-22H01	50	1.1	3.5	G	C
30N/04W-22H02	30	3.0	2.0	G	U
30N/04W-22J01	--	--	--		C
30N/04W-22J02	--	--	--	G	C
30N/04W-22N01	15	15.0	4.0	G	C
30N/04W-22N02	3	0.0	4.0	G	C
30N/04W-22N03	0.00	0.0	--	G	U
30N/04W-22Q01	30	--	2.0	G	U
30N/04W-22R01	2	--	--	G	U
30N/04W-22R02	30	3.0	--	G	C
30N/04W-22R03	30	--	1.0	G	U
30N/04W-22R04	2	1.7	1.5	G	U
30N/04W-23-1	12	--	1.0	G	U
30N/04W-23-2	--	--	--	G	U
30N/04W-23C01	50	--	--	G	U
30N/04W-23E01	175	25.0	6.0	G	C

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
30N/04W-35G03	DAVIS, BOB	06/26/1977	H	95	91	74.00		--	O
30N/04W-35B01	FRICK, D. B	08/10/1977	H	34	34	10.00		--	O
30N/04W-35B02	RIFE, DAL	02/16/1979	H	33	33	12.00		--	O
30N/04W-35C01	COURTIER	03/16/1974	H	95	95	13.00		32	P
30N/04W-35C02	MCCALL, E. J	05/26/1976	H	48	48	12.50		26	P
30N/04W-35D01	SPARKS, DON	11/10/1977	H	54	54	27.00		--	O
30N/04W-35G01	FERNIE, BRUCE	06/01/1977	H	86	86	45.00		--	O
30N/04W-35G02	RIFE, DAL	01/24/1978	H	93	93	82.00		--	O
30N/04W-35L01	ALLEN, LESTER	05/23/1977	H	93	93	85.00		--	O
30N/04W-35L02	BENHAM, JIM	11/02/1977	H	27	27	14.00		--	O
30N/04W-35L03	SMITH, RON	12/01/1978	H	47	47	25.00		--	O
30N/04W-35A01	DE RYSS, ROMAN	04/10/1977	H	92	91	70.50		--	O
30N/04W-35N02	RIDGEFIELD	09/26/1975	H	90	86	64.00		--	O
30N/04W-35N01	WILSON, JAMES	10/23/1978	H	96	96	31.00		16	X
30N/04W-35P01	NORRIS, BOB	06/21/1976	H	135	135	110.00		--	X
30N/04W-35P02	WILKIE	10/25/1972	--	95	95	68.00		74	P
30N/04W-35P03	STIRATT, RALPH	09/22/1977	H	--	--	192.00		214	P
30N/04W-36B01	OQUIST, SELFRID	11/15/1978	H	42	40	24.00		35	S
30N/04W-36J01	COUTU, O L	06/07/1977	--	120	--		D	--	--
30N/04W-36R01	WILLIAMS 2, ROBERT	08/11/1977	H	100	100	2.00+		45	P
30N/04W-36R02	WILLIAMS-3, ROBERT	08/16/1977	H	64	64	11.00		--	X
30N/04W-36R03	WILLIAMS-1, ROBERT	08/09/1977	--	180	--		D	--	--
30N/04W-36R04	COUTU, O L	06/29/1977	--	395	--		D	--	--
~~30N/05E-07G08~~	~~MORGAN, DENNY~~	~~08/29/1978~~	~~H~~	~~102~~	~~102~~	~~91.00~~		~~--~~	~~O~~
30N/05W-02R01	GERHKE	11/ /1966	H	--	142	--		--	--
30N/05W-12A01	CORLETT, DONALD	1962	H	--	152	130.00		--	S
30N/05W-12C01	WEINZERL-DOUGLS	--	H	--	144	--		--	--
30N/05W-12E01	GALLOWAY, ELMER	--	H,S	--	110	79.75		--	--
30N/05W-12H01	JARVIS, E. J	--	H	--	76	67.48		--	--
30N/05W-12K01	BRUCKNER	08/28/1975	H	130	105	84.60		--	S
30N/05W-12K02	SNIDER, VERNON	05/30/1978	H	109	109	92.00		--	O
30N/05W-12L01	DICKINSON, G.	--	H	--	102	97.19		--	--
30N/05W-12N01	ADOLPHSEN, P.	--	H,S	--	4	0.81		--	--
30N/05W-13E01	BAILEY, W. D	--	H,S	--	20	1.55		--	--
30N/05W-13K01	CRAIN, RAY	--	H,S	--	5	2.00		--	--
30N/05W-23J01	DPT PUBLIC WRKS	08/28/1974	H	104	104	70.00		99	S
30N/05W-24D01	FARLEY	11/23/1975	H	131	130	43.00		125	S
30N/05W-25B01	LESTER	06/17/1974	H	193	193	62.00		164	P
30N/05W-25C01	ATHAY, CHARLES	08/27/1978	U	120	120		D	29	X
30N/05W-25C02	ATHAY, CHARLES	09/18/1978	H	101	61	24.00		47	--

xxix.

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE	
				LG	CK
30N/04W-35-1	2	--	--	G	U
30N/04W-35B01	30	3.0	1.0	G	C
30N/04W-35H02	24	4.8	1.5	G	U
30N/04W-35C01	9	0.3	2.0	G	U
30N/04W-35C02	15	--	1.5	G	U
30N/04W-35D01	11	0.7	1.5	G	U
30N/04W-35G01	17	17.0	1.5	G	U
30N/04W-35G02	7	--	2.0	G	U
30N/04W-35L01	15	15.0	1.0	G	U
30N/04W-35L02	11	2.2	1.5	G	U
30N/04W-35L03	13	0.9	--	G	U
30N/04W-35NEQ-1	20	--	1.5	G	U
30N/04W-35NP-2	10	--	3.0	G	U
30N/04W-35N01	4	--	--	G	U
30N/04W-35P01	17	2.6	2.0	G	C
30N/04W-35P02	18	3.0	--	G	U
30N/04W-35P03	3	0.1	--	G	U
30N/04W-36B01	12	1.2	1.5	G	U
30N/04W-36J01	--	--	--	G	U
30N/04W-36R01	4 F	4.0	--	G	U
30N/04W-36R02	5	--	--	G	U
30N/04W-36R03	--	--	--	G	U
30N/04W-36R04	--	--	--		U
30N/05E-07G08	15	--	--	G	U
30N/05W-02R01	10	--	--		C
30N/05W-12A01	--	--	--		C
30N/05W-12C01	--	--	--		C
30N/05W-12E01	--	--	--		C
30N/05W-12H01	--	--	--		C
30N/05W-12K01	25	5.0	--	G	C
30N/05W-12K02	7	--	--	G	U
30N/05W-12L01	--	--	--		C
30N/05W-12N01	--	--	--		C
30N/05W-13E01	--	--	--		C
30N/05W-13K01	--	--	--		C
30N/05W-23J01	--	--	--	G	U
30N/05W-24D01	12	0.5	2.0	G	U
30N/05W-25B01	6	0.1	--	G	U
30N/05W-25C01	0.00	0.0	--	G	U
30N/05W-25C02	6	0.1	2.0	G	U

XXX.

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
30N/05W-25C03	GRATTON, ROBERT	09/22/1978	H	154	154	52.00		149	S
30N/05W-25D01	IRONS, RAY	06/ /1976	H	90	90	27.50		44	P
30N/05W-25M01	NEVENSCHWANDER, FRED	1907	I,H,S	6	6	0.00		--	O
30N/05W-26H01	RADICH	04/03/1974	H	59	59	37.00		54	S
30N/05W-26K01	PETERS, KEITH	08/17/1978	U	261	0		D	--	--
30N/05W-26K02	PETERS, KEITH	08/24/1978	U	207	0		D	--	--
30N/05W-36E01	DAILEY	09/23/1975	H	54	54	14.50		49	S
30N/04W-13K08	THORSON, TOM	01/03/1977	H	70	67	30.00		61	S
31N/04W-25M02	SULLIVAN, JOE	08/03/1978	H	58	58	28.00		53	S
31N/03W-18G01	U.S.COAST GUARD	09/ /1930	H	667	667		F	--	--
31N/03W-30M01	MARSHALL, ERNEST	--	--	--	48	4.60		--	--
31N/03W-30N01	GREEN	03/13/1975	H	39	39	4.00		--	O
31N/03W-30Q01	PETTITT, HARVEY	--	T	3600	250		F	--	--
31N/03W-31L01	CUNNINGHAM, TED H	12/07/1977	H	37	37	2.00		--	O
31N/03W-31B01	DUNGENESS BEACH	08/22/1974	P	52	52	8.00		47	O
31N/03W-31D01	SLICK, BILL L	04/23/1976	H	57	57	7.00		55	P
31N/03W-31E01	SCHAEFER, KENNETH B	05/18/1978	H	41	41	4.00		36	S
31N/03W-31H01	FITZGERALD	03/ /1962	P	44	44		F	40	S
31N/04W-25M03	SHANNON, COL. H R	02/17/1978	H	99	99	74.00		--	O
31N/04W-25P03	DE PALMA	06/28/1974	H	57	57	29.00		52	S
31N/04W-25P04	CAYS	03/28/1974	H	58	57	29.00		52	P
31N/04W-25N01	GORDON	01/25/1974	H	95	95	66.00		--	O
31N/04W-25P05	SPRAGUE, VERN	08/31/1978	H	62	62	43.00		58	S
31N/04W-25P06	GRINNELL, FRED	05/13/1976	H	62	62	37.50		59	S
31N/04W-25R01	BLAKE, JESSE	09/10/1975	H	40	40	4.50		36	S
31N/04W-25N02	KOOMBS, KEN	05/18/1977	H	75	75	53.00		71	P
31N/04W-25M04	HANNON, DON	10/28/1977	H	104	104	70.00		--	O
31N/04W-25N03	DECHENNE, M. F	05/12/1977	H	75	75	54.00		71	P
31N/04W-25P07	WILLIAMS	03/25/1974	H	61	60	38.00		55	--
31N/04W-25P08	RAFF	03/18/1974	H	64	64	25.00		--	O
31N/04W-25P09	LEDBETTER	09/10/1973	H	65	65	30.00		--	O
31N/04W-25M01	DUNGENESS CAMP	1965	R	--	300		F	--	--
31N/04W-25P01	FRANZEN	01/01/1901	H	--	74	--		--	--
31N/04W-25P02	WHELAN, GEORGE M	08/02/1971	H	63	63	46.00		58	P
31N/04W-25Q01	COVER, LEO	04/04/1978	H	44	44	3.50		--	O
31N/04W-25R02	CHENEY	01/03/1974	H	52	52	6.00		--	O
31N/04W-25P10	GORYNSKI, RAY	06/30/1978	H	48	48	6.50		43	S
31N/04W-26Q03	MERRITTE, JOHN	02/13/1976	H	68	68	48.00		63	S
31N/04W-26L01	THIERSCH, J B	11/25/1974	H	165	165	24.00		162	S
31N/04W-26Q04	GILCHRIST, FRED	02/02/1978	H	90	88	43.00		83	S

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/05W-25C03	5	0.1	1.5	G	U
30N/05W-25DE-1	17	0.3	2.0	G	U
30N/05W-25M01	8	1.3	--	G	U
30N/05W-26H01	10	1.7	3.0	G	U
30N/05W-26K01	0.00	0.0	--	G	U
30N/05W-26K02	0.00	0.0	--	G	U
30N/05W-36E01	9	--	--	G	U
30N104W-13K08	35	35.0	1.5	G	U
31 N/04W-25M02	20	20.0	2.0	G	U
31N/03W-18G01	50	--	--	G	U
31N/03W-30M01	27	--	--		C
31N/03W-30N01	20	--	--	G	U
31N/03W-30Q01	--	--	--		C
31N/03W-31-1	36	3.6	--	G	U
31N/03W-31B01	--	--	--	G	C
31N/03W-31D01	30	--	1.0	G	C
31N/03W-31E01	120	34.0	1.0	G	U
31N/03W-31H01	50	2.5	2.0	G	C
31N/04W-25-1	18	1.2	--	G	U
31N/04W-25-10	50	50.0	--	G	U
31N/04W-25-11	40	8.0	2.0	G	U
31N/04W-25-12	20	2.5	2.0	G	U
31N/04W-25-13	25	25.0	--	G	U
31N/04W-25-2	35	7.0	1.0	G	U
31N/04W-25-3	50	10.0	--	G	U
31N/04W-25-4	30	30.0	--	G	U
31N/04W-25-5	34	3.4	1.5	G	U
31N/04W-25-6	30	30.0	--	G	U
31N/04W-25-7	73	12.0	3.0	G	U
31N/04W-25-8	40	4.4	2.5	G	U
31N/04W-25-9	30	5.0	3.0	G	U
31N/04W-25M01	--	--	--		C
31N/04W-25P01	--	--	--		C
31N/04W-25P02	15	15.0	2.0	G	C
31N/04W-25Q01	30	1.0	--	G	U
31N/04W-25SEQ-1	20	1.4	2.0	G	U
31N/04W-25SWQ1	40	5.7	4.0	G	U
31N/04W-26-1	25	25.0	--	G	U
31N/04W-26-2	18	0.6	--	G	U
31N/04W-26-3	40	6.7	2.5	G	U

CLALLAM CO., WA-212

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
31N/04W-26-~~1~~ Q05	VERDICK	03/30/1974	H	66	66	50.00	61	S
31N/04W-26-~~3~~ Q06	THIERSCH	11/25/1974	H	62	62	49.00	58	P
31N/04W-26G01	SAN JUAN FARM	--	H	--	98	F	--	--
31N/04W-26J01	ANDERSON, PHILLIP B	03/18/1978	H	127	126	34.00	--	O
31N/04W-26K01	BOREHAVEN, JACK	03/13/1978	H	163	162	25.00	--	O
31N/04W-26M01	VAN BIBBLER, N. O	--	C	--	49	42.67	--	--
31N/04W-26Q01	BIGELOW	01/01/1901	H	--	92	89.00	--	--
31N/04W-26Q02	WIMMER, VICI	08/20/1974	H	90	90	68.00	--	--
31N/04W-27-~~1~~ P01	BERGSHEND, CHARLES	04/05/1977	H	130	130	95.40	125	S
31N/04W-27-~~2~~ P02	BRIDENBAUGH	04/23/1974	H	84	84	55.00	--	O
31N/04W-27N01	DAWES, ROY A	1952	H	--	118	83.00	--	--
31N/04W-27Q01	OLSON, C. L	--	H	--	84	49.46	--	--
31N/04W-27R01	BODE, F D	10/ /1967	H	--	53	32.96	--	O
31N/04W-34-~~1~~ A01	RYAN, FRANK	09/30/1975	H	98	98	63.20	--	O
31N/04W-34F01	HICKS, RANDELL M	08/29/1978	H	141	138	111.00	133	S
31N/04W-34H01	COVERDALE, HAL M	12/28/1977	H	122	122	85.00	117	S
31N/04W-34H01	LEACH, L. W	--	H	--	126	--	--	--
31N/04W-34M01	CROMWELL	02/05/1972	H	94	94	58.00	--	S
31N/04W-34M02	MOSS, SIDNEY	08/01/1979	H	120	120	90.00	115	S
31N/04W-34M03	BODE, PAUL	03/09/1979	H	93	93	60.00	88	S
31N/04W-34P01	KINNAMAN, JIM	--	H,S	--	90	--	--	--
31N/04W-34Q01	DAVSON, DONALD	06/27/1977	H	107	107	85.00	101	S
31N/04W-35-~~1~~ L02	--	11/14/1974	H	104	104	90.00	97	P
31N/04W-35-~~2~~ L03	CHESNES	01/28/1974	H	120	120	86.00	--	O
31N/04W-35-~~3~~ L04	ROBINSON	02/08/1972	H	114	114	83.00	94	P
31N/04W-35-~~4~~ L05	ROBINSON, ROGER R	02/01/1974	H	112	112	84.00	--	O
31N/04W-35A01	CLARK	01/01/1901	H	--	90	--	--	--
31N/04W-35D01	FOSKETT, ABNER W	09/20/1962	H	94	94	68.15	--	--
31N/04W-35E01	PEDERSON	01/01/1901	P	153	153	65.00	--	--
31N/04W-35E02	PEDERSON	01/01/1910	P	110	110	88.00	--	S
31N/04W-35H01	CLARK, ELLIOTT	08/31/1979	I	618	616	41.30	553	S
31N/04W-35J01	BEEBE, CHAS.	--	H,S	--	65	--	--	--
31N/04W-35L01	HARIG, RICHARD	--	H	--	122	10.95	--	--
31N/04W-35M01	FRESCHLING	01/16/1974	H	132	132	107.25	--	O
31N/04W-35N01	LIDELL, ERIC	05/31/1978	H	130	130	103.00	--	O
31N/04W-35P01	LATZGESELL	1917	H,I	--	31	7.00	--	--
31N/04W-36-~~1~~ E01	MCCARTER, NEAL	08/03/1978	H	130	122	82.00	117	S
31N/04W-35-~~1~~ K01	BAKER, JAMES	11/05/1975	H	90	90	17.00	85	P
31N/04W-36-~~2~~ E02	BURK, J W	06/24/1975	H	103	103	76.00	--	O
31N/04W-36-~~3~~ C02	ENSIGN	07/01/1974	H	70	70	38.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
31N/04W-26-4	15	15.0	--	G	U
31N/04W-26-5	18	--	--	G	U
31N/04W-26G01	--	--	--		C
31N/04W-26J01	9	0.1	1.5	G	U
31N/04W-26K01	10	0.3	1.5	G	U
31N/04W-26M01	--	--	--		C
31N/04W-26Q01	--	--	--		C
31N/04W-26Q02	20	4.0	--	G	C
31N/04W-27-1	35	8.8	2.0	G	U
31N/04W-27-2	14	0.9	1.0	G	U
31N/04W-27N01	--	--	--		C
31N/04W-27Q01	--	--	--		C
31N/04W-27R01	40	--	--	G	C
31N/04W-34-1	20	--	--	G	U
31N/04W-34F01	10	0.4	6.5	G	U
31N/04W-34H01	10	0.8	3.0	G	C
31N/04W-34H01	--	--	--		C
31N/04W-34M01	25	2.5	--	G	C
31N/04W-34M02	24	24.0	2.0	G	U
31N/04W-34M03	30	30.0	2.0	G	U
31N/04W-34P01	--	--	--		C
31N/04W-34Q01	10	1.0	1.5	G	C
31N/04W-35-1	12	12.0	--	G	U
31N/04W-35-2	14	6.8	2.0	G	U
31N/04W-35-3	26	13.0	1.5	G	U
31N/04W-35-4	20	20.0	1.5	G	U
31N/04W-35A01	--	--	--		C
31N/04W-35D01	20	2.0	1.0	G	C
31N/04W-35E01	50	7.1	--	G	U
31N/04W-35E02	20	20.0	--	G	U
31N/04W-35H01	650	9.4	7.5	G	U
31N/04W-35J01	--	--	--		C
31N/04W-35L01	--	--	--		C
31N/04W-35M01	10	--	--	G	U
31N/04W-35N01	8	0.5	1.5	G	U
31N/04W-35P01	--	--	--		U
31N/04W-36-06	20	8.0	1.0	G	U
31N/04W-36-1	20	20.0	2.0	G	U
31N/04W-36-2	30	4.3	--	G	U
31N/04W-36-4	20	1.3	--	G	U

CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/03W-31E02	MCKINNEY	09/ /1974	H	--	34	11.00	--	--
30N/03W-31P01	EMERSON, KENNETH	05/02/1979	H	109	98	81.00	93	S
30N/03W-32E02	HALEY	04/01/1970	P	--	118	F	--	P
30N/03W-34F01	DEVINE, DAN E	05/07/1979	H	183	180	29.00	160	X
30N/03W-35E02	JOHNSON, ROBERT	11/10/1978	H	380	380	45.00	59	X
30N/03W-36→F03	GERAGHTY, DR.THOMAS	07/16/1979	H	110	110	83.00	--	O
30N/03W-36F01	GUNSTONE, CHARLES	1950	H	--	--	50.98	--	--
30N/03W-36F02	MACAULEY, ROBERT	11/19/1975	H	93	87	63.50	82	S
30N/03W-36J02	WILLIAMS, LOUIS	10/26/1974	H	77	77	F	28	P
30N/03W-36K01	EDERER, JOHN	06/21/1978	H	123	123	80.00	118	S
30N/03W-36L01	ANDERSON, RICHARD C	03/16/1978	H	118	118	80.00	--	O
30N/03W-36L02	ENG, FE	10/28/1975	H	78	77	51.00	72	S
30N/04W-01J01	FLANDERS	05/19/1973	P	--	70	26.00	--	S
30N/04W-04N03	GILKISON	04/08/1974	H	--	99	75.00	--	--
30N/04W-04R08 1	MATRIOTTI	12/23/1974	H	--	86	--	--	S
30N/04W-12L01	WILLIAMSON	10/12/1968	H	--	34	21.00	--	--
30N/04W-12M01	KRTZO, Frank	03/ /1957	--	--	--	8.00	--	P
30N/04W-12R02	ROBINS	07/02/1960	--	--	--	6.00	--	--
30N/04W-13F01	BORDEN	10/31/1974	H	--	43	5.00	--	--
30N/04W-13F03	PARKER	11/04/1974	H	--	42	8.00	--	--
30N/04W-13K01	TENNESON	12/29/1973	H	--	71	20.00	66	S
30N/04W-14F01	ADAMS	06/01/1952	I	--	30	16.00	--	--
30N/04W-23K01	HUTCHINSN	03/08/1962	--	--	66	27.00	--	P
30N/04W-25B01	WHELAN	01/01/1901	H	--	63	46.00	--	P
30N/04W-25G01	LIVINGSTON	05/03/1974	H	--	101	78.00	--	--
30N/04W-27A05	HILLS, LAVERNE	08/26/1976	H	170	170	105.00	100	X
30N/04W-30E01	SOBLECK, DAVID	08/08/1979	H	202	110	60.00	68	P
30N/05W-07→Lc1	BATZMAN, HOWARD	05/12/1977	H	232	232	189.50	209	P
30N/05W-10A01	KEHLE & HAWLEY	01/01/1901	U	235	234	213.33	224	S
30N/05W-10F01 ✓	CLALLUM.PUD NO1	12/03/1965	P	214	205	177.00	195	S
30N/05W-10F02 ✓	PHILLIPS, D H	--	U	--	40	--	--	--
30N/05W-14A01	WELLER, CLARENCE	07/13/1979	H	94	94	68.00	--	O
30N/05W-16J01	ABBOTT CONSTRUC	01/26/1978	H	68	68	32.00	63	S
30N/05W-16J02	TEEFY, RAY	06/09/1977	H	68	65	28.00	57	P
30N/05W-18F01	PHILLIPS	1935	H,H,S	--	20	13.00	--	--
30N/05W-18M01	GROVES, TED	04/25/1977	U	180	180	D	--	--
30N/05W-18M02	WOMACK, VINCENT	12/14/1978	H	120	90	33.00	37	P
30N/05W-19→A01	BATES, RICHARD	05/06/1977	H	175	88	28.00	37	P
30N/05W-19L01	HERNANDEZ, BILL	08/31/1978	H	56	56	10.00	20	X
30N/05W-19P01	MARKS, DENNIS	09/19/1977	H	138	138	116.00	--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/03W-31E02	15	--	--		U
30N/03W-31P01	10	1.2	2.0	G	U
30N/03W-32E02	25 F	--	--		U
30N/03W-34F01	5	--	2.0	G	U
30N/03W-35E02	1	--	--	G	U
30N/03W-36-4	15	--	1.5	G	U
30N/03W-36F01	--	--	--		C
30N/03W-36F02	15	5.0	3.0	G	C
30N/03W-36J02	10	0.2	--	G	U
30N/03W-36K01	18	2.2	4.0	G	C
30N/03W-36L01	3	0.2	4.5	G	C
30N/03W-36L02	5	0.2	2.0	G	C
30N/04W-01J01	100	100.0	--	G	C
30N/04W-04N01	18	--	--	G	U
30N/04W-04R02	--	--	--	G	C
30N/04W-12L01	20	--	--	G	C
30N/04W-12M01	120	--	--		C
30N/04W-12R02	180	--	--	G	C
30N/04W-13F01	45	--	--	G	U
30N/04W-13F03	40	--	--	G	U
30N/04W-13K01	12	0.5	2.0	G	U
30N/04W-14F01	100	--	--		C
30N/04W-23K01	50	--	--	G	U
30N/04W-25B01	15	--	--	G	U
30N/04W-25G01	15	--	--	G	U
30N/04W-27A05	0.3	--	--	G	U
30N/04W-30E01	0.8	0.0	1.5	G	U
30N/05W-07-1	20	3.1	2.0	G	U
30N/05W-10A01	140	67.0	19.0		C
30N/05W-10F01	330	82.5	24.0	G	C
30N/05W-10F02	--	--	--		C
30N/05W-14A01	20	20.0	1.5	G	U
30N/05W-16J01	5	0.1	--	G	U
30N/05W-16J02	7	0.6	2.0	G	U
30N/05W-18F01	64	21.0	4.0		C
30N/05W-18M01	--	--	--	G	C
30N/05W-18M02	10	1.0	1.5	G	U
30N/05W-19-1	12	1.0	3.0	G	U
30N/05W-19L01	1	--	--	G	C
30N/05W-19P01	6	1.2	1.5	G	C

CLALLAM CO.. OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
30N/05W-19Q01	CARLSON	10/10/1975	H	126	126	110.00		--	O
30N/05W-19Q02	HULSE, VIC	03/16/1977	H,S	152	152	124.00		--	O
30N/05W-19Q03	BEARD, TOM	01/26/1976	H	135	135	113.50		--	O
30N/05W-19B01	SHARPE, LARS E	01/03/1978	H	127	127	104.00		--	O
30N/05W-20A01	ROGERS, BYRON	05/11/1979	H	95	95	60.00		90	S
30N/05W-20B01	HILL	02/10/1970	S	119	111	58.00		106	S
30N/05W-21H01	SCHMOCKER	06/10/1963	I,H	90	90	8.00		--	O
30N/05W-22G01	DONINER, JEFF	09/11/1979	H	80	80	45.00		75	S
30N/05W-23C01	SIMPKINS	1929	H,S	--	12	6.00		--	--
30N/05W-23M01	TAIT, TOM	06/19/1979	H	42	38	14.00		--	P
30N/05W-26P01	CHILDERS, BILL	05/18/1979	H	135	35	13.50		30	S
30N/05W-27G01	HOPPER 2, SCOTT	11/ /1977	H	--	--	--		--	--
30N/05W-27H01	CRAKER, TOM	05/04/1978	H	87	87	68.00		84	S
30N/05W-29L02	PEARSON, BOB	08/25/1976	H	270	270		D	--	--
30N/05W-29L03	EATON, NORTHROP	09/13/1976	H	120	120	88.00		118	X
30N/05W-29M01	ILK, STEVE	03/23/1977	H	80	80	31.50		18	X
30N/05W-29M03	ERWICK, DALE	06/15/1978	H	47	47	0.00		20	X
30N/05W-29M04	WALDRON, DON	06/29/1978	H	134	134	32.00		34	X
30N/05W-29M05	WILLIAMSON, BILL	09/22/1976	H	40	40	7.60		10	X
30N/05W-29N01	CROUSE	10/18/1975	H	90	90	19.00		20	X
30N/05W-29P01	WRIGHT, AL	04/09/1976	H	100	100	15.00		10	X
30N/05W-30B01	DROZ, ROGER	09/22/1977	H	180	180		D	--	--
30N/05W-30C04	SHORES, DICK	04/23/1977	U	240	--		D	--	--
30N/05W-30C01	RIDER, E	04/25/1977	H	180	180	66.33		120	P
30N/05W-30C02	SCOVIL, ED	04/05/1978	H	112	112	87.00		--	O
30N/05W-30C03	SHORES, DICK	05/02/1977	U	180	--		D	--	--
30N/05W-30C05	LEEM, AL	09/05/1979	--	60	60	2.00		12	X
30N/05W-30D03	LEE, ED	04/18/1977	H	94	94		F	34	P
30N/05W-30F01	BAILEY, JOHN W	05/10/1977	H	135	135	25.00		95	P
30N/05W-30F02	MEINER, G S	04/15/1977	H	200	200		F	20	X
30N/05W-30F03	LEE, ED,JR.	05/10/1977	H	152	152	14.70		112	P
30N/05W-30F04	MULLINS, MELVIN	08/09/1978	H,S	37	37	5.00		35	X
30N/05W-30H01	WHITTY	07/24/1974	H	170	170	34.00		130	P
30N/05W-30J01	TEEL	11/16/1972	I,H	80	80	3.00		11	X
30N/05W-30K01	BECK, ED	08/14/1979	H	76	76	2.00		10	X
30N/05W-30K02	FRYER, MELL	12/22/1976	H	160	160	0.00		39	X
30N/05W-30L01	PEARMAN, BLAINE	10/26/1976	H	102	102	3.50+		22	X
30N/05W-30L02	KRICK, RICHARD	03/22/1978	H	200	200	52.00		8	X
30N/05W-30L03	EUBANK, JOHN	07/12/1978	H	87	87	46.00		12	X
30N/05W-30Q01	THIE, LOUIE	07/31/1979	H	105	105	60.00		20	X

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/05W-19Q01	12	2.4	--	G	C
30N/05W-19Q02	7	0.4	--	G	C
30N/05W-19Q03	15	1.5	1.0	G	C
30N/05W-19301	9	0.6	3.0	G	C
30N/05W-20A01	10	0.5	1.5	G	U
30N/05W-20B01	8	0.2	2.0	G	C
30N/05W-21B01	17	0.3	2.0	G	C
30N/05W-22-1	8	--	1.5	G	U
30N/05W-23C01	--	--	--		C
30N/05W-23M01	12	0.5	2.0	G	U
30N/05W-26P01	3	0.4	2.0	G	U
30N/05W-27G01	--	--	--	G	C
30N/05W-27H01	6	1.2	1.5	G	C
30N/05W-29L02	--	--	--	G	C
30N/05W-29L03	20	--	1.0	G	C
30N/05W-29M01	25	0.7	--	G	C
30N/05W-29M03	6	--	1.5	G	C
30N/05W-29M04	3	--	2.0	G	C
30N/05W-29M05	15	--	--	G	C
30N/05W-29N01	12	0.2	--	G	C
30N/05W-29P01	8	0.1	--	G	C
30N/05W-30B01	--	--	--	G	C
30N/05W-30C/4	0.00	0.0	--	G	C
30N/05W-30C01	2	0.0	2.0	G	C
30N/05W-30C02	6	1.5	1.5	G	C
30N/05W-30C03	0.00	0.0	--	G	C
30N/05W-30C05	50	3.3	1.5	G	U
30N/05W-30D03	7	--	2.0	G	C
30N/05W-30F01	30	--	1.5	G	C
30N/05W-30F02	5	--	2.0	G	C
30N/05W-30F03	30	--	1.5	G	C
30N/05W-30F04	30	--	--	G	C
30N/05W-30H01	6	0.1	2.0	G	C
30N/05W-30J01	15	0.3	--	G	C
30N/05W-30K01	50	1.7	1.5	G	U
30N/05W-30K02	8	0.1	--	G	C
30N/05W-30L01	20	--	1.0	G	C
30N/05W-30L02	2	0.0	--	G	C
30N/05W-30L03	16	0.5	--	G	C
30N/05W-30Q01	30	30.0	1.5	G	U

CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/05W-30R01	BAUBLITS	02/10/1975	H,S	98	98	38.00	23	X
30N/05W-30R02	HAGGER, STEVE	09/30/1976	H	100	100	20.00	10	X
30N/05W-30R03	HANSON, RAY&BETTY	05/11/1978	H,S	96	96	60.00	8	X
30N/05W-31A01	HALDEMAN	05/02/1968	H,S	357	357	83.00	15	X
30N/05W-31C01	MCLEAN	09/07/1974	H	102	102	48.00	30	X
30N/05W-31C02	ELLEFSON	09/02/1974	H	140	140	78.00	56	X
30N/05W-31G01	STAFFORD	08/30/1974	H	174	174	--	20	X
30N/05W-31G02	STEVENS, HAROLD	08/12/1977	H	110	110	13.00	80	X
30N/05W-31G03	STAFFORD&DUNKEL	09/15/1977	H	91	91	16.00	--	--
30N/05W-32D01	KITSELMAN, EDWARD	07/14/1977	H	102	102	53.00	27	X
30N/05W-32K01	WATKINS, ROBERT	10/17/1979	H	112	112	70.00	12	X
30N/05W-32M01	COULTER	09/05/1974	H	160	160	18.00	120	P
30N/05W-32R01	MALONEY	11/27/1966	H,S	301	301	180.00	--	O
30N/05W-34Q01	COLLIE, GARY	07/29/1977	H	36	36	12.00	32	S
30N/05W-36E02	GRIFFITH, CHRIS	03/14/1977	H	94	87	16.00	82	S
30N/05W-07B01	BALLARD	01/01/1901	H,S	--	22	0.46	--	--
30N/05W-07C01	GILLESPIE	01/01/1901	H	--	22	2.37	--	--
30N/05W-07C02	THOMAS	01/01/1901	H	--	16	1.00	--	--
30N/06W-07H01	WHEELER	07/ /1953	H	--	45	7.46	--	--
30N/05W-07H02	DOUGHERTY	1934	H	--	48	36.60	--	--
30N/06W-07N01	RYGAARD, EDGAR	07/06/1978	C	320	320	189.00	315	S
30N/05W-07Q01	NYHUS	1933	H	--	25	15.90	--	--
30N/05W-08Q01	BROOKS&LARSEN	05/12/1967	H	93	93	69.00	--	O
30N/05W-09J01	CHERRY HILL, BAPTIST CH	04/05/1979	H	155	155	121.00	--	O
30N/06W-09P01	MCCABE	06/15/1954	H	72	72	65.00	--	O
30N/05W-11A01	RAYONIER INC	06/ /1941	U	--	500		--	P
30N/06W-11K01	RAYMENT	1941	I	--	68	--	--	--
30N/06W-12H01	BALSER, FRED	01/27/1977	H,S	196	196	180.00	--	O
30N/05W-14D01	PRIEST, GLEN R	09/06/1979	U	182	182	70.00	--	--
30N/05W-15M01	PORT ANGELES	01/01/1901	U	378	378		--	--
30N/06W-16D01	THOMPSON	07/23/1974	H,S	82	82	38.00	76	S
30N/05W-16M01	TRIVICH	07/17/1968	I,H	135	135	41.00	130	S
30N/06W-17 G01	WILCOX	01/01/1901	H	--	50	--	--	--
30N/06W-17A01	MOWBRAY, ROBERT	03/22/1977	H	265	99	16.00	57	F
30N/06W-17C01	DAVIS, RALPH	06/19/1978	H	143	142	70.00	137	S
30N/06W-17G02	MILLER, CARL	02/09/1976	H,S	122	122	102.00	--	O
30N/06W-18A01	OLYMPIC WOOD PD	12/16/1977	H	200	200	98.00	173	X
30N/05W-19M02	JARNAGIN, PAT	11/09/1977	H	18	18	2.00	14	X
30N/06W-20M01	KECKEL, HARLAN	08/23/1979	H	96	96	50.00	30	X
30N/05W-22C01	HAPPY MOTORS	09/19/1977	H	260	260	12.00	--	X

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/05W-30R01	35	1.4	--	G	C
30N/05W-30R02	2	--	--	G	C
30N/05W-30R03	15	1.0	3.0	G	C
30N/05W-31A01	30	0.2	3.0	G	C
30N/05W-31C01	25	1.2	1.0	G	C
30N/05W-31C02	10	0.5	1.0	G	C
30N/05W-31G01	6	--	--	G	C
30N/05W-31G02	7	0.1	2.0	G	C
30N/05W-31G03	5	--	--	G	C
30N/05W-32D01	25	--	1.0	G	C
30N/05W-32K01	10	--	1.5		U
30N/05W-32M01	15	--	--	G	C
30N/05W-32R01	15	1.2	3.0	G	C
30N/05W-34Q01	12	0.8	--	G	C
30N/05W-36E02	5	0.1	4.0	G	U
30N/06W-07B01	--	--	--		C
30N/06W-07C01	--	--	--		C
30N/06W-07C02	--	--	--		C
30N/06W-07H01	--	--	--		C
30N/06W-07H02	--	--	--		C
30N/06W-07N01	10	10.0	4.0	G	U
30N/06W-07Q01	--	--	--		C
30N/06W-08Q01	15	3.8	1.5	G	U
30N/06W-09J01	4	--	3.0	G	U
30N/06W-09P01	--	--	--		C
30N/06W-11A01	--	--	--		C
30N/06W-11K01	--	--	--	G	C
30N/06W-12H01	13	13.0	--	G	C
30N/06W-14D01	1	0.0	1.0	G	U
30N/06W-15M01	--	--	--	G	U
30N/06W-16D01	--	--	--	G	C
30N/06W-16M01	600	33.0	4.0	G	C
30N/06W-17-2	--	--	--		U
30N/06W-17A01	3	--	1.0	G	C
30N/06W-17C01	12	0.8	1.0	G	U
30N/06W-17G02	16	4.0	--	G	C
30N/06W-18A01	30	30.0	2.5	G	C
30N/06W-19M02	25	5.0	1.5	G	C
30N/06W-20M01	5	0.1	2.0	G	U
30N/06W-22C01	3	0.0	2.0	G	C

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CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/06W-22D01	HOPKINS, LEE	07/14/1978	H	200	147	10.00	40	P
30N/06W-22E01	PRICE, KEN	01/09/1978	H	240	240	36.00	90	P
30N/06W-22E02	PRICE, KEN	04/30/1979	H	200	125	42.70	58	P
30N/06W-22F01	HAPPY MOTORS	09/21/1977	U	250	250	D	37	X
30N/06W-22F02	ANDERSON	05/27/1974	H	250	250	62.00	--	X
30N/06W-23A01	CROTHERS	01/01/1910	H	--	12	2.00	--	--
30N/06W-23B01	EIGENHERG, ED	08/03/1977	H	28	26	13.00	21	S
30N/06W-23G01	CORNELL, JIM	04/03/1978	H	37	37	23.00	--	O
30N/06W-23L01	JESSINGER, LEONARD	09/07/1978	H	125	125	12.00	13	X
30N/06W-23N01	CORNEBY, PAUL	04/15/1976	H	130	130	24.75	24	X
30N/06W-23P01	TAYLOR, BROOKE	03/17/1979	H	111	111	50.00	40	X
30N/06W-23Q01	HARPER, JOHN	03/14/1979	H	88	88	38.00	19	X
30N/05W-24E01	WEILER, JERRY	03/01/1979	H	165	165	12.00	20	X
30N/06W-24H01	LINDENAU	03/ /1973	H	46	40	32.00	--	O
30N/05W-24J01	JARNAGIN, PAT	06/07/1977	H	120	120	40.00	18	X
30N/06W-24K01	MURRAY	09/12/1964	H	127	127	16.00	--	X
30N/06W-24K02	KED TER CONSTRU	03/13/1975	H	132	132	22.00	20	X
30N/06W-24K03	JURISON	02/25/1975	H	130	130	13.00	20	X
30N/05W-24K04	KUSSLER	04/11/1976	H	250	250	50.00	90	P
30N/06W-24K05	VAN SICKLE, M. N	07/17/1978	H	71	71	11.00	20	X
30N/05W-24L01	LONG, BILL	11/09/1977	H	70	70	30.00	46	X
30N/05W-24P01	COOPER	09/27/1974	H,S	102	102	16.00	98	S
30N/05W-24P02	MCDOUGALD, GERALD	07/05/1977	H	30	30	7.00	18	X
30N/06W-24P03	CHRYSLER, GRIFF	09/01/1977	H	105	105	44.00	60	X
30N/06W-24R01	ANDERSON	07/21/1975	H	49	49	33.60	--	O
30N/05W-24R03	RUUD, ART	10/26/1977	H	52	52	26.00	47	S
30N/05W-25B01	GARES, DON	01/30/1977	H	45	45	12.00	10	X
30N/05W-25B02	WOODSIDE, PAUL	06/21/1977	H	95	95	14.00	18	X
30N/05W-25C01	VALLAT	10/19/1964	H,I	61	61	12.00+	40	P
30N/05W-25C01	MALANEY	02/06/1975	H	34	34	7.50	18	X
30N/06W-25C02	VELIE, GARY	09/13/1977	H	30	30	6.00	--	--
30N/06W-25E02	ROSE	06/22/1974	H	150	150	8.00	--	X
30N/06W-25E04	RINGUS, WESLEY R	08/09/1976	H	100	100	--	20	X
30N/06W-25E05	NORTHERN, ROBERT	08/08/1979	H	230	230	37.00	23	X
30N/05W-25F01	ROONEY, TOM	09/12/1977	H	40	40	12.00	10	X
30N/05W-25F02	HREN, STEVE	06/19/1978	H	140	140	2.00+	23	X
30N/06W-25G02	FERGUSON, BOB	08/12/1976	H	70	70	F	20	X
30N/05W-25G03	POGANY, JOHN	08/05/1976	H	90	90	41.00	20	X
30N/05W-25G04	BAUMWELL, COL. KARL	07/06/1978	H	47	47	26.00	15	X
30N/06W-25H01	ZALUSKEY	10/15/1974	H	122	122	10.00	--	X

