# APPENDIX G
# HYDROLOGY TECHNICAL MEMO

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## 1.0 PROJECT LOCATION AND VICINITY

The project area for the proposed improvements to SR 101 is located in the vicinity of Sequim, Washington on the Olympic Peninsula. The proposed alternatives and hydrological features for the West Half and East Half projects are shown in Figures 1 and 2.

## 2.0 SURFACE WATER QUANTITY

The effects of construction and operation of the proposed alternatives on surface water quantity are discussed in the Surface Water Hydrology section in Chapter 3. Average annual flows were determined at various locations for streams in the project area. Stormflow in streams resulting from 25-year storms of duration equal to time of basin concentration was calculated using the Rational Runoff Formula, and stormflow from contributing segments for these storms was calculated as well. By comparing the streamflows to the road stormflows, the magnitude of the effect of road stormflow was determined for each stream/road segment intersection. The effect of road stormflow on streamflow before basin equilibration was examined as well.

It was assumed that the chosen alternative could be designed such that adjacent wetlands would suffer no increase in flow rate or pollutant loading. Irrigation ditches were not studied as streams since they are not natural features and flow is controlled manually.

The calculated stormflow from road segments is less than two percent of the combined stormflow of the watershed and the surrounding area. The operation of the proposed road segments would have only a minimal effect on the streams in the area during storm events of 24 hours duration and 25-year frequency (design events). No significant difference exists between alternative alignments on surface water runoff quantity. The calculations of runoff are presented in this document.

### 2.1 AVERAGE ANNUAL FLOW IN STREAMS

Average annual flows for Siebert's Creek and the Dungeness River were determined from records from gaging stations located on Siebert's Creek and the Dungeness River (U.S.G.S., 1984; Drost, 1986). Miscellaneous streamflow measurements have been recorded on Siebert's Creek, McDonnell Creek, Bell Creek, Johnson Creek, Sequim Bay Tributary and several of the unnamed tributaries and small creeks in the project area (Drost, 1986). Flow was measured or estimated at various locations pertinent to proposed alternatives.

Based on records from 1952 to 1969, the mean annual flow in Siebert's Creek was 17.1 cfs with a standard deviation of 7.3 cfs. The highest monthly average flows were recorded in January (43.6 cfs) and the lowest monthly average flows were recorded in

