Appendix B
Preliminary Hydrology and Hydraulics Report

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Ketchikan to Shelter Cove Road

Preliminary Hydraulic/Hydrologic Analysis

Alaska Department of Transportation and Public Facilities
Southeast Region Materials Section
Juneau, Alaska

December 2011

Prepared: ______________________
Robert Trousil, PE
Regional Hydraulics Engineer
Southeast Region

STATE OF ALASKA
49TH
12/19/2011
Robert E. Trousil Jr.
PE 12504
REGISTERED PROFESSIONAL ENGINEER

Approved: ______________________
Bruce Brunette, PE
Regional Materials Engineer
Southeast Region

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ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES

Ketchikan to Shelter Cove Road

Ketchikan, Alaska

Preliminary Hydraulic/Hydrologic Analysis

Heckman Lake Tributary Complex (AK DOT&PF, September 2011)

Prepared by:

SE Region Materials Section

December 2011

Abstract: *A preliminary investigation considered the hydrologic and hydraulic elements associated with four (4) proposed alignments. Watershed/catchment areas were estimated and unit area runoff coefficients were determined. Stream-crossing frequency analyses provided a means to estimate the number of crossings potentially required for each alternative. Land slope values were used to approximate hydrological conditions. Application of the 50-yr flood flow discharge provided a means to estimate relative runoff potential. A cursory analysis provides span lengths and minimum number of bridges. The preliminary hydraulic/hydrologic analysis does not recommend one alternative over another. Additional field verification/reconnaissance is required to ascertain bridge/culvert designs once a preferred route is selected.*

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Conclusions

A preliminary analysis of the hydraulic and hydrologic character for various alignments associated with the Shelter Cove Road Project, Revillagigedo Island, SE Alaska, is presented, (Figure 1). This memorandum provides an overview of the hydrologic features that are anticipated to be encountered, in addition to identifying major hydraulic design elements that are anticipated during construction of the roadway. Four (4) route alternatives, also shown in Figure 1, were examined.

The area of investigation is extensive, and as such, a detailed evaluation of hydrologic and hydraulic configurations for all possible alignments and sub-alignments, is not feasible at this stage of investigation. Once a final alignment and its alternate are selected, a more detailed, design-level investigation and analysis can proceed. Thus, a complete inventory of existing or proposed culvert and/or bridge crossings is not provided.

All alternatives will be confronted with unique hydrologic and hydraulic challenges, given the considerable precipitation this area receives and the geomorphologic nature of the terrain. The ease or difficulty associated with the construction of drainage and stream conveyance structures are not fully known, but shall be assessed and verified by field reconnaissance, review of existing data, and application of standard hydrological methods at a future date.

For existing logging road segments, there will be a number of fish stream crossings that will require upgrading, and/or enhancement. It is anticipated that culvert designs will be finalized, or otherwise revised, as as-builts are obtained. A detailed site reconnaissance will be required by both Alaska Department of Fish and Game (AK F&G) and Alaska Department of Transportation and Public Facilities (AK DOT&PF) staff to characterize fish habitat and hydraulic requirements to provide fish passage in candidate streams.

A cursory unit area runoff analysis was performed, which attempts to estimate stream discharge for a given catchment area. These data are presented graphically, (Figures 3 through 6) distinguishing those areas of relatively high discharge. The results will be useful to initially identify regions prone to high runoff, requiring significantly larger and/or a higher number of drainage related structures then may be required along other alignments.

Runoff analyses indicate that all alignments are more or less subject to the same hydrologic challenges; only the form of these challenges appear to vary. Routes that are predominantly 'high' (Alternative 1) are likely to cross extensive muskeg and other surface water features, such as those encountered near Leask Lake and the Heckman Lake tributary complex. In contrast, 'low' alignments (Alternatives 2, 3 and 4) tend to encounter stream systems that are entrenched and have significantly larger catchment areas. This implies the need for more frequent stream crossings on these lower alignments. Challenges associated with 'low' alignments may be offset by longer and more complex crossings across wider tributary complexes on the higher routes.

Despite these differences, and the challenges unique to any particular route being considered, there does not appear to be an alternative that is more preferred than another based on the preliminary hydrologic/hydraulic analysis.