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/06W-22D01	2	--	6.0	G	U
30N/06W-22E01	1	--	--	G	C
30N/06W-22E02	1	0.1	2.0	G	U
30N/05W-22F01	0.00	0.0	--	G	C
30N/05W-22F02	--	--	--	G	C
30N/06W-23A01	--	--	--		U
30N/06W-23BG-1	7	1.4	1.5	G	U
30N/06W-23G01	5	0.4	1.5	G	C
30N/05W-23L01	3	--	--	G	C
30N/05W-23N01	13	0.1	1.5	G	C
30N/06W-23P01	9	--	1.5	G	U
30N/05W-23Q01	6	--	1.5	G	U
30N/06W-24E01	3	--	1.5	G	U
30N/06W-24H01	10	--	--	G	C
30N/05W-24J01	2	0.0	0.5	G	C
30N/06W-24K01	3	0.0	2.0	G	C
30N/06W-24K02	6	0.1	--	G	C
30N/05W-24K03	10	0.1	--	G	C
30N/05W-24K04	1	0.0	1.5	G	C
30N/06W-24K05	10	0.2	--	G	C
30N/05W-24L01	17	4.3	1.5	G	U
30N/06W-24P01	8	--	--	G	C
30N/06W-24P02	20	2.0	1.5	G	U
30N/06W-24P03	15	--	--	G	C
30N/06W-24R01	17	3.4	--	G	C
30N/05W-24R03	15	2.8	1.5	G	C
30N/06W-25B01	5	--	2.0	G	C
30N/05W-25B02	11	1.8	1.5	G	C
30N/06W-25C01	12 F	--	--	G	C
30N/06W-25C01	25	2.1	--	G	C
30N/06W-25C02	12	1.2	1.5	G	C
30N/06W-25E02	3	--	--		C
30N/05W-25E04	20	--	--	G	U
30N/06W-25E05	3	0.0	1.0	G	U
30N/06W-25F01	5	5.0	--	G	U
30N/05W-25F02	10 F	--	--	G	C
30N/06W-25G02	10	0.2	--	G	U
30N/05W-25G03	7	0.2	--	G	C
30N/06W-25G04	8	0.5	--	G	C
30N/06W-25H01	5	--	--	G	C

CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)	DEPTH TO FIRST OPENING (FEET)	FINISH
30N/06W-25J01	BENNETT, STEVE	02/16/1977	H	140	140	0.00	30	P
30N/06W-25R01	GEORGI, WILLIAM	05/24/1976	H	100	100	0.00	57	S
30N/06W-26D02	FELTON	10/14/1974	H	--	162	24.00	--	--
30N/06W-26D03	MILLER 3, HARLD E	03/06/1977	H	365	365	20.50	20	X
30N/06W-26E01	SNYDER, JAMES	07/22/1978	H	149	145	14.00	31	P
30N/06W-26E02	MILLER, HAROLD	07/18/1974	H	230	230	35.00	--	X
30N/06W-26L02	BRANDLAND, DALE	08/10/1978	H	38	38	4.00	18	X
30N/06W-26M02	KALAPACA, JOHN	09/21/1978	H	150	150	7.00+	22	X
30N/06W-26P01	BIGELOW	04/17/1974	H	110	110	40.00	92	X
30N/06W-27A01	ANDERSON, RAY	03/04/1977	H	325	325	89.00	19	X
30N/06W-27A02	BELLINGER, DICK	05/05/1977	H	120	120	50.00	60	P
30N/06W-27D01	BRUCH	02/11/1971	H	130	130	0.00	33	X
30N/06W-08Q01	LIGON, WARREN	08/11/1975	H	140	120	25.00	40	P
30N/07W-01N01	NORMAN	1933	H	--	156	151.09	--	--
30N/07W-01Q01	CRITCHFIELD	01/01/1901	H	--	15	1.48	--	--
30N/07W-02B01	PORT ANGELES	1929	--	--	118	D	--	--
30N/07W-02B02	SMITH	1923	U	--	185	171.00	--	--
30N/07W-02H01	POLLOW	01/01/1901	H	--	20	0.73	--	--
30N/07W-02L01	WALKER	--	H,S	--	200	--	--	--
30N/07W-03H01	TOBIN	1948	H	--	20	10.00	--	T
30N/07W-03R01	DEPT FISHERIES	10/16/1974	H	72	72	16.00	67	S
30N/07W-03R02	PORT ANGELES, RANNEY CLL	10/21/1977	P	63	63	12.92	--	H
30N/07W-07J01	WHEATLEY, DONALD	10/08/1978	H	70	70	23.00	20	P
30N/07W-07J02	ALWINE, DENNIS	10/07/1978	H	120	120	53.00	50	--
30N/07W-08L01	EIKEY, ERNIE	08/02/1979	I	170	170	162.00+	30	X
30N/07W-09A01	TRABAND, JOSEPH	01/22/1976	H	177	177	155.00	--	O
30N/07W-09A02	TRABAND	1970	U	290	290	--	150	X
30N/07W-09B01	MORGAN, BRIGHAM	09/09/1977	H,S,I	67	67	46.00	--	O
30N/07W-09C01	LONG	01/01/1901	U	--	35	4.24	--	--
30N/07W-09F01	DORAN, EARL	08/06/1979	H	65	65	30.00	20	X
30N/07W-09H01	TRABAND	01/01/1901	H	--	18	3.83	--	--
30N/07W-09K01	JILES, R. J	08/23/1978	H	39	39	26.00	--	O
30N/07W-09P01	JONES, CHRIS	12/21/1978	H	81	81	36.00	62	P
30N/07W-10B01	DRY CREEK WATER	06/ /1965	P	20	20	9.00	10	P
30N/07W-10D01	BURFORD	11/21/1975	H	200	200	120.00	123	P
30N/07W-10R01	SAMPSON	01/01/1901	--	--	8	0.56	--	--
30N/07W-11B01	THORSEN	01/01/1901	U	--	272	221.59	--	--
30N/07W-11B02	EVANGER	1950	U	--	212	--	--	--
30N/07W-11J01	GAGNON	01/01/1901	--	--	23	1.24	--	--
30N/07W-11P01	CAMERON	1938	H,S	--	14	2.18	--	--

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/06W-25J01	10	--	2.0	G	C
30N/06W-25R01	6	0.1	1.0	G	U
30N/06W-26D02	20	0.3	--	G	U
30N/06W-26D03	2	0.0	1.0	G	C
30N/06W-26E01	9	--	--	G	C
30N/06W-26E02	3	0.1	--	G	C
30N/06W-26L02	5	--	1.5	G	C
30N/06W-26M02	3 F	0.4	--	G	C
30N/06W-26P01	9	1.3	2.0	G	U
30N/06W-27A01	2	0.0	2.0	G	C
30N/06W-27A02	10	--	2.0	G	C
30N/06W-27D01	36	0.8	0.5	G	U
30N/06W-8-1	4	0.2	2.0	G	U
30N/07W-01N01	--	--	--		C
30N/07W-01Q01	--	--	--		C
30N/07W-02B01	--	--	--		C
30N/07W-02B02	--	--	--		C
30N/07W-02H01	--	--	--		C
30N/07W-02L01	--	--	--		C
30N/07W-03H01	--	--	--	G	C
30N/07W-03R01	40	16.0	--	G	C
30N/07W-03R02	7685	396.1	96.0	G	C
30N/07W-07J01	4	--	--	G	C
30N/07W-07J02	8	--	--	G	C
30N/07W-08L01	2 F	0.0	--	G	U
30N/07W-09A01	15	15.0	4.5	G	C
30N/07W-09A02	--	--	--		C
30N/07W-09B01	10	1.0	1.5	G	C
30N/07W-09C01	--	--	--	G	C
30N/07W-09F01	10	1.0	1.5	G	U
30N/07W-09H01	--	--	--		C
30N/07W-09K01	5	1.3	1.5	G	C
30N/07W-09P01	15	--	--	G	U
30N/07W-10B01	200	100.0	4.0	G	U
30N/07W-10D01	15	15.0	2.0	G	U
30N/07W-10R01	--	--	--		C
30N/07W-11B01	--	--	--		C
30N/07W-11B02	--	--	--		C
30N/07W-11J01	--	--	--		C
30N/07W-11P01	--	--	--		C

CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
30N/08W-13M01	HALLBURG, WAYNE	03/25/1978	--	96	96	89.00		86	X
30N/08W-17N01	MC KEE, DAVID	10/10/1978	H	250	250	202.00		50	P
30N/08W-21E01	ELVERUM, DARREL	07/11/1978	H	34	34	12.00		--	O
30N/08W-24N01	LEBUIS, WALTER	07/10/1979	H	94	94	81.00		72	X
30N/09W-10P01	CRESCENT WTR AS	02/09/1976	H	20	20	5.00		--	--
30N/09W-11J01S	COUNTY RD DEPT	--	U	--	--	--		--	--
30N/09W-13A01	NATIONAL PARK, EAST BEACH	10/30/1979	P	25	25	8.20		20	X
30N/09W-15B01	NATL PARK, LOG CABIN	10/31/1979	U	200	200		D	--	--
30N/09W-15G01	NATL PARK, LOG CABIN	11/01/1979	U	125	125		D	--	--
30N/09W-26H01	OLYMPIC NATL PK, BARNES PT	01/04/1967	U	63	45	7.80		38	P
30N/09W-30D01	NATIONAL PARK, FAIRHOLM	10/22/1979	P	69	69	45.70		--	O
30N/09W-30F01	OLYMPIC NATL PK, FAIRHOLM	01/10/1967	U	63	44	11.80		37	P
30N/09W-31C01	NATIONAL PARK, LA POEL	11/03/1979	U	125	125		D	--	--
30N/09W-35H01	OLYMPIC NATL PK, BARNES PT	01/20/1978	R	--	--	--		--	--
30N/10W-25G01S	OLYMPIC NP	--	C	--	--	--		--	--
30N/11W-28G01	SNIDER WORK CNT, OLYMPIC PK	10/09/1978	R	100	99	6.25		94	S
30N/11W-28H01	KLAHOWYA CAMPGR	04/11/1958	R	43	42	25.00		29	P
30N/11W-28H02	U S FOREST SER	12/17/1963	H	150	150		F	135	P
30N/11W-28K01	U S FOREST SERV	12/ /1963	H	--	150		F	--	--
30N/12W-25D01	WHITE, CALVIN H	05/03/1976	H	20	20	8.00		--	Z
30N/12W-26D01	DUBEN, JAMES	07/13/1977	H	88	12		D	--	--
30N/12W-27E01	SACKETT, VERLIN	05/20/1976	U	310	310		D	--	--
30N/12W-27M01	DAVIS	11/25/1974	H	200	200	140.00		--	O
30N/12W-27N01	WASHINGTON, STATE OF	08/04/1977	H	26	26	8.00		--	O
30N/12W-28D01	STARK, MALCOLM JR	05/09/1978	H	34	34	20.50		23	P
30N/12W-28H01	BATES	09/26/1974	H	160	33	20.00		--	S
30N/12W-28R01	WASHINGTON DNR	01/01/1901	H	111	111	38.00		59	P
30N/12W-30L01	DECKER, GORDON	07/27/1977	H	78	78	43.00		73	S
30N/12W-30M01	DECKER, GORDON	07/20/1977	U	118	118		D	--	--
30N/12W-35D01	NORDMAN	1901	H	93	93	82.00		83	P
30N/13W-34K01	KONOPASKI	06/26/1965	U	121	115	97.00		106	P
30N/13W-34K02	OLD CHIEF, MOBILE PRK	10/07/1971	P,I	121	121	93.00		--	P
30N/13W-34P01	PRAIRIE CEDAR	05/21/1976	H	120	110	81.50		86	P
30N/13W-35E01	BENTLEY	08/27/1951	P	112	112	102.00		--	O
30N/13W-36A01	MUNSON, GREG S	09/22/1978	H	110	110	85.00		--	O
30N/16W-26D01	MILLER	07/18/1974	H	--	230	35.00		--	--
31N/04W-27R01	BODE, F D	10/ /1967	--	53	53	33.00		--	--
31N/04W-34E01	SWANTON, BOB	03/08/1977	H	108	108	89.00		--	O
31N/07W-26N01	PHILLIPS, BEN	--	H	--	8	--		--	--
31N/07W-26N02	HUNT	09/13/1974	H	43	43	7.00		--	O

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
30N/08W-13H01	9	9.0	1.5	G	U
30N/08W-17N01	10	--	--	G	U
30N/08W-21B01	20	10.0	4.0	G	U
30N/08W-24N01	10	10.0	1.5	G	U
30N/09W-10P01	--	--	--		U
30N/09W-11J01S	0.5 F	--	--		C
30N/09W-13A01	89	305.1	1.0	G	U
30N/09W-15H01	0.00	0.0	--	G	U
30N/09W-15G01	0.00	0.0	--	G	U
30N/09W-26R01	60	11.1	3.0	G	C
30N/09W-30D01	75	75.0	2.5	G	U
30N/09W-30F01	38	4.0	3.5		C
30N/09W-31C01	0.00	0.0	--	G	U
30N/09W-35H01	--	--	--		U
30N/10W-25G01S	--	--	--		C
30N/11W-28G01	30	2.9	10.0	G	U
30N/11W-28H01	22	170.0	1.0	G	U
30N/11W-28H02	5 F	--	--	G	U
30N/11W-28K01	--	--	--		U
30N/12W-25D01	--	--	--		C
30N/12W-26D01	--	--	--	G	C
30N/12W-27E01	0.00	0.0	--	G	C
30N/12W-27M01	60	--	--	G	C
30N/12W-27N01	30	3.0	2.0	G	C
30N/12W-28D01	8	0.6	2.5	G	U
30N/12W-28H01	10	2.0	--	G	C
30N/12W-28R01	11	5.5	1.0	G	C
30N/12W-30L01	45	45.0	2.5	G	C
30N/12W-30M01	0.00	0.0	--	G	C
30N/12W-35D01	3	0.3	--	G	C
30N/13W-34K01	40	40.0	2.0	G	C
30N/13W-34K02	30	30.0	2.0	G	C
30N/13W-34P01	50	50.0	3.5	G	C
30N/13W-35E01	10	3.2	6.0	G	U
30N/13W-36A01	60	--	1.5	G	C
30N/16W-26D01	3	--	--		U
31N/04W-27R01	40	--	--	G	C
31N/04W-34E01	15	2.1	--	G	U
31N/07W-26N01	--	--	--		C
31N/07W-26N02	60	60.0	3.0	G	U

CLALLAM CO., OUTSIDE WA-212 AREA

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	DEPTH DRILLED (FEET)	DEPTH OF WELL (FEET)	WATER LEVEL (FEET)		DEPTH TO FIRST OPENING (FEET)	FINISH
31N/07W-26P01	PHILLIPS	1941	U	--	55	3.37		--	--
31N/07W-27J01	HOPIE, MARTIN	--	H	--	14	8.00		--	--
31N/07W-27J03	HEPFER, LAVERNE	05/ /1969	--	--	41	--		--	--
31N/07W-32N01	JAMES, LARRY L	07/29/1977	H	48	48	20.00		19	X
31N/07W-33G01	MAGNESON	06/14/1974	H	17	17	9.00		14	T
31N/07W-33A01	HOOPER, ARCHIE	--	M	--	13	11.00		--	O
31N/07W-33A02	SKOTHEIM, S	07/16/1975	H	30	21	10.00		--	O
31N/07W-33F01	BOICE, ROBERT	1963	H	--	15	11.00		--	O
31N/07W-34G02	RAMBO, CHRIS	05/01/1978	H	80	80	12.60		28	P
31N/07W-34A02	--	--	--	--	--		F	--	--
31N/07W-34B01	JOHNSON	01/01/1901	H	--	9	7.07		--	--
31N/07W-34B03	--	--	--	--	33		F	--	--
31N/07W-34D01	SHOTWELL, JOHN D	04/13/1977	H	30	30	9.28		--	O
31N/07W-34D02	RAYMOND	06/14/1974	H	17	17	9.00		14	T
31N/07W-34E01	STROMSKI, FRED	02/22/1978	H	160	160	117.00		--	O
31N/07W-34F01	MILETICH, JOHN	09/26/1977	H	122	119	53.00		62	P
31N/07W-34H01	CRAIG	01/01/1901	H,S	--	12	10.44		--	--
31N/07W-34N01	WINTERS, ROBERT	04/01/1977	H	207	205	119.00		200	S
31N/07W-34N02	KEYS, JOHNNY	09/16/1976	H	190	190	114.00		162	P
31N/07W-34R01	HALBERG	--	S,H	--	20	8.00		--	--
31N/07W-35C01	AT AND T	04/04/1965	N,H	124	124	112.00		119	S
31N/07W-35C04	AT AND T	03/29/1965	N	--	134	11.00		--	S
31N/07W-35D01	WADDELL	1952	H,S	--	15	12.00		--	--
31N/07W-35E01	--	--	--	--	33		F	--	--
31N/07W-35K01	PETERSON	1947	H	--	260	145.00		--	--
31N/07W-35N01	--	--	--	--	53		F	--	--
31N/07W-35Q01	PORT ANGELES	1929	U	--	135		D	--	--
31N/08W-28R01	PRICE, WAYNE	03/29/1979	H	97	94	34.00		89	S
31N/08W-36A02	WIEDERSHERG, VICTOR	06/05/1975	H	92	92	43.00		33	X
31N/08W-36A01	WIEDERSHERG, VICTOR	06/05/1975	U	60	0		D	--	--
31N/08W-36B01	VANDERHOOF, LAUREN R	01/13/1976	H	69	69	33.00		--	O
31N/09W-28A01	FREELUND, ART	01/17/1976	U	40	0		D	--	--
31N/09W-31G01S	TWIN MAINT SITE	--	H	--	--	--		--	--
31N/09W-35M01	HARPER, IRWIN&MARY	1892	H	--	12	9.00		--	W
31N/11W-04D01	MERRILL-RING	1960	U	--	8520	--		--	--
31N/11W-09H01	PYSHTTREE FARM	1952	U	85	30	--		--	--
31N/11W-10E01	FERNANDEZ, I	--	U	--	11	5.11		--	--
32N/12W-20M01	STERNBECK	08/26/1975	U	40	0		D	--	--
32N/12W-21M01	CLALLAM	11/ /1958	--	72	--	--		--	--
32N/12W-26N01	HANSEN, DAN	09/10/1977	H	25	22	7.00		12	X

LOCAL NUMBER	DISCHARGE (GALLONS PER MINUTE)	SPECIFIC CAPACITY (GPM/FT)	PUMPING PERIOD (HOURS)	OTHER DATA AVAILABLE LG	CK
31N/07W-26P01	--	--	--		C
31N/07W-27J01	--	--	--		C
31N/07W-27J03	--	--	--		U
31N/07W-32N01	15	1.5	1.5	G	C
31N/07W-33-3	28	--	--	G	U
31N/07W-33A01	--	--	--		C
31N/07W-33A02	6	0.9	--	G	C
31N/07W-33F01	--	--	--	G	C
31N/07W-34-1	200	67.0	4.0	G	U
31N/07W-34A02	252 F	--	--		U
31N/07W-34B01	--	--	--		C
31N/07W-34B03	6 F	--	--		U
31N/07W-34D01	30	--	1.5	G	C
31N/07W-34D02	60	--	1.5	G	C
31N/07W-34E01	10	0.3	2.0	G	U
31N/07W-34F01	--	--	--		U
31N/07W-34H01	--	--	--		C
31N/07W-34N01	4	0.0	3.5	G	U
31N/07W-34N02	5	0.1	--	G	U
31N/07W-34R01	--	--	--		C
31N/07W-35C01	31	27.0	4.0	G	U
31N/07W-35C04	15	--	--	G	U
31N/07W-35D01	--	--	--		C
31N/07W-35E01	5 F	--	--		U
31N/07W-35K01	--	--	--		C
31N/07W-35N01	6 F	--	--		U
31N/07W-35Q01	--	--	--		C
31N/08W-28B01	3	0.1	2.5	G	U
31N/08W-36-1	0.08	--	--	G	U
31N/08W-36-2	0.00	0.0	--	G	U
31N/08W-36-3	40	6.7	--	G	U
31N/09W-28-1	0.00	0.0	--	G	U
31N/09W-31G01S	--	--	--		U
31N/09W-35M01	--	--	--		U
31N/11W-04D01	--	--	--		U
31N/11W-09H01	--	--	--	G	C
31N/11W-10E01	--	--	--		C
32N/12W-20-1	--	--	--	G	U
32N/12W-21M01	200	5.6	0.5	G	U
32N/12W-28N01	10	2.0	1.5	G	C

APPENDIX III-1

Characteristics of River Scours

by Douglas M. Johnson

Systems of flow-aligned elliptical, arcuate and spindle-shaped scour hollows are a common feature of many straight reaches of river channels devoid of meandering tendencies. At low water they form thatched or scattered puddles partly or fully infilled with sediment, and on some rivers at high water echo-sounder records have revealed that the scours are open and migrate downstream. Some scour elements are associated with comparable-in-size megaripples and sand waves and are spread fairly evenly along and across the channel. Other usually much larger scours may be crowded or scattered along a smooth bed or appear only above some streamwise or spanwise segments of the channel, with no relationship to the distribution of smaller bed forms. Many elliptical scours can reach a width of eight meters and up to 50 meters in length and are preserved in the geologic record as trough-type cross stratification. Coleman (1969) has described migrating troughs up to 100 meters wide and well over 2000 meters long from peak flows along the Brahmaputra River.