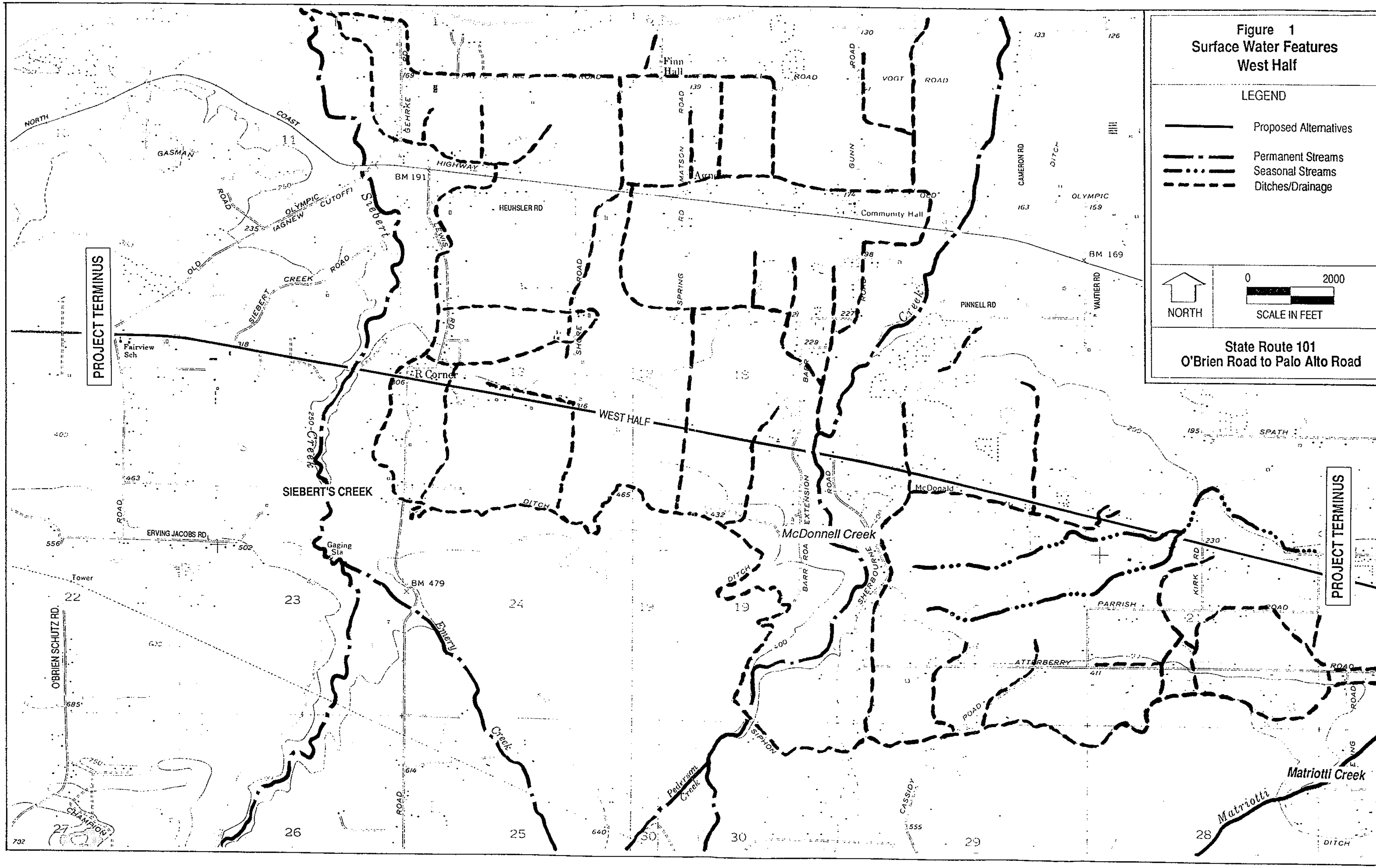
Figure 1
Surface Water Features
West Half
LEGEND
Proposed Alternatives
Permanent Streams
Seasonal Streams
Ditches/Drainage
NORTH
0
2000
SCALE IN FEET
State Route 101
O'Brien Road to Palo Alto Road
PROJECT TERMINUS
PROJECT TERMINUS
WEST HALF
SIEBERT'S CREEK
McDonnell Creek
Matriotti Creek
Siebert Creek
Emery Creek
Pedersen Creek
HEUHSLER RD
PINNELL RD
ERVING JACOBS RD
O'BRIEN SCHUTZ RD.
Community Hall
BM 191
BM 169
BM 479