In addition to the scouring action due to the natural flow variations in a river, with increased civil development along the banks of the river there will be a tendency towards localized channelization due to level construction, etc. Man-made control of the channel width will cause flow velocities to increase during flood stages, thereby increasing the potential extent of scouring action near these locations.

A variety of mechanisms for scour action have been suggested. Among these perhaps the most realistic for high flow velocities is the varticity/ model. The model becomes effective as an erosional agent when flow velocities approach what is known as supercritical flow. Supercritical flow occurs when the hydrodynamic Froude numver exceeds 1.0, where the Froude number F is computed using the formula

$$F= \overline{V}/ \sqrt{g\overline{D}}$$

where $\overline{V}$ is the mean flow velocity, $\overline{D}$ is the mean channel depth, and g is the acceleration of gravity. When F is greater than 1.0 supercritical flow exists. Engineers concerned with canel design make a practice of avoiding supercritical flow because of its great erosive power, and, as pointed out by Koloseus (1971, p. 3-49), the higher stagnation pressures of supercritical flow give rise to uplift forces of such magnitude as to remove the lining of a canal. Hence as a stream reach approaches F=1 the scouring potential must increase substantially and thus under certain circumstances, the Froude number could be used as a qualatative gauge to estimate scouring potential.

Appendix IV-1

Submarine Slumping and the initiation of Turbidity Currents

by N. R. Morgenstern
Marine Geotechnique, A. F. Richards ed.
Univ. of Illinois Press, 1967

SUBMARINE SLUMPING AND THE INITIATION OF TURBIDITY CURRENTS

ABSTRACT

The conditions under which submarine slumping is known to have occurred are reviewed and the agencies causing them are discussed. Special attention is given to earthquake effects. It is pointed out that slumps can result in a wide variety of sedimentary structures and many of these structures are associated with liquefaction. The strength of sediments is considered, and the influence of underconsolidation due to high rates of sedimentation on the strength of marine sediments is treated in detail. The mechanics of slumping are analyzed from the point of view of both drained and undrained failure. It is thought that some slumps transform into high-density turbidity currents. The evidence for the existence of such currents is summarized and a theory presented to show that a slump can achieve sufficiently high velocities to transform into a turbidity current if the pore pressures induced at failure are high enough.

INTRODUCTION

Much of the progress in understanding the processes involved in subaerial landslides has been possible only through detailed analysis of particular cases. A minimum requirement for carrying out such an analysis is knowledge of the slope profile, the shape and location of the major slip surface, the water pressure conditions at the time of failure, the appropriate soil strength parameters, and the soil densities. With these data it is possible to perform faily reliable calculations to account for the movements of the soil mass. In the case of subaqueous landslides or slumps the necessary information is seldom available and few properly documented case records exist. It is therefore necessary to extrapolate from experience gained in the study of subaerial movements. It is also essential to study the fossil structures of slumps preserved in the geological record in order to establish the conditions under which slumping has occurred and to observe the influence of the movements on the structure of the sediments. Observations of stable submarine slopes and knowledge of the properties of the sediments composing them can be used to bound the occurrence of slumps. A review of some of the information that is available regarding submarine slumping suggests that there are two problems associated with the phenomenon that deserve particular attention. The first is whether it is possible for slumps to occur on gentle slopes, particularly on the open continental shelf and slope. The second problem is to account for the wide variety of sedimentary structures that have been attributed to slumping. These range from large sheets of strata that have been transported intact to turbidites (Dzulynski and Walton, 1965). Turbidite deposits are widespread (see Bouma, 1962) and their origin is still a matter of some debate. One mechanism that has been suggested is the transformation of a slump into a turbidity current and subsequent deposition of the turbidite.

Most sediments involved in slumps are likely to be normally consolidated.

However, in regions of high rates of sedimentation such as exist in some deltas, there will be a lag between the accumulation of the material and the consolidation associated with it. This gives rise to an excess pore pressure and the sediment is accordingly weaker. This underconsolidated material is evidently prone to slumping. Overconsolidated sediments also exist in a marine environment, the overconsolidation having been induced by removal of overburden by erosion of sediment during the development of submarine canyons and channels associated with sea fans. It will be seen that some very steep slopes that have been observed must be composed of material that is either overconsolidated or cemented. Nevertheless, the amount of exposure of overconsolidated material (excepting in submarine canyons) is probably small, and the influence of this aspect of sediment behavior will not be considered in any detail.

In the following, data regarding slope angles for both stable and unstable profiles are presented, and the agencies that can induce slumping are discussed. A further section reviews the various sedimentary structures that slumping can produce and shows that sediments after slumping can achieve a broad range of mobility from rigid block motion to turbulent flow. Shear strength properties of sediments are then discussed with special reference to the influence of metastability and underconsolidation. The mechanics of various modes of failure are introduced. Finally the acceleration of a soil mass moving down a slope is analyzed, and some conditions that must be satisfied for transformation into a turbidity current are suggested.

OCCURRENCE OF SLUMPING

Slumping has been observed or has been inferred to have occurred on a wide range of slope inclinations. One of the first papers to draw attention to the possibility of slumping on slopes of gentle gradient was by Heim (1908) who described the slip that flowed into Lake Zug, Switzerland, in 1887. The slope had an inclination of 2.5 degrees. Unfortunately, the reasons for the initiation of the movement are not clear. The observations of Archanguelsky (1930) are also often cited in this context. In studying a sequence of cores from the Black Sea, he observed that recent sediments were often absent from the slope leading from the upper part of the shore terrace to the deep basin of the sea. He did, however, find such sediments in a state of intense deformation and with duplicate succession on the steeper lower slopes and concluded that they had slumped from above on inclinations of 1 to 3 degrees. Slumping on inclinations of 1 degree has been suggested by Shepard (1955) to account for the delta-front valleys associated with the Mississippi River. The existence of underconsolidated material in this region suggests that this explanation is likely. Submarine slumping of Norian strata in New Zealand has been discussed by Grant-Mackie and Lowry (1964) who describe an exposure of 530 ft of highly disturbed sediment. This layer lies within a sequence of regular undisturbed Upper Triassic strata but displays slump balls, welded contacts, and other features associated with submarine slumps. By correlating sediments and fauna the authors infer that the slope at the time of movement may have been less than 1/2 degree. Movement occurred during a period of tilting of 8 degrees by the sea floor and the slope angle quoted must be considered to be a minimum.

It should be noted that the possibility of slumping on such gentle slopes has been questioned by Moore (1961) excepting areas of rapid accumulation. In particular, Moore doubts the existence of slumping on the deep sea floor and normal open continental shelf. Regarding the continental slope, he observes that the amount of slumping will vary with the type of sediment, its rate of accumulation and the topographic features in the regions in which it is being deposited. Detailed discussion of some of Moore's conclusions will be given in a further section. However, it is of interest here to introduce some aspects of submarine topography in order to distinguish between the various gradients associated with ocean bottom features. A detailed discussion of submarine topography may be found in Shepard (1963), Hill (1963), and Menard (1964).

Moving seaward from a continent to the ocean floor, it is in general possible to distinguish between the continental shelf, continental slope and continental rise. Though by no means uniform, the average slope of the continental shelf is only 0° 07' and is slightly steeper along the inner half. For the continental slope, Shepard (1963) quotes an average inclination of 4°17' for the first 6000 feet of descent. Menard (1964) states that continental slopes are about 1 to 10 km high in the Pacific and have gradients of 1 to 10 degrees. However, the continental slopes are cut by submarine canyons. These are important to the problem of slumping because of the possibility of sediment accumulating in their heads, and the channeling effect that they provide for the flow of the sediment. The slopes of submarine canyons are also usually greater than that of the continental shelf. The continental rise is generally a smooth feature connecting the continental slope to the abyssal plain. Heezen and Menard (1963) quote an average gradient for the continental rise of 300:1 with some slopes as low as 700:1 and others as steep as 50:1.* Gradients of abyssal plains range from 1000:1 to 10,000:1. Other features of interest are the sediment fans at the mouths of submarine canyons, which have their origin in slump and turbidity current deposits, and the abyssal hills which are small undulations in the floor of the abyssal regions. On the basis of slope alone, it is evident that the continental slope is much more favorable for slumping than any of the other main regions mentioned above. The heads of submarine canyons provide an extremely suitable environment for slumping because of their steeper inclination and their action as sediment traps.

The effects of submarine slumping have been observed in various geological strata in many locations. Among the many examples that could be cited are the observations of Jones (1937) on Silurian rocks in North Wales and the discussion by Beets (1946) on Miocene slumping in northern Italy. Renz, Lakeman, and van der Meulen (1955) provide evidence for extensive submarine sliding in western Venezuela during the Paleocene and Eocene. For example, the geological section near the town of Carora reveals slipped masses of strongly contorted Paleocene shales containing many Cretaceous blocks and slabs. The slump material alternates with very fine-grained Paleocene sandstones and shales which were apparently deposited in quiet deep water. The authors suggest that periods of quiet sedimentation were interrupted by tectonic events along the border of the trough. Submarine slumping on a smaller scale has been inferred by Van Straaten (1949) from the evidence of contorted glacial clays in Finland, which, he suggests, may have slid off a steep-sided esker. Finally Kuenen (1949) has described structures attributed to slumping in the Carboniferous rocks of southern Wales and he favors the view that these movements took place down slopes not exceeding a few degrees.

Subaqueous slumps on slopes inclined at steeper angles than those mentioned in an earlier paragraph have been discussed by Terzaghi (1956) and Koppejan, van Wamelen, and Weinberg (1948). These include the slope failure in clean sands and gravel in Howe Sound, British Columbia, which probably had an inclination greater than 28 degrees, and the slides composed of fine sand that occur along the coast of Zeeland. Original angles of 15 degrees are known to exist in the latter case.

Dill (1964a, 1964b, 1966) has observed in considerable detail the movement of sediment in Scripps and La Jolla submarine canyons. Slumping in fine micaceous sand occurred on inclinations of approximately 30 degrees. Sand falls over steeper inclinations and gravity creep were also important processes aiding the transport of the material down the slope.

There are many mechanisms that can induce slumping. The most common one is probably over-steepening of the slope. This may occur due to deposition or possibly crustal tilting associated with local tectonic movement. Erosion due to water currents or turbidity currents may cause local over-steepening leading to progressive failure. Slumping is particularly common at the head of submarine canyons and in the vicinity of mouths of large rivers. These are both environments of rapid deposition. Heezen (1956) has observed that submarine cables near the mouth of the Magdalena River break most frequently in August and in the period of late November to early December. The breaks are probably due to turbidity currents initiated by submarine slumps. Progressive slumping or liquefaction are alternative mechanisms. These periods of frequent slumping correspond to the times when the river has just deposited its greatest sediment load. Dill (1964a) has found that the generation of gas associated with the decomposition of plant material that accumulates in a canyon head can lead to significant creep movements. Wave and storm action is unlikely to have any direct influence

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*In accord with soil mechanics practice a gradient quoted in this way is the ratio of a horizontal to a vertical distance.

on the stability of deeply submerged slopes. However, slides in shallow water may be triggered by erosion or rapid drawdown, nd the displaced sediment acting as a sudden load could induce failure on a slope in deeper water. Shepard (1951) has reported the results of bathymetric traverses repeated for several years at the head of the submarine canyon at La Jolla, California. There was no correlation between storms and the observed mass movements which occurred on slopes of 5 to 8 degrees. An example of a slump which occurred in calm weather at the head of the Redondo Canyon has been given by Shepard and Emery (1941).

Loading due to severe earthquakes is widely accepted as an important agency causing slumps. Since some of these slumps may have transformed into turbidity currents and have broken submarine cables on their descent, the source areas have been of particular interest and studies have been made of the topography. From these bathymetric surveys it is possible to approximate the slope inclinations prior to failure (Heezen and Ewing, 1952; Heezen and Ewing, 1955; Houtz, 1962; Ryan and Heezen, 1965). Gutenberg (1939) provides evidence for a submarine slide, caused by the Chilean earthquake of November 11, 1922, having occurred on a slope of about 6 degrees at a location 100 miles from the epicenter. A case of submarine slumping due to an earthquake has also been presented by Ambraseys (1960). The Alaska earthquake of March 27, 1964, caused many submarine slumps. The largest reported to date occurred at Valdez and contained an estimated volume of 75,000,000 cu m (Coulter and Migliaccio, 1966). An inclination of 6 degrees was typical of large areas of the slump, which was composed mainly of loose to medium-dense gravelly sand containing thin lenses of silt. It is of considerable interest to note that no slump toe was discovered by the post-earthquake survey, and it therefore appears that a turbidity current was formed and the sediment moved out a considerable distance from shore. There is also a history in the Valdez area of numerous cable breaks occurring during or immediately after earthquakes.

Slope inclinations in the cases mentioned above are presented in Table 1, and where the submarine slope failure lay within the epicentral region, a comment is made accordingly. The magnitude and focal depths of the shocks are also given.

The largest recorded slump occurred in Sagami Wan, Japan, and was caused by the Kwanto earthquake of 1923. The average deepening over the area of the main slump was 100 m, and in all 7 x 10^{10} cu m of sediment were transported from the bay. Menard (1964) has compiled the approximate volumes of some major submarine slumps and these data are reproduced in Table 2, together with the Valdez case.

Stable slopes of various inclinations have also been observed. Kuenen (1950) reports that irrefutable evidence of slumping was not found in the deep basins of the Moluccas even though the slopes are as steep as 10 degrees in places and it is an area of high seismicity. Sea muds in thicknesses of half a meter or more have been found on slopes of at least 15 degrees. Moore (1960) has also observed recent sediments of at least one meter thickness on slopes up to 18 degrees. Buffington (1961) has found both Pleistocene sediments standing vertically and medium sand to be stable at 35 degrees in shallow water environments. During bathyscaph descents to water depths of about 3000 ft in the La Jolla fan valley, nearly horizontal beds of stiff cohesive clays alternating with cohesionless silts were found exposed in the wall of the channel, which sloped at 40 to 45 degrees (Moore, 1965). Lesser slopes in silty clay were also found. It is suggested that these steep slopes are the result of lateral erosion by turbidity currents. Slide action from the wall of the channel is also a contributing factor and explains the existence of down-slope grooves along the wall. There is no doubt that these sediments are overconsolidated. However, the ease with which the silts are disturbed suggests that diagenetic bonding may not in this case be a contributing factor to the strength of the sediments. The studies made by Emery and Terry (1956) of a submarine slope off southern California are also of interest here. Their echo-sounder profiles revealed that the shelf had an inclination of 1 degree, and the gradients of the upper portion of the slope were generally between 9 and 18 degrees. The lower slope was more regular and had an average inclination of 12 degrees. This average value is the same as that for the gullies found incising the upper slope. These gullies may be due to slumping. The slope is underlain by thick sediments, and coring with penetrations of 10 to 18 ft recovered samples of green mud. The

TABLE 1.

SOME SLUMPS CAUSED BY EARTHQUAKES

Location and Date	Slope degrees	Magnitude M	Focal Depth km	Within Epicentral Region	Reference
Grand Banks, 1929	3.5	7.2	Shallow	Yes	Heezen and Ewing (1952)
Orleansville, 1954	4-20	6.7	7	No	Heezen and Ewing (1955)
Strait of Messina, 1908	4	7.5	8	Yes	Ryan and Heezen (1965)
Suva, 1953	3	6.75	60	Yes	Houtz (1962)
Chile, 1922	6	8.3	Shallow	No	Gutenberg (1939)
Valdez, 1964	6	8.5	Shallow	Yes	Coulter and Migliaccio (1966)
Aegean Archipelago, July 9, 1956	10	7.5	15	No	Ambraseys (1960) and Admiralty Chart No. 1866 (1951), Royal Hellenic Navy

TABLE 2.

VOLUMES OF SUBMARINE SLUMPS

Location	Volume m^3
Magdalena River Delta	3×10^8
Mississippi River Delta	4×10^7
Suva, Fiji	1.5×10^8
Valdez, Alaska	7.5×10^7
Folla Fjord	3×10^5
Orkdals Fjord	10^7
Sagami Wan	7×10^{10}

grain size of the specimens seaward of the self break decreases with depth in an orderly way which suggests continuous deposition. The authors provide some cross sections with soil mechanics classification data. Of considerable importance are the quantitative data that a marine sediment 5 ft below the mud-line having a liquid limit of 55 percent, a plastic limit of 30 percent, and a natural moisture content of 70 percent is presently stable on a slope of approximately 15 degrees in an area of considerable seismic activity.

SEDIMENTARY STRUCTURES ASSOCIATED WITH SLUMPING

It is beyond the scope of this study to discuss in detail the many sedimentary structures whose origin has been associated with submarine slumps and the mass movements that ensue from them. However, it is of interest to review briefly the wide variety of slump structures that have been observed, because of the information this provides for assessing the problem of the mobility of sediments after movement has begun. More comprehensive studies have been provided by Bouma (1962), Dott (1963), and Dzulynski and Walton (1965).

It is possible to distinguish four major divisions of increasing mobility of moving sediment. This is not to imply that any slump must pass through each division, but it is simply a classification to illustrate the decreasing disorder of initial sedimentary structure. The first stage is a coherent slump where little mixing of sediment has occurred and the beds have retained their identity to a large degree. Features associated with this type of slump are pull-apart structures with intrusion of sandstone dikes as described by Kuenen (1953) and intraformational folding as described by Fairbridge (1946). The distinguishing feature of this division is that either the beds have not moved very far or the composition of the sediment above the slip surface gave it sufficient shearing resistance to maintain coherence even though it was intensely deformed. The second stage, which Dzulynski (1963) has called an incoherent slump, occurs when there has been extensive mixing of indurated sediment in a mass of sand, silt, or clay. Examples for this division are the slump structures mapped in Venezuela (Renz, Lakeman, and van der Meulen, 1955) and the features in flysch described by Dzulynski and Slaczka (1958) where the section contains many slump balls. The origin of pebbly mudstones (Crowell, 1957) is also probably due to incoherent slumping. The third division in increasing mobility results in fluxoturbidites. Here the mixing of the sediment and its velocity are not sufficient to develop the features characteristic of turbidites, which are the structures resulting from the final division, that is, turbidity currents. Graded bedding is an important criterion for distinguishing turbidites. It is possible that some turbidite structures can be explained by the pulsating bottom currents observed by Dill (1966).

Liquefaction plays an important role in causing many minor features observed in slumps, as well as decreasing the overall shearing resistance of the sediment and hence increasing its mobility. Liquefaction occurs most commonly in saturated loose sands and silts which, when loaded, collapse and transfer the load to the pore water. Pore pressure gradients can be set up which eliminate the shearing resistance of the sediment, and if the seepage velocity due to the hydraulic gradient is high enough, solid particles can be carried with the flow. Liquefaction is the cause of the sandstone dikes mentioned in the previous paragraph and the extensive sand volcanoes described by Gill and Kuenen (1957). In the latter case, the field evidence has prompted the authors to note that the extrusion of the sediment required a considerable period of time, starting in some cases before movement had ceased and in others after planing off of the slumped masses.

Terzaghi (1956) argued against the existence of slump-initiated turbidity currents on the basis of the short duration of liquefaction. He felt that the pore pressures would dissipate quickly and that the slump material would come to rest within a relatively short distance from its original location. However, after the Alaska Good Friday earthquake, sandspouting occurred for a duration of 5 to 10 minutes and it is likely that excess pore pressures existed within the sediment for longer than that (Reimnitz and Marshall, 1965). It is also common experience that sediments that have been liquefied after an earthquake remain extremely soft for some time. A more detailed discussion of the influence of pore-pressure dissipation on velocity of slump movements will be given in a later section.

Terzaghi and Peck (1948) state that a saturated sand must have a relative density less than 0.4 or 0.5 before it can start to flow. They also observe that the most unstable sediments have an effective size, D_{10}, less than 0.1 mm, and a uniformity coefficient,

$$\frac{D_{60}}{D_{10}},$$

less than 5. It is of interest to analyze the gradings of some slump and turbidity current deposits to see if they meet this criterion. This only provides a necessary condition that these materials were prone to liquefaction. It is possible that part of the initial grading was deposited elsewhere and the data being compared are not representative. The effective sizes and uniformity coefficients are given in Table 3 and for comparative purposes results from sediments liquefied after the Niigata earthquake of 1964 (Kishida, 1965) and from a fine sand which almost liquefied during laboratory shear tests (Bjerrum, Kringstad, and Kummeneje, 1961) are included.

Each case quoted in Table 3 including the complete graded sea bed from the Hudson sea fan, satisfies the criterion put forward by Terzaghi and Peck. Although this alone by no means establishes liquefaction as a mechanism, at least the grading of these deposits suggests that the source sediments may be prone to it.

STRENGTH OF SEDIMENTS

In terms of effective stress, the shear resistance along a plane of failure in a saturated soil is given by

$$\tau_f = c' + (\sigma - u)\tan \phi' \qquad (1)$$

where τ_f denotes the shear stress on

c' denotes the apparent cohesion

ϕ' denotes the angle of shearing resistance

$\left.\right\}$ in terms of effective stress

σ denotes the total stress normal to the failure plane

and u denotes the pore pressure.

TABLE 3.

EFFECTIVE SIZES AND UNIFORMITY COEFFICIENTS

Sediment	Effective Size D_{10} (mm)	Uniformity Coefficient $\frac{D_{60}}{D_{10}}$	Reference
Core A180-1, Top	.016	3.3	Heezen (1963)
Core A180-2, 64 cm	.016	3.8	"
Hudson Sea Fan 0-4 cm	.022	4.4	Kuenen (1964)
" 4-18 cm	.035	3.7	"
" 18-24 cm	.053	3.0	"
" 24-48 cm	.053	3.4	"
" 48-72 cm	.060	3.3	"
San Pedro Basin (lower portion of graded layer)	.062	2.6	Gorsline and Emery (1959)
Niigata	.09	2.8	Kishida (1965)
Fine Sand	.07	2.5	Bjerrum, Kringstad, and Kummeneje (1961)

For normally consolidated clays and granular soils, the apparent cohesion is zero and equation (1) becomes

$$\tau_f = (\sigma - u)\tan \phi'$$

It is possible to distinguish between structurally stable and structurally metastable soils. Metastable soils show a very large rate of volume decrease during drained shear and may even display an initial yield point at a stress less than their maximum strength. Some stress-strain relations for stable and metastable soils are shown diagrammatically in Figure 1.

Quick clays and very loose sands are examples of structurally metastable soils which may be defined as soils that, when brought to failure under drained conditions, deform further under undrained conditions.

For stable clays ϕ' varies between 20 and 35 degrees. A correlation between ϕ' and plasticity index has been given by Bjerrum and Simons (1961). Stable loose silts and sands typically have values of ϕ' between 28 and 34 degrees.

Large deformations in soils containing a clay content greater than approximately 35 per cent induce preferred orientation of the clay particles in the shear zone and cause a reduction of ϕ' (Skempton, 1964). Angles of shearing resistance as low as 10 degrees are not uncommon in clays that have been subject to large strains. Few data giving strength parameters in terms of effective stress are available for present day marine sediments. The results of Moore (1961, 1962) are ambiguous because the conditions of drainage in his tests are not adequately defined. This is not the case for the strength data for sediments from the experimental Mohole (Moore, 1964). The average of six results on the calcareous silty clay from one borehole gives a ϕ' of 28 degrees and a c' of about 8 psi. There is as yet no evidence to suggest that the effective stress strength paramenters of stable deep-sea deposits will be any lower than the range commonly encountered on land. Indeed, the presence of diagenetic bonding agents in some marine enviroments can make the sediment stronger than the usual range.

When a fully saturated soil is sheared under undrained conditions and the results are interpreted in terms of total stresses, the material behaves as though it is purely cohesive. This holds for saturated sands as well as for clays (Bishop and Eldin, 1950). For a normally consolidated clay or a sand in the ground, the undrained shear strength, c_u, is related to the stresses under which the soil has been consolidated, the effective angle of shearing resistance, and the pore pressures at failure by:

$$c_u = \frac{p \sin \phi' \left[K + (1 - K)A_f\right]}{1 + (2A_f - 1)\sin \phi'} \qquad (3)$$

where p denotes the vertical effective pressure,
K denotes the ratio between the horizontal and vertical effective pressures,
and A_f is the appropriate pore pressure parameter at failure (Skempton, 1954).

For stress conditions associated with no lateral yielding, as might be assumed to exist during deposition either horizontally or on a gentle inclination, K may be expressed empirically by (Bishop, 1958):

$$K = 1 - \sin \phi' \qquad (4)$$

Equation (3) then becomes

$$\frac{c_u}{p} = \frac{\sin \phi' \left[1 - \sin \phi' + A_f \sin \phi'\right]}{1 + (2A_f - 1)\sin \phi'} \qquad (5)$$

For any particular fully consolidated soil, the ratio

$$\frac{c_u}{p}$$

is a constant and indicates that the undrained strength increases with depth. It is know that this ratio correlates closely with the plasticity index of many marine clays (Skempton, 1957), and the correlation is given in Figure 2. Owing to sample disturbance and improvements in testing technique since the data were gathered, this relation may be considered to be a lower boundary to the true relation. However, there is no reason to expect that more refined data will produce major changes in the relation.

Moore (1964) has shown that the strength data from the Mohole sediments lie appreciably above the correlation. As he has observed, there are at least two factors which may account for this.

His experiments were carried out under isotropic consolidation and this will in general result in a higher value of the

$$\frac{c_u}{p}$$

ratio (Skempton and Bishop, 1954). The actual difference is difficult to estimate because the pore pressure parameter, A_f, depends upon the history of consolidation. It is likely that the most dominant factor accounting for the deviation from the correlation is carbonate bonding. Assuming the relation of Figure 2 to hold, a predicted value of

$$\frac{c_u}{p}$$

can be obtained from the plasticity index data given by Moore. Figure 3 shows that the ratio of the predicted to measured values decreases with increasing carbonate content. Higher values of

$$\frac{c_u}{p}$$

than might be expected have also been found in short cores of shallow water sediments from Lower Chesapeake Bay (Harrison, Lynch, and Altschaeffl, 1964) and in short cores of deep-sea sediments (Richards, 1962). Fisk and McClelland (1959), however, report that fully consolidated sediments from the Mississippi delta agree with the correlation. Although it is premature to generalize with regard to the undrained strength of recent marine sediments, it is unlikely that a fully consolidated stable material will have an undrained strength below the relation shown in Figure 2.

Terzaghi (1956) drew attention to the influence of high rates of sedimentation on the development of strength in a consolidating sediment. Excess pore pressures can develop in a stratum that is undergoing an increase in height due to deposition. These excess pore pressures will depend upon the rate of sedimentation, the height of the stratum, and the coefficient of consolidation of the material. The excess pore pressure at any level in the stratum will reduce the effective stress under which the material has been consolidated and, as is evident from equation (3), the undrained strength at that level will be reduced accordingly.

Consider the stratum shown in Figure 4. When fully consolidated, the maximum effective overburden pressures, p_m, at some depth, z, is given by

$$p_m = \gamma' z \qquad (6)$$

where γ' is the submerged density of the soil, assumed constant with depth. The increase of undrained strength with depth for a fully consolidated material may be denoted by

$$\frac{c_u}{p_m} = N \qquad (7)$$

If during consolidation excess pore pressures exist as shown diagrammatically in Figure 4, the effective overburden pressure, p, at any instant is

$$p = \gamma' z - u = \gamma' z(1 - \frac{u}{\gamma' z}) \qquad (8)$$

where u is the excess pore pressure at that instant. At any instant the excess pore pressure isochrome may be approximated by a linear variation with depth,

$$u = nz \qquad (9)$$

and equation (8) becomes

$$p = \gamma' z(1 - \frac{n}{\gamma'}) \qquad (10)$$

However,

$$1 - \frac{n}{\gamma'} = \bar{U} \qquad (11)$$

where $\bar{U}$ is the average degree of consolidation. Therefore the undrained strength available in an underconsolidated clay should be proportional to the average degree of consolidation, that is,

$$(\frac{c_u}{p_m})_{\bar{U}} = N\bar{U} \qquad (12)$$

Estimates of the degree of consolidation in a layer subject to sedimentation at a constant rate can be obtained from the solution presented by Gibson (1958) for the problem of the progress of consolidation in a clay layer which increases in thickness with time. Considering a layer growing on an impermeable base at a constant rate, it is of interest to calculate the degree of consolidation for a range of rates of sedimentation and coefficients of consolidation when the layer has grown to a height that might be typical of a significant submarine slump. A height of 15 m has been assumed, and coefficients of consolidation from 1 x 10^{-5} cm^2/sec for a clay to 1 x 10^{-2} cm^2/sec for a coarse silt have been adopted. The degrees of consolidation of the layer for a range of rates of deposition from abyssal conditions to extreme deltaic conditions have been computed and are given in Figure 5, plotted against the rate of sedimentation for the range of consolidation parameters chosen. The results reveal that for a layer of this thickness, underconsolidation is only significant for silty clays and clays deposited at deltaic rates. Since the heads of some submarine canyons act as sediment traps, the rate of accumulation may be sufficiently high to suggest that underconsolidation is a factor associated with slumping in them. It is also possible to speculate that slumping occurred more frequently in the Pleistocene, during the recession of the glaciers, because of higher rates of sedimentation. This, together with turbidity current erosion and a lowered sea level during the Pleistocene, may be the dominant mechanism accounting for the origin of many submarine canyons (Kuenen, 1950; Shepard, 1963).

Subject to some assumptions, the relation between underconsolidation and strength presented in equation (12) is corroborated by the observations of Fisk and McClelland (1959) on the deltaic deposits on the continental shelf off Louisiana. The authors provide data for three locations of similar composition, but of different degrees of consolidation and hence of different strengths. The relevant information is assembled in Table 4.

Evidence of full consolidation for the Eugene Island stratum is provided by the fit of the

$$\frac{c_u}{p}$$

and plasticity index values with the correlation in Figure 2. For purposes of comparison the three cases are plotted on Figure 2. Assuming that the 96 ft of the Eugene Island sediment were deposited in 10,000 years gives a rate of sedimentation of 0.29 cm per year. Theoretically, infinite time is required for full consolidation. However, if it is assumed that consolidation is essentially complete when the degree of consolidation is 95 percent, it is possible to compute the coefficient of consolidation for the material from the theoretical relation obtained by Gibson (1958). A value of 2.7 x 10^{-4} cm^2 per sec is found, which is quite reasonable, considering the Atterberg limits of the material. Now, using this value, it is possible to compute the average degree of consolidation for the two other locations if the rates of sedimentation can be fixed. For the Grand Isle location, a rate of sedimentation of 3.5 cm per year has been used, based upon the accumulation of 170 ft in 1500 years. In the case of the South Pass location the base of the layer is indistinct, but bounds for its thickness have been given. Calculations have been carried out for both bounds with a time for deposition of 450 years. The computed degrees of consolidation are given in Table 5, together with the ratio of the observed

$$\frac{c_u}{p}$$

value to the maximum. The relation between degree of consolidation and available strength for this sediment is plotted in Figure 6, and it is seen that the linear relationship of equation (12) fits the data extremely well.

Metastable sands and silts which are prone to liquefaction are difficult to obtain in an undisturbed state. They are also difficult to reproduce in the laboratory, and therefore reliable data concerning their behavior are accordingly rare. Bjerrum, Kringstad, and Kummeneje (1961), however, have succeeded in carrying out both drained and undrained triaxial compression tests on a very loose fine sand. Their observations of the low strength mobilized are of particular interest. Under fully drained conditions, values of ϕ' as low as 19 degrees were found. Under undrained conditions, the very loose sand showed values of ϕ' as low as 11 degrees and a ratio of undrained strength to effective consolidation pressure as low as 0.11. The pore pressures set up during undrained failure were very high. Values of A of 2.7 were observed at failure and the results of one typical test showed that A continued to increase after failure to approximately 9. It is evident that both the drained and undrained strengths of very loose sands are much lower than those of corresponding stable materials. The undrained strengths are comparable to the lowest values observed in normally consolidated marine clays. Further-

TABLE 4.

DELTAIC DEPOSITS OFF LOUISIANA (FISK AND McCLELLAND, 1959)

Location	State	Liquid Limit %	Plastic Limit %	Plasticity Index % (average)	$\frac{c_u}{p}$	Depth ft	Age Years
Eugene Island Block 188	Fully consolidated	80-90	25-30	53	0.31	96	not less than 10,000
Grand Isle Block 23	Underconsolidated	80-90	25-30	53	0.15	170	not more than 1500
South Pass Block 20	Very underconsolidated	60-100	20-30	55	0.028 (average)	255-320	450

TABLE 5.

UNDERCONSOLIDATION OF DELTAIC DEPOSITS OFF LOUISIANA

Location	Rate of Sedimentation cm/year	Average Degree of Consolidation	$\frac{c_u}{p}$ (observed) / $\frac{c_u}{p}$ (maximum)
Eugene Island Block 188	0.29	1.00	1.00
Grand Isle Block 23	3.5	0.48	0.48
South Pass Block 20	17 21.6	.11 0.08	0.09

more, the exceedingly high pore pressures set up during undrained failure are probably an important factor aiding the post-failure mobility of such metastable materials.

Seed and Lee (1964) have studied the influence on the strength of a fine silty sand of pulsating loads such as might occur during an earthquake, and they demonstrated that in a given material consolidated to a particular void ratio, the deviator stress required to cause failure decreases with the number of pulses to failure. This also depends upon the principal stress ratio during consolidation and the manner in which the pulsating load test is carried out. Seed and Lee have found

$$\frac{c_u}{p}$$

values less than 0.1 for loose cohesionless soils subject to pulsating load.

Observations on the strength of sensitive clays, such as the quick clays of Scandinavia, may also have a bearing on the possible in-place strength of cohesive submarine sediments, if, due to the formation of weak bonds, they develop a loose structure. Bjerrum (1961) has discussed in detail the strength of materials with loose structure, and he cites tests on quick clay which gave drained angles of shearing resistance between 9 and 13 degrees. Of particular importance here is the observation that in undrained tests on such material, failure may occur before the frictional resistance is fully mobilized.

MECHANICS OF SLUMPING

As Moore (1961) has indicated, consideration of the equilibrium of an infinite slope with failure occurring on a plane or planes parallel to the slope provides an adequate framework within which to discuss the mechanics of slumping. It is possible to consider more complicated configurations (for example, Morgenstern and Price, 1965); however, the available data regarding slope profiles, sediment strength, and initiating mechanism are insufficient to warrant this. The strength of any sediment depends, among other things, upon the conditions of drainage operating during shear. It is therefore essential to distinguish between *drained* and *undrained* slumping. It will be seen that the slope inclination at which slumping occurs is strongly dependent upon whether the initiating process induces a drained or an undrained slump. A third type of slumping, termed *collapse* slumping, may also be denoted. This type of slumping is associated with metastable sediments, and although it has only been studied in a subaerial environment, the possibility of formation of metastable sediments in a marine environment suggests that collapse slumping may be an important mechanism there. It will be defined and discussed in more detail in a later paragraph.

No excess pore pressures exist at failure in a drained slump. By considering the horizontal and vertical equilibrium of a slice shown in Figure 7, the relation between the slope angle at failure and the properties of the sediment may be readily shown to be

$$\tan \alpha = \tan \phi' + \frac{c'}{\gamma' h} \times \sec^2 \alpha \qquad (13)$$

where α denotes the inclination of the slope to the horizontal

$$\left.\begin{array}{l}\phi' \text{ denotes the angle of shearing resistance}\\ c' \text{ denotes the apparent cohesion}\end{array}\right\} \text{in terms of effective stress}$$

γ' denotes submerged density of the sediment

and h denotes the height of sediment participating in the slump.

It is of interest to note that a comparable analysis for subaerial conditions would involve the bulk density of the material in the resulting form of equation (13). Therefore a given amount of cohesion is more effective in maintaining stability under submarine conditions, all other conditions being the same. When the sediment is a normally consolidated clay or an uncemented sand or silt, the following well-known relation holds at failure:

$$\tan \alpha = \tan \phi' \qquad (14)$$

Drained slumping is most commonly caused by depositional oversteepening. Since the ϕ' for stable material is generally greater than 20 degrees, and few features in deep water have inclinations as steep as this, it appears that drained slumping of stable sediments is not a dominant mechanism. It can, however, occur on the steep slopes of erosion channels. Steep slopes such as those observed by Moore (1965) require the existence of some cohesion whose origin is either in overconsolidation or cementing to account for their stability. Terzaghi (1956) stated that steep slopes of coarse-grained sediments are most commonly encountered in deltas deposited by mountain streams and cited the sand and gravel delta of Howe Sound, British Columbia, as an example. Here slope angles of 27 to 28 degrees are stable. The slump which occurred here must have originally had a slope steeper than this, and Terzaghi suggested that residual pore pressures after drawdown reduced the shearing resistance sufficiently to cause failure. This is not a drained slump like those considered above. The influence of drawdown pore pressures may be estimated by methods commonly used in the design of earth dams (Bishop, 1957; Bishop and Morgenstern, 1960) and will not be considered further here. Under fully drained conditions the mobility of the sediment will be small and it will come to rest when the slope angle is slightly less than the angle of shearing resistance. Mobility under undrained conditions will be considered in the section relating to the initiation of turbidity currents.

Undrained slumps may be caused by stresses set up during rapid deposition or erosion. Dynamic loading due to earthquakes will also produce undrained failure. Slumping in underconsolidated sediment is also best considered in terms of the undrained strength of the material.

The influence of an earthquake in the analysis of undrained slumping may be incorporated by introducing a horizontal body force, k, as some percentage of gravity and considering the equilibrium of a slice in the infinite slope. Earthquakes will in general also produce a vertical acceleration, but this is usually less than the horizontal acceleration, and for simplicity will be neglected here.

Considering the equilibrium of the slice shown in Figure 8, and resolving forces parallel to the slope one obtains

$$Cu \cdot 1 = W' \cdot \sin \alpha + k \cdot W \cdot \cos \alpha \qquad (15)$$

where Cu denotes the undrained strength mobilized at failure

W' denotes the submerged density of the slice and is given by $\gamma' \cdot b \cdot h$

W denotes the bulk density of the slice and is given by $b \cdot h$

l is the length along the base of the slice

and k is some percentage of gravity.