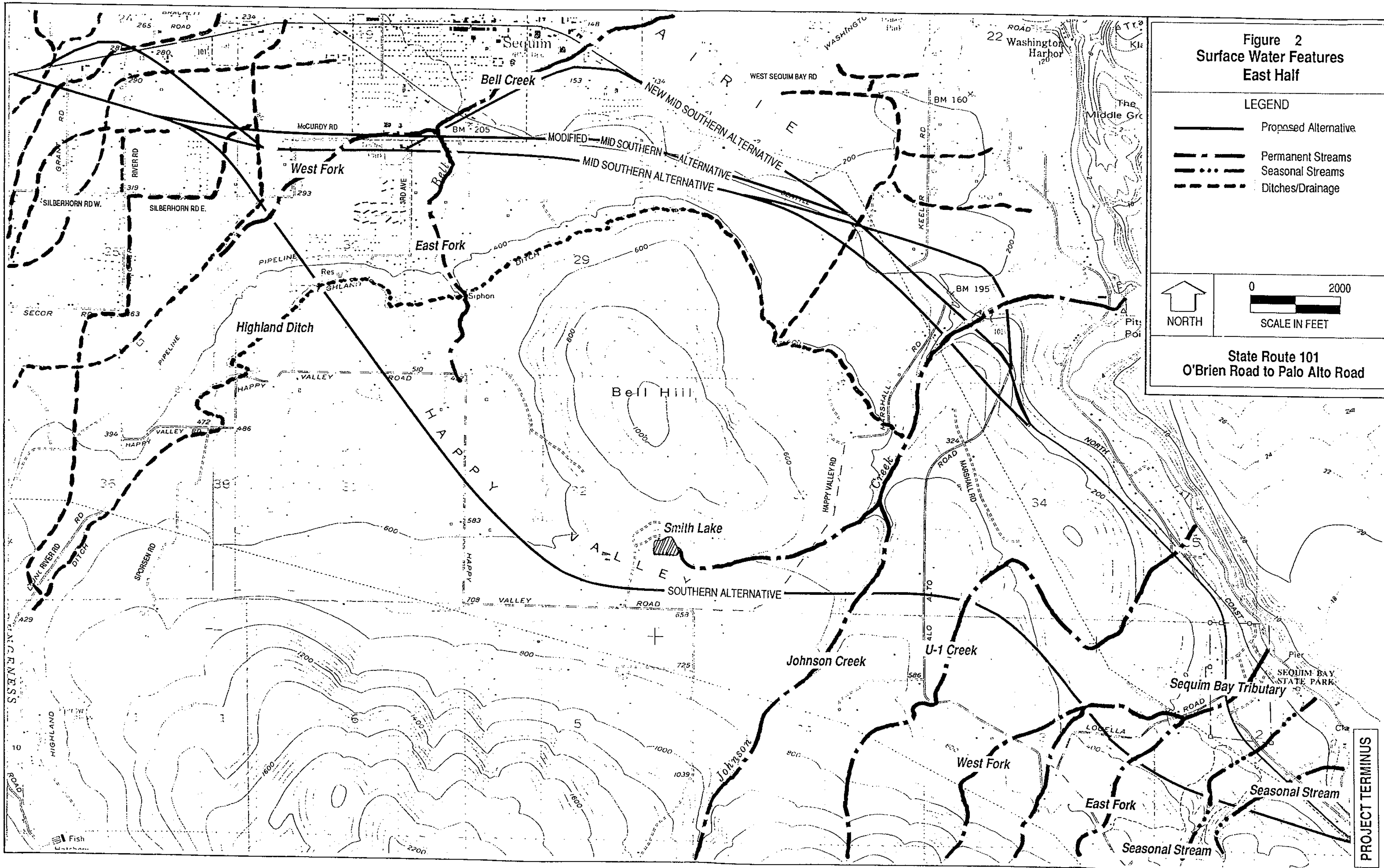
Figure 2
Surface Water Features
East Half
LEGEND
Proposed Alternative
Permanent Streams
Seasonal Streams
Ditches/Drainage
NORTH
0
2000
SCALE IN FEET
State Route 101
O'Brien Road to Palo Alto Road
PROJECT TERMINUS
Sequim
Bell Creek
West Fork
East Fork
Highland Ditch
Siphon
Bell Hill
Smith Lake
NEW MID SOUTHERN ALTERNATIVE
MODIFIED MID SOUTHERN ALTERNATIVE
MID SOUTHERN ALTERNATIVE
SOUTHERN ALTERNATIVE
Johnson Creek
U-1 Creek
Sequim Bay Tributary
Seasonal Stream
West Fork
East Fork
Seasonal Stream
HAPPY VALLEY
McCURDY RD
WEST SEQUIM BAY RD
SILBERHORN RD W.
SILBERHORN RD E.
BM 205
BM 195
BM 160
Washington Harbor
SEQUIM BAY STATE PARK

August and September (3.5 cfs) (U.S.G.S., 1984). The drainage area above the mouth is 19.4 $mi^2$ (Drost, 1986), and the drainage area at S.R. 101 is 16.4 $mi^2$, which is 85 percent of the total basin. For the purpose of further calculations, the average annual flow in Siebert's Creek at SR 101 is assumed to be 14.5 cfs, which is 85 percent of the assumed average annual flow at the mouth (17.1 cfs). Flow in Siebert's Creek was estimated as 8 cfs on August 6, 1991.