After simplification, equation (15) reduces to

$$\frac{Cu}{\gamma' h} = \frac{1}{2} \sin 2\alpha + k \cdot \frac{\gamma}{\gamma'} \cdot \cos^2 \alpha \qquad (16)$$

Equation (16) relates, for undrained slumping, the slope angle at which failure takes place to the undrained strength and density of the sediment, the height of the slope, and the horizontal earthquake acceleration, if any. For slopes of gentle inclination

$$\frac{Cu}{\gamma' h} \approx \frac{Cu}{P} = N \qquad (17)$$

and for many sediments

$$\gamma \doteq 3\gamma' \qquad (18)$$

Equation (16) now becomes

$$N = \frac{1}{2} \sin 2\alpha + 3k \cos^2 \alpha \qquad (19)$$

Values of N required to equilibrate a range of slopes inclined from 0 to 20 degrees, and subject to horizontal accelerations up to 15 percent of gravity, have been computed and are plotted in Figure 9. Considering first the stability of slopes free of earthquake loading, if the observed range of N values for most normally consolidated sediments (Figure 2) is taken to apply ($N<0.4$), few slopes subject to undrained loading can stand at inclinations greater than 25 degrees. Overconsolidated sediments and sediments with strong diagenetic bonds can, of course, stand more steeply. Slumping on very gentle gradients of, say, less than 2 degrees, without the aid of earthquakes, can only occur in very underconsolidated material. Terzaghi (1956) and Moore (1961) have already drawn attention to the evidence that the low strengths of the very underconsolidated Mississippi delta sediments are consistent with slumping on slope angles barely in excess of 1 degree. If very loose, cohesionless sediments have an N value of about 0.11 as found by Bjerrum, Kringstad, and Kummeneje (1961) it is seen that failure takes place on slopes of about 6 degrees, and it is of interest to note that this is a fairly typical inclination for the continental shelf.

Figure 9 shows that even small earthquake-induced accelerations are very detrimental to the stability of a submarine slope. However, in a detailed study of mass transport of sediment in the heads of Scripps Submarine Canyon, California, Chamberlain (1964) concluded that there is insufficient reason to believe that a relationship exists between the occurrence of submarine canyon deepenings and earthquake disturbances. Based on direct observations, Dill (1964a) states that earthquakes have little effect on the failures that cause the removal of sediment from the head of Scripps Canyon. The slope failures caused by earthquakes listed in Table 1 provide evidence that there is at least a correlation between submarine slumping and near earthquakes of large magnitude. It seems significant that all the shocks cited in this table had a magnitude greater than 6.5. Taking 6 degrees as a typical angle representing some of the cases listed in Table 1, and assuming the sediment to have undrained strengths in terms of N between .25 and .40, it is seen from Figure 9 that the slope must have responded with an acceleration between 5 and 10 percent of gravity.

The observations of Emery and Terry (1956), described in an earlier section, provide an interesting case of a relatively steep stable slope in a seismically active area. Since the sediment has a plasticity index of about

25 percent, the value of N might, from Figure 2, be at least 0.22 and the equilibrium slope for undrained failure without earthquake loading is 13 degrees. This fits well within the range of the observed slope angles and is close to the average of 12 degrees. However, steeper slopes were observed, and the index data quoted above refer to a slope of approximately 15 degrees. A slope of 15 degrees requires an N value of 0.25 for stability. This is within the scatter to be expected from correlation with Figure 2, but it leaves no margin for incorporating the influence of earthquake loading. To obviate this difficulty, it is worthwhile noting that although bedrock accelerations during an earthquake may be high, the response of the overlying sediment depends upon its modulus of rigidity, and if this is very low, the shear stresses induced in the sediment may be low, although the displacements will be large.* In a normally consolidated sediment the modulus of rigidity will vary with depth, and it could be that for typical ground motions associated with near earthquakes of magnitude less than 6, the dynamic stresses in the sediment are not very significant. If data on the variation of rigidity with depth in a slope could be obtained, the solution given by Ambraseys (1959) to the problem of the response to an arbitrary ground motion of an elastic overburden with varying rigidity could be used to investigate this point.

A collapse slump is defined as one that fails initially under drained conditions, but the deformations associated with failure bring about a large increase in pore pressures. These pore pressures reduce the shearing resistance, and the soil mass accelerates. This type of mechanism has only received detailed attention in the study of one landslide which occurred in a thin layer of quick clay (Hutchinson, 1961). It is probably a feature peculiar to structurally metastable sediments. The analysis of this slide, using pore pressures based upon ground water level observations, indicated that failure occurred with a drained angle of shearing resistance of only 7 ± 1.5 degrees. This value was substantiated by both in-place and laboratory shear box tests. Conventional isotropically consolidated undrained triaxial tests gave values of ϕ' of 25 degrees, and Bjerrum (1961) has suggested that the lower initial yield is destroyed by sample disturbance and reconsolidation. Further information on this phenomenon is given by Bjerrum and Landva (1966). Hutchinson (1961) also observed pore pressures in excess of hydrostatic pressure within the clay layer and remarked that the sliding caused breakdown of the clay structure, and hence part of the overburden load was transferred to the pore water. Therefore, although the initial failure occurred under drained conditions, further movement occurred under undrained conditions. This can only happen when the undrained resistance is less than the drained resistance at failure, as it was in the case discussed here.

Although these quick clays do not commonly exist in a submarine environment because they have been made metastable by the leaching of salt water, some submarine sediments may achieve metastability and high sensitivity in other ways and could be subject to collapse slumping. Therefore the possibility of initial slumping under drained conditions with acceleration under undrained conditions on slopes of 5 to 10 degrees cannot be excluded without further study.

Moore (1961) concluded that in general most sediments are theoretically stable to great thicknesses on very steep slopes. This conclusion was based upon the use of strength parameters typical for drained compression of stable sediments, and the analysis presented here, for this case, is in agreement. Undrained failure of stable, fully consolidated sediments can lead to slumping on slopes of more gentle inclination, particularly if the sediment responds to earthquake loading with a significant acceleration. Therefore considerable slumping may occur on the normal open shelf where

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*The dynamic shear stress in the sediment is given by:

$$\tau_d = \frac{\gamma}{g} \cdot Vs \cdot \dot{u} \qquad (20)$$

where τ_d denotes the dynamic shear stress

Vs denotes the shear wave velocity

$\dot{u}$ denotes the particle velocity

and $\frac{\gamma}{g}$ denotes the mass density.

If the computed response of the sediment to earthquake loading shows low strain rates and hence low particle velocities, and if Vs is small due to the low rigidity, the dynamic stress, τ_d, will also be small.

collapse slumping may also be important. In agreement with Moore, the deep sea is probably almost free of slumping. This is because the gradients of most physical features there are very low; sediments are likely to be fully consolidated and possibly stronger due to diagenetic bonding, and the slopes are situated out of range of several of the agencies which can produce undrained failure. Slumping is undoubtedly frequent in areas of rapid deposition, and here may occur on very gentle gradients.

INITIATION OF TURBIDITY CURRENTS

When a slump takes place in a stable cohesive sediment of low sensitivity, experience of subaerial landslides suggests that shearing will take place on a plane or set of planes while the mass of the sediment remains relatively intact. The mass of sediment should come to rest at a new equilibrium position consistent with the strength obtaining after failure, and although it may exhibit features associated with a coherent slump, such as intraformational folding, it is difficult to imagine that the stresses acting on the slump mass during motion can disrupt its structure sufficiently to allow dispersion of the sediment and mixing with water. However, cohesive sediments of high sensitivity and cohesionless soils, particularly metastable ones, can achieve a greater mobility, and in the limit a slump may be transformed into a turbidity current.

There is considerable evidence that some sediments in the deep sea have had their origin in shallow water. In a study of deep-sea sands, Kuenen (1964) stated that practically all deep-sea sands were emplaced by turbidity currents. Heezen and Hollister (1964) suggested that although deep-sea currents are capable of transporting coarse material, they cannot account for the graded bedding which is a common feature of deep-sea sands. However, in the light of Dill's observations (1964a, 1966) of bottom current pulsations and creep and slump effects, these conclusions are possibly premature, and the presence of deep-sea sands cannot be taken as wholly unambiguous evidence for the existence of turbidity currents. Other evidence for turbidity current deposition includes the displacement of shallow-water benthonic fauna to deep water, and the relief and distribution of abyssal plains, channels, and fans (Menard, 1964). The timing of submarine cable breaks, after slumping was caused by an earthquake, demonstrates the mobility of the sediment. The first confirmation that a slump can transform into a turbidity current was given by Heezen, Ericson, and Ewing (1954), who discovered a graded bed of silt south of the Grand Banks. This bed had its origin in a turbidity current caused by the slump which occurred during the earthquake of 1929. Heezen and Drake (1964) have suggested that there was deep-seated coherent slumping as well in this case. Slumping has also been cited by Holtedahl (1965) as the initiating agency to account for the abundant recent turbidites found in the Hardangerfjord, Norway.

Not all turbidity currents have their origin in slumps. In the case of the Congo Submarine Canyons (Heezen and others, 1964) cable breaks occurred most frequently at the times of greatest bed load discharge, and since a delta is not being formed at the river mouth, it is possible that large sediment discharges continue directly as turbidity flows.

Only low density turbidity currents have been directly observed. These often occur due to the discharge of sediment by a river into a lake or reservoir. In the case of the Lake Mead turbidity current, it is known that the excess density is only about 1 percent and the velocity less than 2 ft per sec on a gradient of approximately 2000:1 (Gould, 1951). Kuenen (1950) postulated the existence of turbidity currents with densities comparable to the bulk density of typical sediments and was able to produce them in the laboratory. The density of turbidity currents in the sea remains debatable. The high-density current explains sea-floor phenomena more easily, but is yet to be observed. If the low-density current begins as a slump, it is not clear how the extreme dispersion of the sediment occurs. The twisting and abrasion of cables broken by the Suva turbidity current described by Houtz and Wellman (1962) favors the high density interpretation. Alternative mechanisms for a sequence of cable breaks, such as a wave of liquefaction or progressive slumping, appear less satisfactory.

Data on times of breakage of submarine cables provide evidence that turbidity currents can maintain velocities of about 15 to 30 ft per sec on the very gentle gradients of the abyssal plains. Although it is generally accepted that higher velocities are developed on the steeper continental slope, few conclusive data are available and the exact values are still debated. Menard (1964) suggests that the Grand Banks turbidity current reached a velocity of 63 ft per sec before it began to decelerate, and even higher values have been quoted.

While there has been considerable study of the mechanics of turbidity flow (see Johnson, 1962, 1964, for a review) little attention has been paid to the problem of how a current is initiated. Moreover, small-scale experiments carried out on a naturally sloping sea floor 40 ft below sea level were not successful in producing a high-density, high-velocity current (Buffington, 1961). In the following, the acceleration of a slump after failure is considered in an attempt to delineate some of the conditions necessary for a slump to attain sufficient velocity that it may transform into a turbidity current. These considerations may explain the failure of the experiments mentioned previously.

The problem is best treated in terms of effective stress. It is assumed that some unspecified mechanism has brought the cohesionless sediment on an infinite slope into a state of limiting equilibrium by inducing an undrained failure, and that the excess pore pressure in the sediment at this instant is given by

$$u = nz \qquad (21)$$

where u denotes the excess pore pressure
n is some number
and z is measured perpendicular to the slope, increasing downwards from the surface of the slope.

If the slice shown in Figure 10 is to be in a state of limiting equilibrium, it is readily shown that

$$\frac{n}{\gamma'} = \frac{\cos\alpha \tan\phi' - \sin\alpha}{\tan\phi'} \qquad (22)$$

From equation (22) the values of $\frac{n}{\gamma'}$ have been computed for a range of slope angles and for values of ϕ' of 10, 20, and 30 degrees. These values are plotted in Figure 11. If for a given value of α and ϕ' the magnitude of

$$\frac{n}{\gamma'}$$

obtaining in the slope is less than that shown in Figure 11, motion will not occur. If, however, it is greater, though not necessarily liquefied, the sediment will not be in equilibrium and it will accelerate due to the force unbalance acting upon the mass. (The viscous stress acting on the upper surface may be neglected.) Assuming that the mass is initially at rest, the equation of motion gives

$$V_r = \frac{g}{\gamma} [\gamma'\sin - (\gamma'\cos\alpha - n)\tan\phi']t \qquad (23)$$

where V_r denotes velocity for this rigid block model
t denotes time
and g denotes the acceleration due to gravity.

It is seen that for this model the velocity increases linearly with time, and depends upon the slope angle, the excess pore pressure gradient, and the density and strength of the sediment. A diagrammatic velocity profile is shown in Figure 10.

A more realistic model may be developed by incorporating a viscous resistance due to the strain rate in the sediment. This would give rise to a velocity profile of the type shown for this mode of flow in Figure 10. Since the slope is infinite there is no variation of any stress or strain-rate in the x direction. The equation of motion for an infinitesimal element accelerating in the x direction becomes

$$\gamma'\sin\alpha - \frac{\partial\tau_{xz}}{\partial z} = \frac{\gamma}{g}\frac{\partial V_v}{\partial t} \qquad (24)$$

where V_v denotes the velocity in the x direction.

There is no acceleration in the z direction. Incorporating a viscous resistance into the failure criterion for the sediment gives

$$\tau_{xz} = (\gamma'\cos\alpha \cdot z - nz)\tan\phi' - \eta\frac{\partial V_v}{\partial z} \qquad (25)$$

where η denotes the viscosity of the sediment.

The viscous term is negative here because, owing to the choice of axes, the velocity gradient is negative. Substituting equation (25) into (24) gives

$$\frac{\partial^2 V_v}{\partial z^2} - \frac{1}{a}\frac{\partial V_v}{\partial t} = -b \qquad (26)$$

$$\text{where } a = \frac{g\eta}{\gamma} \qquad (27)$$

and $$b = \left\{\frac{\gamma'\sin\alpha - (\gamma'\cos\alpha - n)\tan\phi'}{n}\right\} \qquad (28)$$

Equation (26) is to be solved subject to the boundary conditions

$$\left.\begin{array}{l} t = 0,\ V_v = 0; \\ t > 0 \begin{cases} z = 0,\ \dfrac{\partial V_v}{\partial z} = 0; \\ z = h,\ V_v = 0. \end{cases} \end{array}\right\} \qquad (29)$$

where h is the depth of the slump. This problem has been considered by Carslaw and Jaeger (1959) in the context of heat conduction and the solution is:

$$V_v = \frac{bh^2}{2}\left\{1 - \frac{z^2}{h^2} - \frac{32}{\pi^3}\sum_{n=0}^{\infty}\frac{(-1)^n}{(2n+1)^3}\cos\frac{(2n+1)}{2h}\pi z \cdot e^{\frac{-a(2n+1)^2\pi^2 t}{4h^2}}\right\} \qquad (30)$$

Equation (30) may be expressed in terms of a dimensionless depth factor

$$\frac{z}{h},$$

time factor

$$\frac{at}{h^2},$$

and velocity factor

$$\frac{2V_v}{bh^2}$$

and plotted graphically as in Figure 12 to reveal the development of the velocity profile with increasing time. The maximum velocity occurs at the surface of the flow, and plotting the velocity factor against time factor for $z = 0$, it is seen from Figure 13 that for a small time a linear relationship exists. More particularly

$$\frac{2V_v}{bh^2} = 2\,\frac{at}{h^2} \qquad (31)$$

Therefore, for small time

$$V_v = \frac{g}{\gamma}\left[\gamma'\sin\alpha - (\gamma'\cos\alpha - n)\tan\phi'\right]t \qquad (32)$$

and comparing equation (32) with equation (23) one finds

$$V_v = V_r \qquad (33)$$

In the early stages of motion the maximum velocity developed in the frictional-viscous flow will be the same as that in the purely frictional flow. The average velocity will be slightly less. For larger times the viscosity will now be more significant. Viscosity data for sediments of high concentration are scarce. However, on the basis of experiments reported by Yano and Daido (1965) values of between 0.4 and 0.5 lb (force) sec per sq ft may be used in calculations for the concentration of sediments likely to exist in an accelerating slump.

The process of transformation into a turbidity current involves the onset of turbulence and the likelihood of some mixing with overlying water due to instability and wave formation at the interface. This is a difficult problem and is by no means fully resolved at present. Among the factors that would deter a slump from transforming into a turbidity current are rapid decrease of slope inclination and the dissipation of pore pressure. It is of interest, then, to adopt a relationship that has been applied to the steady state flow of a turbidity current in order to find a velocity at which it may be assumed that transformation is complete, and then, for an assumed slump, compute the time required to achieve this velocity. The degree of dissipation at this time can also be estimated.

A slump 30 ft thick is assumed to have occurred on a slope of 5 degrees and following Kuenen (1952) it is assumed that the Chezy equation is valid when the turbidity current is created. It is also assumed that the bulk density of the sediment is three times the submerged density. From the Chezy equation a velocity of 58.5 ft per sec is obtained. If it be further assumed that the angle of shearing resistance is 20 degrees and

$$\frac{n}{\gamma'}$$

is 0.8, this velocity is attained in only 340 seconds. It is evident that the degree of dissipation of pore pressure for a slump of this size after 340 seconds is negligible for all but the coarsest sediment. It seems probable that in the experiments carried out by Buffington (1961) the amount of sediment was so small that, aggravated by spreading, the drainage path was sufficienty small to allow almost instantaneous dissipation of the excess pore pressure.

For a slump to turn into a turbidity current, the analysis presented here shows that it is necessary that at failure the strength be reduced sufficiently to permit the acceleration of the mass, and that deeper slumps will transform more readily because, other things being equal, the dissipation of pore pressure will be less.

CONCLUDING REMARKS

Much of this study is necessarily speculative because of the paucity of reliable strength data for submarine sediments. It is evident that a more profound understanding of submarine slumping requires this information, as well as more detailed studies of topography, occurrence of slumping, and rate of accumulation of material in varying sedimentary environments. The development of underconsolidation in deltas and submarine canyon heads deserves special attention.

The transformation of a moving slump into a turbidity current is a complicated problem involving both soil and fluid mechanics. Conditions that must be satisfied for the onset of turbulence and the development of the dispersive forces that arise and maintain the sediment in suspension are not well understood. The mixing with overlying water is an important factor in the development of a turbidity current, and controls its density. This process must be clarified before the mechanics of turbidity currents of high density can be founded on a firm physical base.

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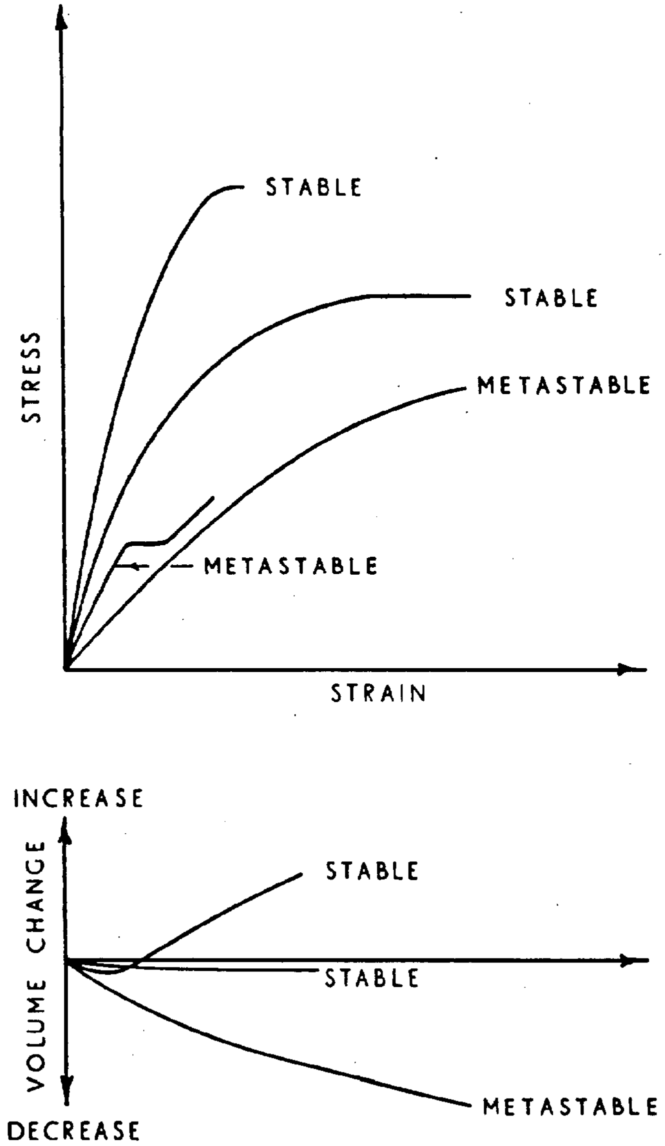


FIGURE 1. DIAGRAMMATIC STRESS – STRAIN RELATIONS FOR STABLE AND METASTABLE SEDIMENTS.

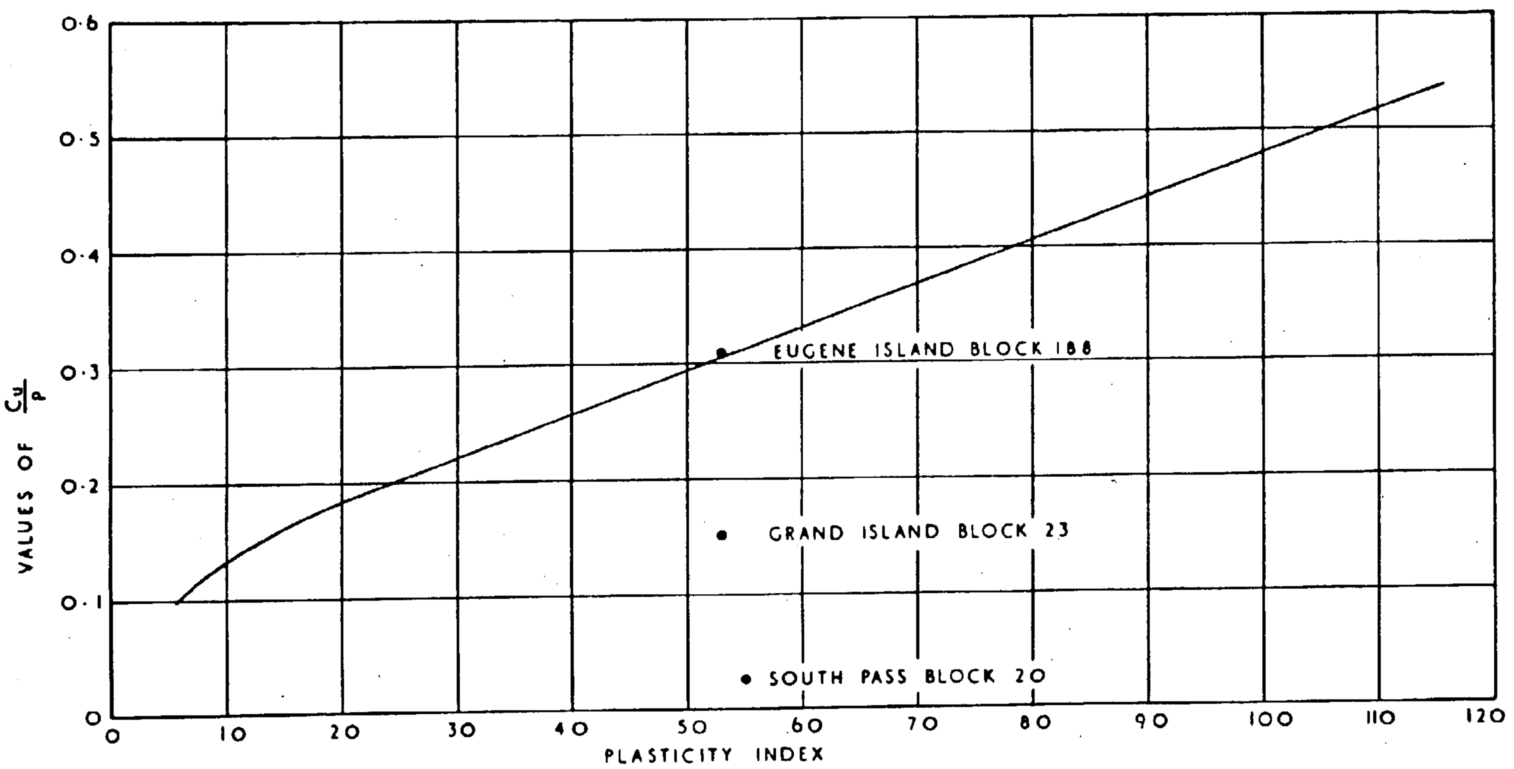


FIGURE 2. RELATION BETWEEN UNDRAINED STRENGTH AND PLASTICITY INDEX FOR NORMALLY CONSOLIDATED SEDIMENT.

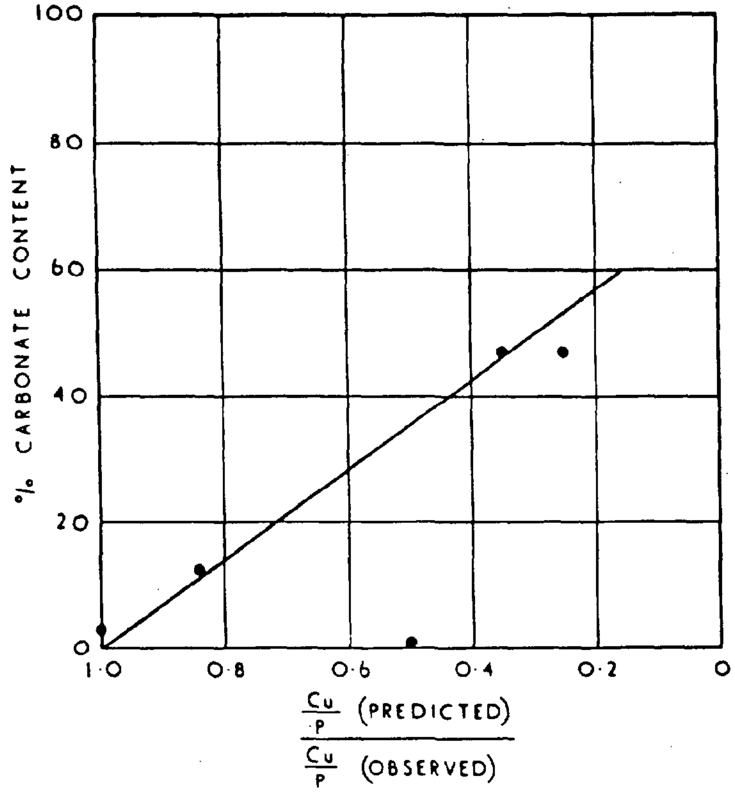


FIGURE 3. INFLUENCE OF CARBONATE CONTENT ON UNDRAINED STRENGTH OF SEDIMENTS FROM EXPERIMENTAL MOHOLE.

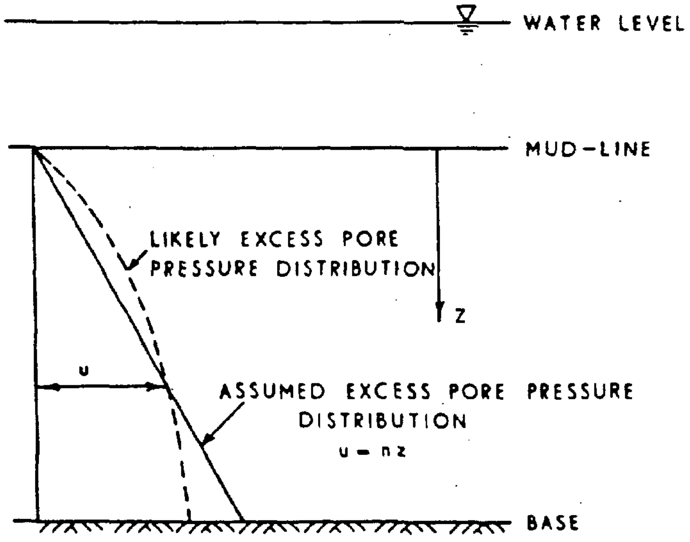


FIGURE 4. AN UNDERCONSOLIDATED STRATUM.

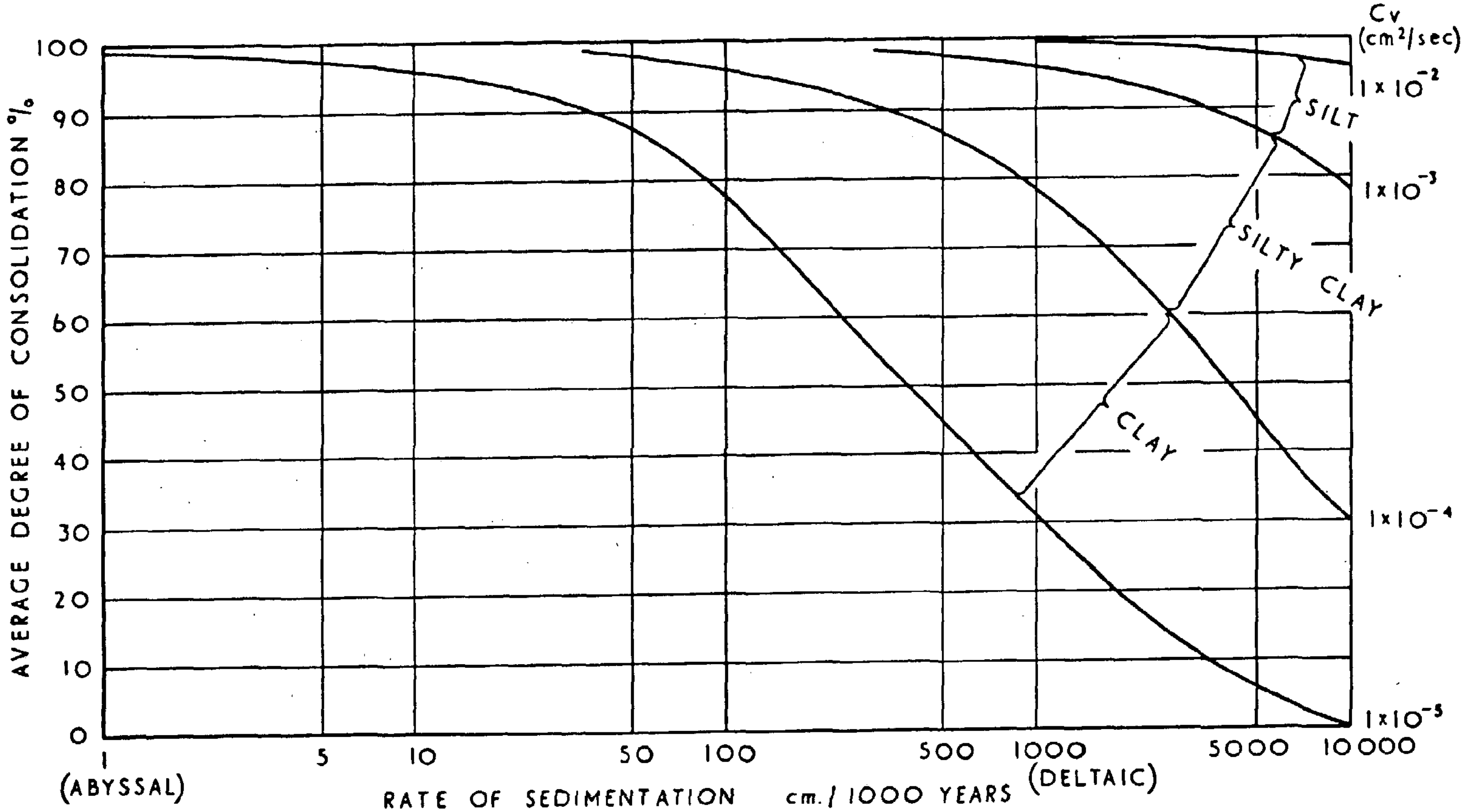


FIGURE 5. RELATION BETWEEN RATE OF SEDIMENTATION AND DEGREE OF CONSOLIDATION FOR 15 m LAYER.

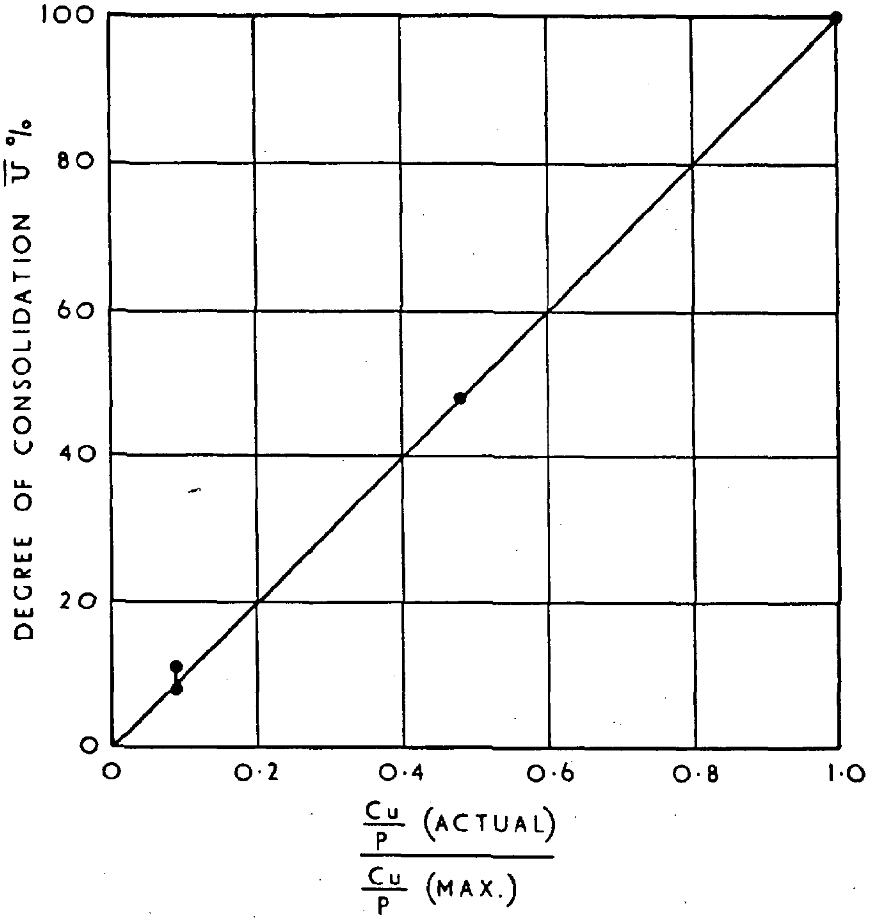
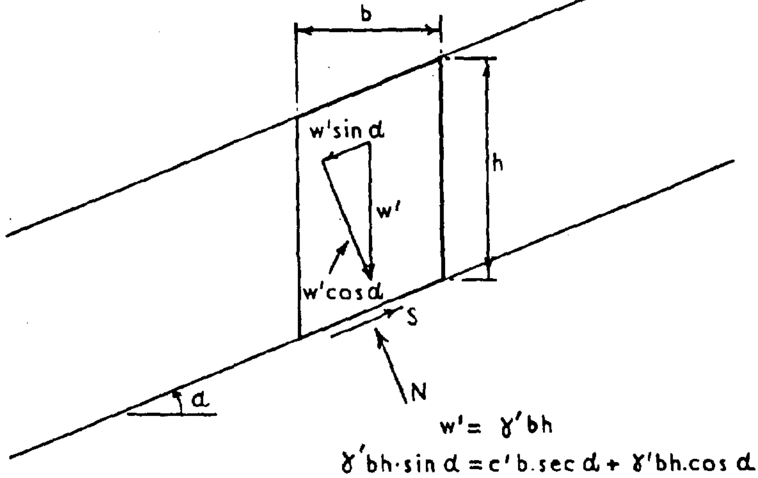


FIGURE 6. INFLUENCE OF UNDERCONSOLIDATION ON UNDRAINED STRENGTH OF MISSISSIPPI DELTA SEDIMENTS.



$$w' = \gamma' bh$$

$$\gamma' bh \cdot \sin\alpha = c' b . \sec\alpha + \gamma' bh . \cos\alpha . \tan\phi'$$

$$\therefore \tan\alpha = \tan\phi' + \frac{c'}{\gamma h} . \sec^2\alpha$$

FIGURE 7. EQUILIBRIUM OF INFINITE SLOPE UNDER DRAINED CONDITIONS.

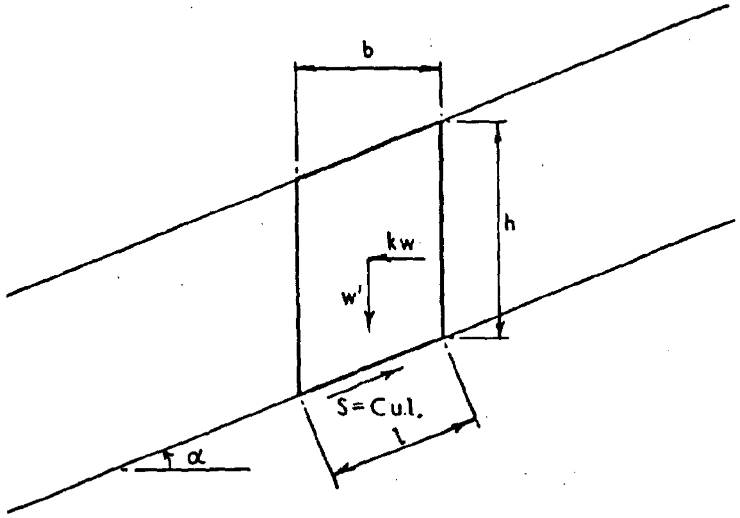


FIGURE 8. EQUILIBRIUM OF INFINITE SLOPE UNDER UNDRAINED CONDITIONS.

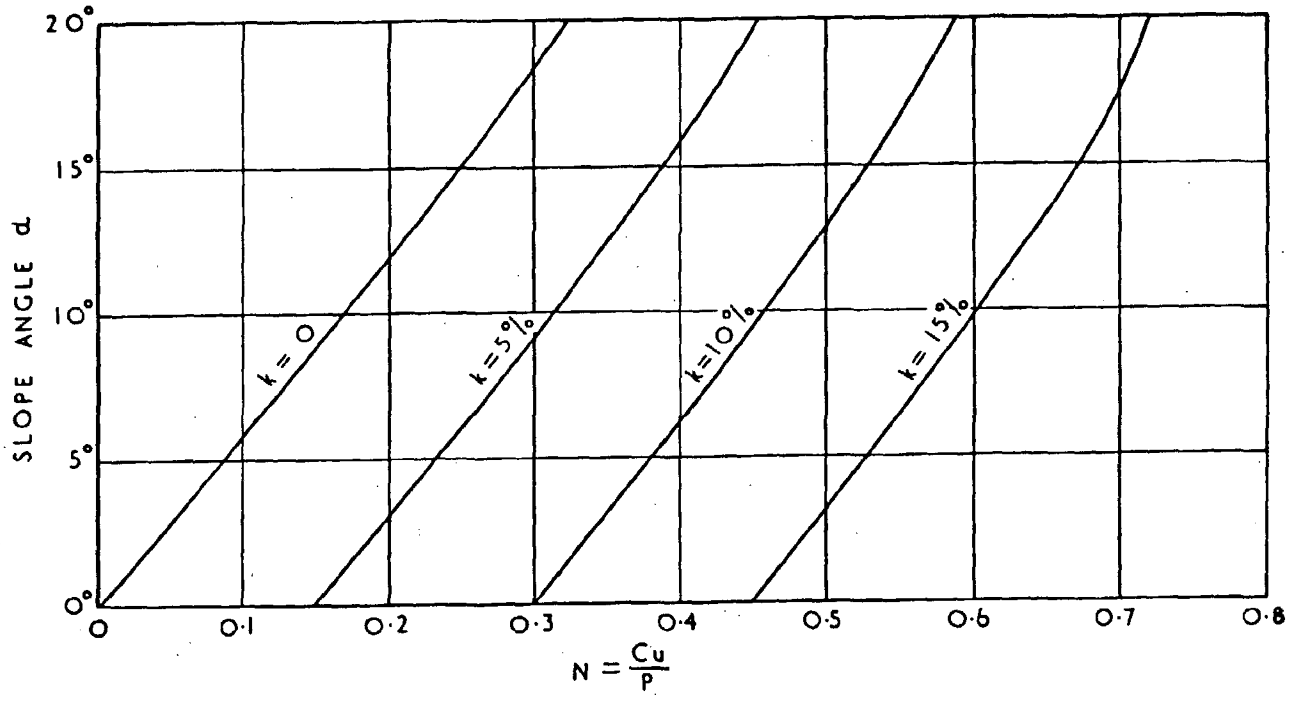
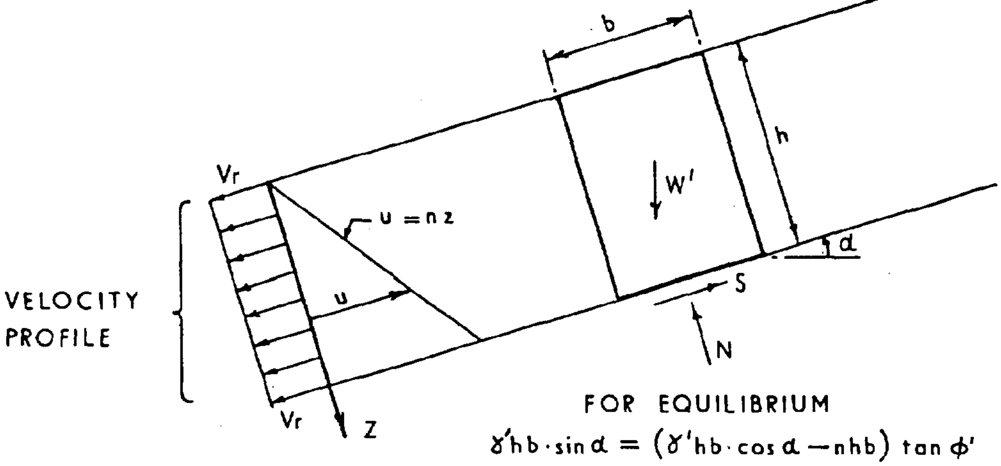


FIGURE 9. RELATION BETWEEN SLOPE ANGLE AND UNDRAINED STRENGTH FOR AN INFINITE SLOPE AT LIMITING EQUILIBRIUM AND SUBJECT TO AN EARTHQUAKE ACCELERATION k PERCENT OF GRAVITY.