Based on records from 1923 to 1979, the mean annual flow in the Dungeness River was 377 cfs with a standard deviation of 89 cfs. The highest monthly average flows were recorded in January (411.3 cfs) and the lowest monthly average flow was recorded in September (179.3 cfs) (U.S.G.S., 1984).

Discrete flow measurements were made on a monthly basis on McDonnell Creek and Bell Creek during 1978 to 1979 (Drost, 1986). The data were collected near the middle of each month and represent twelve random measurements during that year. The discharge in the Dungeness River for water year 1979 (October 1978 to September 1979) was 379 cfs, which is nearly equal to the long-term annual average of 377 cfs. Therefore, the water year 1979 average flows for McDonnell Creek, Matriotti Creek and Bell Creek are assumed to be reasonably close to the long-term average flows for these streams.

The average of twelve flows measured in McDonnell Creek near the mouth between September 11, 1978 and August 17, 1979 is 10.2 cfs, with a standard deviation of 8.8 cfs. The highest flow measured during this period was 27.6 cfs on April 17, 1979, and the lowest flow was 1.8 cfs on August 17, 1979 (Drost, 1986). The drainage area above the mouth is 22.9 $mi^2$, and the drainage area at S.R. 101 is 21.3 $mi^2$ (Drost, 1986), which is 93 percent of the total basin. For the purpose of further calculations, the average annual flow in McDonnell Creek at SR 101 is assumed to be 9.5 cfs, which is 93 percent of the assumed average annual flow at the mouth (10.2 cfs).

The average of twelve flows measured at the mouth of Bell Creek between September 11, 1978 and August 16, 1979 is 6.4 cfs, with a standard deviation of 2.2 cfs. The highest flow measured during this period was 9.24 cfs on April 16, 1979, and the lowest flow was 3.08 cfs on August 16, 1979 (Drost, 1986). The drainage area above the mouth is 8.9 $mi^2$. The drainage area at Sequim Avenue is 21.3 $mi^2$, which is percent of the total basin. For the purpose of further calculations, the average annual flow in McDonnell Creek at SR 101 is assumed to be 9.5 cfs, which is 93 percent of the assumed average annual flow at the mouth (10.2 cfs). The drainage area of Bell Creek is complicated by the irrigation ditches, most notably the Highland Ditch, which would intercept flow from the upper basin, and add flow to the creek in the lower basin. Flow in Bell Creek at Silberhorn Road and at Sequim Avenue was estimated by URS Consultants as 1 cfs on August 6, 1991.

Mean annual flows in Johnson Creek, U-1 Creek and Sequim Bay Tributary were calculated by multiplying the mean annual flow in Bell Creek (6.4 cfs) by the drainage

area of the subject creek and dividing by the drainage area of Bell Creek at the mouth (8.9 $mi^2$).

The drainage area of Johnson Creek at the proposed intersection point with Segment 6 is 3.2 $mi^2$, yielding an estimated average annual flow in Johnson Creek at Segment 6 of 4.5 cfs. At SR 101, near the proposed intersection with Segments 11 and 12, the drainage area of Johnson Creek is 4.3 $mi^2$, yielding an estimated annual average flow of 6.0 cfs.

The drainage area of U-1 Creek at the intersection of this stream and Segment 6 is 0.8 $mi^2$, yielding an estimated average annual flow in U-1 Creek of 0.6 cfs. On July 23, 1991, flow in U-1 Creek was estimated at approximately 0.2 cfs. This is a very approximate estimate, based on observations of stream width, depth and velocity from the railroad trestle above.