RIGID BLOCK MODEL



VISCO-FRICTIONAL MODEL

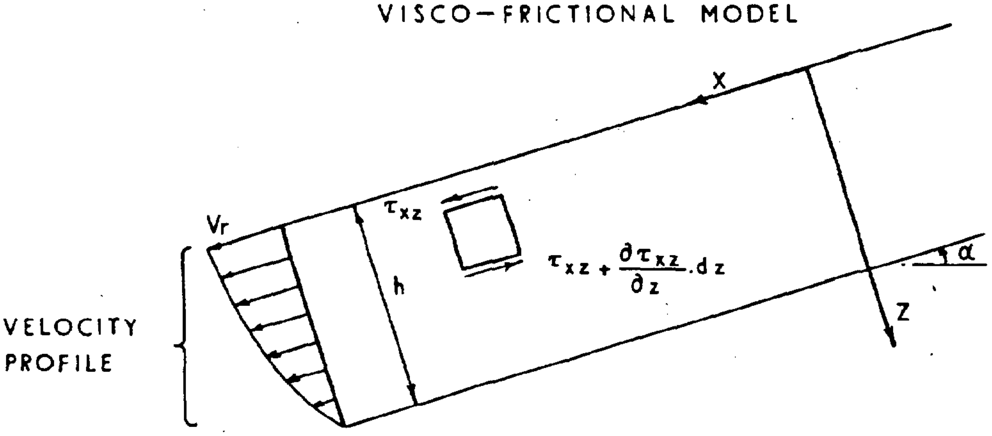


FIGURE 10. ACCELERATION OF AN INFINITE SLOPE.

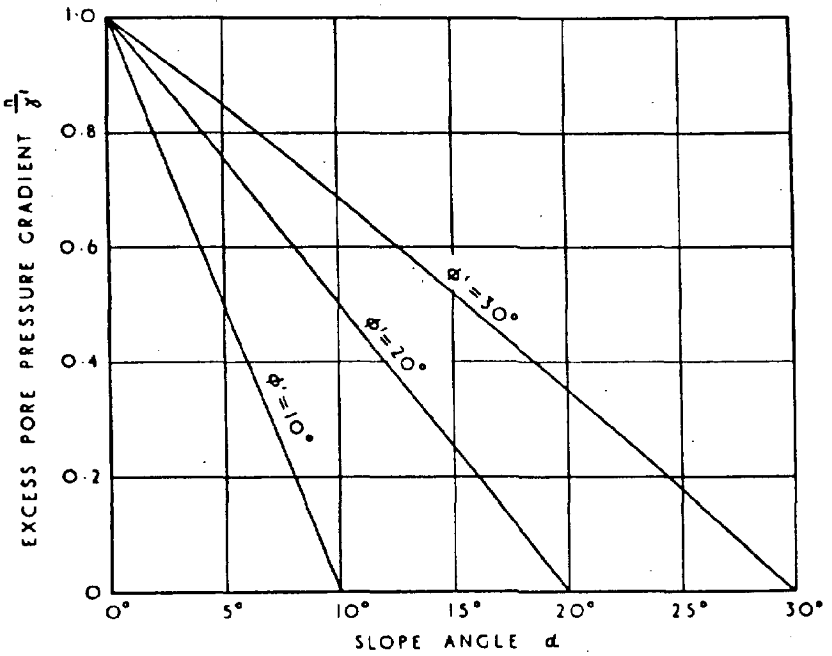


FIGURE 11. RELATION BETWEEN EXCESS PORE PRESSURE AND INCLINATION FOR AN INFINITE SLOPE AT LIMITING EQUILIBRIUM.

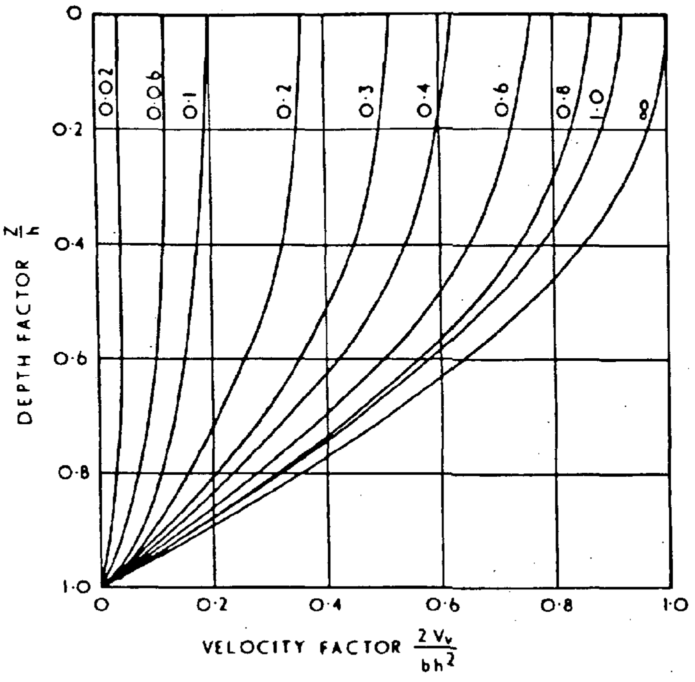


FIGURE 12. VELOCITY PROFILES FOR INCREASING VALUES OF TIME FACTOR $\frac{at}{h^2}$.

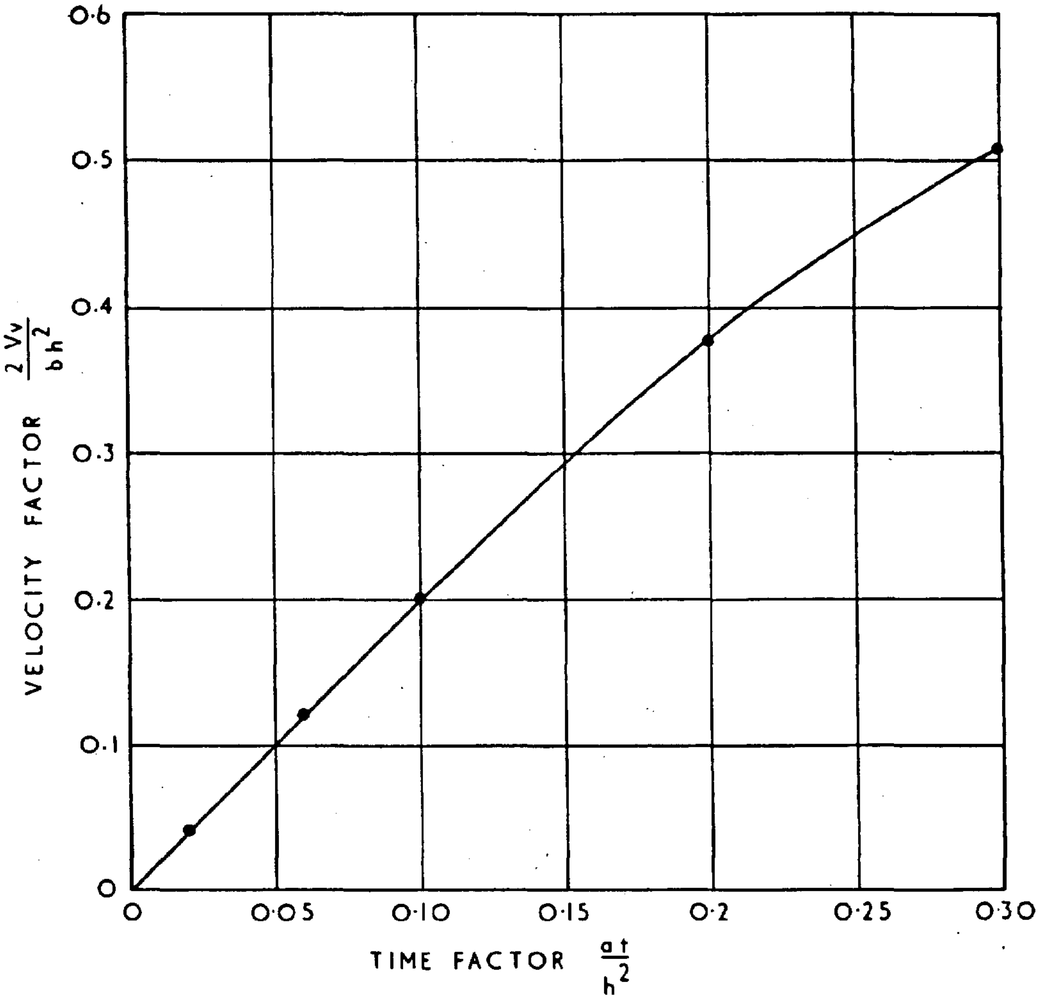


FIGURE 13. RELATION BETWEEN VELOCITY FACTOR AND TIME FACTOR AT $\frac{z}{h} = 0$.

Appendix VIII-1

Characteristics of Marine Seismic Sources

by Douglas M. Johnson

Appendix VIII-1
Characteristics of Marine Seismic Sources

Introduction

"High resolution continuous seismic reflection" (or continuous seismic sounding) is the widest-used and most economical method for studying the first hundred metres of soil beneath the sea floor.

The method enables the geometry, structure and configuration of the geolocial strata to be determined. However, in the prevailing state of techniques, seismics alone does not make it possible to make any affirmation:

- as to the nature of the soils,
- and yet less, as to their physical and mechanical properties.

While certain interpretations sometimes justify a presumption as to the state of consolidation of the soils (owing to the degree of penetration, for instance of signals with a given frequency and energy), these assumptions must necessarily be verified by core samples or in situ geotechnical measurements.

Preliminary recording of seismic profiles on a marine site makes it possible:

- to fix the locations of the geological and geotechnical soundings (drilling/core drillings and in situ measurements) as a function of the variations in the configuration of the subsoil,
- to reduce the number of these soundings,
- to extrapolate where necessary the results of core drillings and in situ measurements.

All seismic techniques currently applied for the reconnaissance of marine soils use the continuous reflection method. The refraction method is applied only when seismic reflection proves to be inoperative or the results obtained do not yield the expected accuracy.

Several types of devices are used in "high resolution seismics." The main of them are:

- sediment sounders (or echo sounders)
- boomers

- sparkers
- side scan sonar

These devices are characterized by their transmission frequency and consequently the penetration of the signal and its resolving power (or definition):

- the penetration is inversely proportional to the transmission frequency,
- the resolving power (and relective quality) decreases with the penetration and increases with frequency.

Since "Boomer", Echo Sounders, and Side Scan Sonar was used in the Shannon-Wilson reports, a discussion of their characteristics has been included in this Appendix.

BOOMERS (AND THE UNIBOOM)

The boomer or thumper is an electromechanical source invented by EEG.

Principle and characteristics of the boomer

Principle of the boomer

The boomer consists of:

- an induction coil against which an aluminium plate is applied by a system of springs,
- a bank of capacitors (connected to a sparking circuit) producing electrical discharges through the coil at regular intervals.

With each discharge, the eddy currents induced in the conductive plate cause it to move violently away from the coil. The initial movement of the plate triggers the acoustic pulse.

Characteristics of the boomer and Uniboom

The acoustic signature of a 1,000 J boomer has a signal duration of about 5 ms.

The spectrum for this boomer ranges from 200 to 2,000 Hz.

From the standpoint of enery distribution, the figure reveals:

- a very high amplitude of the initial pulse peak (a),
- a peak of negative amplitude (b) extending the signal.

This secondary peak is caused by the cavitation which arises behind the plate in the depressurized zone.

In the Uniboom system, the secondary pulse is eliminated by providing an elastic diaphragm on the inner face of the plate from the depressurized side. This diaphragm then absorbs part of the enrgy and thus limits the cavitation.

The duration of the Uniboom signal is limited to about 0.2 ms.

The frequency spectrum ranges from 500 to 10,000 Hz on the average (the frequency decreases slightly as the energy output increases).

The resolving power:

- of the boomer proper is not less than 2 m, owing to the considerable length of the signal,
- with the Uniboom, it can theoretically get down to 30-40 cm (comparable to the best sediment sounders).

Principle and equipment of the echo sounder

Principle of the echo sounder

The echo sounder puts out a brief ultrasonic pulse which is reflected from the sea bottom. The return echo is amplified and then continuously recorded.

Let V be the speed of sound in water and t the time interval between the emitted and return echo, the depth H is given by:

$$H = \frac{Vt}{2}$$

Equipment of the echo sounder

Transmission and reception are ensured by a common electro-acoustic transformer or transducer which converts the mechanical vibrations into electrical vibrations of the same frequency.

Coupled to an electric pulse generator, the transducer converts the electrical energy into acoustic energy on transmission, and conversely the reflected acoustic signal is converted into an electrical signal.

The most widely used transducers are based on the piezoelectric properties of certain ceramics (barium titanate, zirconate). They vibrate at a certain resonance frequency. These vibrations, transmitted to the water, act as sound pulses.

The optimum frequency range, which depends on the depths of water and nature of the bottom, extends from about 15 to 200 kHz, depending on the type of device. The higher the frequency, the more efficient the absorption.

At the recording end, the propagation times measured are converted into depth, depending on the speed of sound in water (from 1,460 to 1,560 m/s in sea water). For a given speed, the rate of the stylus, which inscribes along a strip of paper, determines the scale of the soundings, namely the number of metres of water represented on the width of the recording paper.

Characteristics of transducers

Transducers are characterized by their nominal frequency, directivity and level of energy.

The nominal frequency of a transducer designates its transmission frequency under permanent excitation (i.e., resonance).

For precision echo sounders, used for bathymetry, the sound beam is relatively narrow. The following are typical orders of magnitude:

- for common echo sounders:

$10\text{-}20^{\circ}$ at 50-30 kHz

- for large diameter echo sounders with very narrow beams, used at great water depths:

$3\text{-}6^{\circ}$ at 30-15 kHz

The transmission level of a transducer is a measure of the energy transmitted along the axis of the transducer, measured one metre away. A high transmission for the same electric power is the sign of better efficiency.

Resolving power of an echo sounder

Resolving power of an echo sounder essentially depends on the duration of the pulse, the angle of the ultrasonic beam, the depth of the water and topography of the bottom.

A resolving power is limited by the fact that it is impossible to transmit an extremely brief signal.

If Δt is the shortest discernible time interval between two echoes, then the depth resolutions is:

$$\Delta H = \frac{V}{2} \cdot \Delta t$$

where: V is the speed of sound in water.

Principle of the side-scan sonar. Formation of the echoes

The side-scan sonar transducer acts both as transmitter and receiver of the ultrasonic signals.

The system generally consists of:

- a round-nosed cylindrical body towed from the vessel (known as the "fish"), containing one or two (1) transducers (together with the associated electronic circuits),
- a towing cable ensuring the elctrical and mechanical links to the towing vessel,
- a one or two rack recorder using either electrosensitive paper or a magnetic tape.

The side-scan sonar transducer:

- transmits short sound pulses to the water, perpendicular to the direction of travel,
- receives the echoes recorded aboard the vessel (following conversion into electric pulses).

The frequencies used vary from a few tens to about 100 kHz, depending on the particular unit.

Formation of the images

The sound pulses transmitted at regular time intervals (the repetition rate essentially depends on the lateral range selected) and the echoes resulting from the irregularities on the sea bottom are recorded as a function of time (two-way trip): clearly, the nearest echoes arrive first, followed by echoes from more distant zones at ever increasing intervals.

Each group of echoes resulting from a transmission is displayed on the recorder in the form of a trace inscribed cross-wise by the stylus on the recording paper which moves longitudinally.

As the vessel advances and the pulses occur one after the other, an image is formed on the recording paper by

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(1) The sonar is generally bilateral.

juxtapostion of the traces (somewhat similar to that obtained on a television screen).

Geometry of the ultrasonic beam

The fineness and precision of the recording are a function of the narrowness of the ultrasonic beam, and of the frequency and duration of the pulse transmitted.

The shape of the transducer is selected so as to transmit a fan-shaped beam:

- with an angle of a few degrees in the horizontal plane (azimuth),
- with an angle of about 10 to few tens of degrees in the vertical plane (elevation).

The ultrasonic beam can be broken down into the following:

- a primary lobe with an angle defined conventionally as the sector in which the sound intensity is only 3 dB beneath that of the axial (maximum) intensity,
- a number of secondary lobes.

Even though only the primary lobe is actually used in practice, the secondary lobes present a certain interest. In particular, the sub-vertical lobe:

- gives a section of the bottom of the sea along the path of the vessel,
- enables any echo from an object situated in the water near the vertical of the vessel to be identified (for instance a shoal of fish).

Formation of the echoes. Angle of incidence

The features of the bottom brought to light are:

- either of topographical nature (variation of the angle of incidence),
- or related to the physical characteristics of the soil (variations in the coefficient of reflection or backscattering).

The way in which topographic echoes are formed is shown in Fig. . All the folds in the bottom cause the angle of incidence of the acoustic rays to vary and hence also the amount of reflected energy.

The useful part of the recording is that corresponding to angles of incidence of less than 30°, where the coefficient of reflection varies sharply with the angle of incidence. The ideal conditions therefore prevail for detecting variations in the angle of incidence and hence variations in the topography.

A change in the nature of the bottom modifies the intensity of the signal as much or even more than a change in the gradient (especially if the angle of incidence is between 20 and 60°). The reflection coefficient varies considerably when changing from mud to pebbles or rock, while sand lies somewhere in between.

Characteristics of the side-scan sonar

The side-scan sonar is essentially characterized by its longitudinal and transverse resolving powers.

Lateral range

The maximum range of a side-scan sonar depends on many factors, the leading ones being:

- the characteristics of the instrument:
- the pulse duration,
- the transmission power,
- the signal/noise ratio,
- the frequency ($rF^2 = 1,300$ is an empirical formula expressing the range in kilometres for an optimum frequency in kilocycles),

- the physico-chemical properties of the medium through which the sound waves are propagated,
- the implementation parameters
- the height of the "fish" above the bottom,
- the inclination of the axis of the beam from the horizontal.

Distortion of side-scan sonar images

There are various causes for the distortion of side-scan images, including the following:

- the obliqueness of the beams
- the slope of the bottom,
- the anisotropy of the medium through which the rays propagate,
- the navigating conditions
- the scales on the recordings.