The drainage area of the west fork of Sequim Bay Tributary at the intersection of this stream and Segment 6 is 0.7 $mi^2$, yielding an estimated average annual flow of 0.5 cfs. The drainage area of the east fork of Sequim Bay Tributary at the intersection of this stream and Segment 6 is 0.2 cfs. Flow in Sequim Bay Tributary was measured as 0.04 cfs near the mouth on July 23, 1991. This measurement was made where the creek flows in an iron pipe section near the mouth. No flow was observed in tributaries to Sequim Bay Tributary at Palo Alto Road on July 30, 1991, although established channels were present.

No flow was observed in the unnamed streams between Sequim Bay Tributary and Dean Creek at S.R. 101 on July 23, 1991, although established channels were present.

## 2.2 CALCULATED STORMFLOW FROM STREAMS AND ROADS

Stormflow in streams and associated road sections were calculated using the Rational Runoff Method, using a rainfall intensity corresponding to a 25-year storm with a duration equal to the time of concentration for the basin ($T_{cb}$). The discharges from contributing road section was calculated for the same rainfall intensity, and the effects of the road drainage were expressed as a percentage of the total combined flow, i.e.:

$$\frac{Q_{rs}}{Q_{rs} + Q_{ss}}$$

in which

$Q_{rs}$ = road stormflow
$Q_{ss}$ = stream stormflow

In calculating $Q_{rs}$, it was assumed that storm drainage would be contributed by only the eastbound (southern) lanes of the proposed road, as the westbound lanes and shoulder would drain without concentration to the north, or into the median and thence discharged by culvert to the north. A width of 50 feet was used for the eastbound lanes and shoulders.

The calculated stormflow from road segments is a maximum of 2 percent of the combined stormflow, which suggests that operation of the proposed road segments would have only a small effect on the stream during storm events of the durations and intensities indicated, and that there is no significant difference between the various alternatives.

Although conservative values of coefficients were used in the Rational Runoff Formula, the stream stormflows are 20 to 100 times greater than the average annual flows. For example, the calculated average annual flow for Johnson Creek above Segment 6 (basin area 3.2 $mi^2$) is 4.5 cfs, and the calculated 25 year, 318 minute stormflow is 181 cfs. As a comparison, the greatest instantaneous discharge on record for Dean Creek (basin area 3.0 $mi^2$) between 1949 and 1970 is 108 cfs. Since the rainfall intensity used in each case was the same for the stream and the basin, the stormflow ratios are equivalent to

$$\frac{C_r A_r}{(C_r A_r + C_s A_s)}$$

in which

$C_r$ = runoff coefficient for road
$A_r$ = area of contributing road section
$C_s$ = runoff coefficient for stream
$A_s$ = contributing drainage basin area

The primary confounding factor in the calculation of $Q_{ss}$ is the level of uncertainty regarding the "true" value of $C_s$, which is the aggregate coefficient representing actual behavior of storm runoff in the basin. Uncertainty regarding $C_s$ increases in general with increasing basin size and level of development. Multiple land uses and ground covers add difficulty to the determination of a single cover coefficient. In addition, the established systems of road and irrigation ditches intercept overland flow, and in some cases route flow from one natural basin to another. A conservative estimate of the uncertainty of $C_s$ for these basins is a factor of 2, given the extensive ditch systems and variety of land uses in the project area. This uncertainty notwithstanding, the stormflow ratios indicate that only a small percentage of stormflow would come from roads after runoff in the basins reaches equilibration.

The flow ratios discussed above assume that streamflow is equilibrium with the storm. Since the road section areas are much smaller than the corresponding basins, and the road surface "ground cover coefficient" reflects the impervious nature of the pavement, the times of concentration for road sections ($T_{cr}$) are 1-2 orders of magnitude less than corresponding $T_{cb}$ values. As a result, at the elapsed storm duration equal to $T_{cr}$, the hydrograph of the stream would be in the rising limb, and thus the discharge of the road would be a greater fraction of the total stormflow. To estimate the effect of road stormflow under these conditions, "partial stream stormflow" values, designated $Q_{ss*}$, were calculated as

$$Q_{ss*} = Q_{aa} + Q_{ss}\left(\frac{T_{cr}}{T_{cb}}\right)$$

The term $Q_{ss}(T_{cr}/T_{cb})$ accounts for the contribution of the lower part of the basin which would be contributing storm runoff at time = $T_{cr}$.

According to these analyses, the percentage of total stormflow composed of road stormflow at time $T_{cr}$ would range from approximately 14 percent in the smaller basins affected by Segment 6 of the Southern Alternative to 2 percent in McDonnell Creek and Siebert's Creek at Segment 1, which is common to all action alternatives. Operation of Segment 6 of the Southern Alternative would cause a greater proportion of increase in total stormflow in Bell Creek and Johnson Creek than would operation of Segments 9 and 11 or 12 of the Mid-Southern Alternative or Segments 8 and 10 of the New Mid-Southern Alternative. The greater impact of the Southern Alternative on these creeks is due to the upstream position and thus smaller drainage basins relative to the other alternatives. As with the calculation of $Q_{ss}$, the main element of uncertainty in determining $Q_{ss*}$ is $C_s$, which probably is known to no better than a factor of 2.

## 3.0 SURFACE WATER QUALITY

The effect of operation of the various alternatives on surface water quality was calculated using methods presented in the Highway Water Quality Manual (HWQM) (WSDOT, 1988). The pollutants of concern which are addressed in HWQM are total suspended solids (TSS), zinc (Zn), copper (Cu), nitrate plus nitrite ($NO_3+NO_2$), total Kjeldahl nitrogen (TKN), and total phosphorus (TP). Annual pollutant loadings, expressed in pounds per year, were calculated for basins and road segments. Additional calculations based on flow dilution were performed as well.

## 3.1 MEASURED WATER QUALITY DATA

Water quality data were unavailable for any of the surface drainages with the exception of Sequim Bay Tributary. In this stream on November 16, 1977, the dissolved nitrate concentration was 0.7 mg/L, the dissolved lead concentration was 10 $\mu g/L$ and the dissolved cadmium concentration was 2 $\mu g/L$.

## 3.2 CALCULATED ANNUAL POLLUTANT LOADING

Annual pollutant loadings, expressed in pounds per year, were calculated for basins and road segments. The calculations for pollutant loadings from basins were based on area and ground cover type, using area-specific loading rates as presented in the HWQM for each pollutant considered. The TSS loads from road segments were calculated based on length of road segment, number of average daily trips (ADT) in the design year of 2015 A.D. and hours per year of wet roadway. Pollutants other than TSS were calculated from TSS loads using coefficients presented in the HWQM. The calculations assume no mitigation factor due to the use of vegetated swales or other methods of sediment removal.

In general, the pollutants which would be significantly increased due to road operation were TSS and Zn. Estimated increases in loadings of Cu, ($NO_3$ + $NO_2$), TKN and TP were in no case greater than two percent.

The effect of expansion of SR 101 west of the Dungeness River on Siebert's and McDonnell Creeks was estimated as less than or equal to 3 percent for all pollutants. Operation of the New Mid Southern, Modified Mid Southern, and Mid Southern alternatives would cause relatively similar increases in TSS (30-36 percent), and Zn (19-24 percent) in the West Fork of Bell Creek. In comparison, operation of the Southern Alternative would increase TSS by 19 percent, and Zn by 7 percent in Bell Creek. Operation of all alternatives including No Action would increase TSS in Johnson Creek by 4-7 percent, with corresponding increases in Zn.

The use of mitigation measures such as vegetated swales for sediment removal could remove up to 80 percent of the road pollutant loadings, based on design criteria in the HWQM.

The analyses presented above are dependent to a great extent on contributing road segment length. During the design phase, positions of culverts, ditches and other structures can be determined so that water quality impacts are minimized.

## 4.0 FLOODPLAINS

The regional area of Sequim, Washington is classified by the Federal Emergency Management Agency (FEMA) as a Zone 3. No special flood hazard areas exist in this area. The proposed project alternatives thus will have no impact to significant floodplains or flooding.

## 5.0 REFERENCES


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