It is anticipated that several major bridge structures (greater than 80-ft in length) will be required regardless of which alternative selected. Identifying spans shorter than 80 feet is beyond the scope of this report. The number and the estimated length of these bridge structures was estimated by selecting those catchment areas that were relatively large.

Snow loading on ‘high’ routes are anticipated to be significant, driven by the higher elevations along these alignments. The maximum estimated elevation of ‘high’ (Alternatives 1 and 3) and ‘low’ routes, (Alternatives 2 and 4) are 1089 ft and 542 ft MSL respectively.

Preliminary Hydraulic/Hydrologic Evaluation

Data extraction using GIS query methods resulted in a considerable volume of information for use in a reconnaissance level evaluation of the hydrologic and hydraulic characteristics for the Shelter Cove Road project area. Separate data bases were developed for each of the four (4) proposed alternatives that include the following parameters;

- Centerline Station
- Ground Elevation
- Ground Slope
- Catchment Area
- Wetness Index and
- Direct Insolation

Although not all of the available data was used in the preliminary analysis, estimates of relative flow magnitudes for specific recurrence intervals could be calculated, catchment area size and distribution evaluated, and a cursory categorization of hydrologic conditions made.

Although not specifically analyzed in this technical memorandum, specific environmental conditions that are heavily influenced by climate, i.e. snow pack, are anticipated to play a significant role in the final design and post construction maintenance and operation of the roadway.

Climate

The hydrologic study area encompasses approximately 120 square miles of terrain of moderate to relatively high relief. This portion of southeast Alaska is characterized as a maritime climate. In this climate zone, coastal mountain ranges, coupled with plentiful moisture, produces annual precipitation amounts up to 200 inches. No permafrost exists in the study area.

There are no weather collection stations within the project area that offer definitive climate data. The weather station located at the Ketchikan Airport, (504590) reports average annual precipitation and snowfall depths of 153-inches and 37-inches respectively. Based on anecdotal and published information, these values are likely to be significantly understated for much of the study area. Snow loading on 'high' routes are anticipated to be significant, driven by the higher elevations encountered along these alignments. The maximum estimated elevation of 'high' (Alternatives 1 and 3) and 'low' (Alternatives 2 and 4) routes, are 1089-ft and 542-ft MSL respectively, a difference of over 500-ft vertical.

Mean annual temperatures in southeast Alaska are under maritime influence, with temperature contrasts being much more moderate than in other portions of the state. In the maritime zone, the summer to winter range of average temperatures is from near 60 to the 20's respectively. The minimum mean low temperature for January, used in the regression analysis, ranges from 27^{o}F to 29^{o}F.

The normal storm track along the coastal areas of the Gulf of Alaska exposes these parts of the state to a large majority of the storms crossing the North Pacific, resulting in a variety of wind challenges. Direct exposure to these storms results in the frequent occurrence of winds in excess of 50 mph during all but the summer months.

Watershed/Catchment Basin Analysis

Using GIS data query methods and CAD mapping techniques, individual watersheds, or catchments, within the districts were delineated. Point locations, spaced every 20 feet, were created on each of the respective alignments. Values for catchment area were processed from the digital elevation model (DEM) for these stations and exported for evaluation. Catchment areas, defined as that portion of the watershed located upslope from the roadway, were determined along all four (4) proposed alignments, (Figure 1).

In addition, a unit area peak flow analysis was performed, utilizing existing linear regression data and climate information available for the surrounding area. The unit area peak flow is given in units of cubic feet per second per square mile, (CFSM) and is used to perform a *reconnaissance-level* estimate of the discharge potential at defined points along the roadway alignment. This is determined by multiplying the catchment area by the appropriate unit area runoff value. Table 1 summarizes the unit area discharge potential for a given recurrence interval for large and small watersheds.

In addition, the centerline elevation of the roadway (ft) was plotted together with the catchment area. The resultant plots (Figures 2 through 5) graphically depict the relative magnitude of flows associated with a 50-yr flood event along a particular alignment.

A variety of hydrological models will be used to verify the magnitude of flood flows for a given recurrence interval once an alignment is chosen and the project progresses to design. Application of regression equations will likely be appropriate to estimate flood flows for basins that meet the minimal watershed area threshold (0.720 mi^2) established by the USGS. Watershed areas that fall below this established threshold will require additional evaluation using other runoff models and/or adjusted unit area peak flow values.

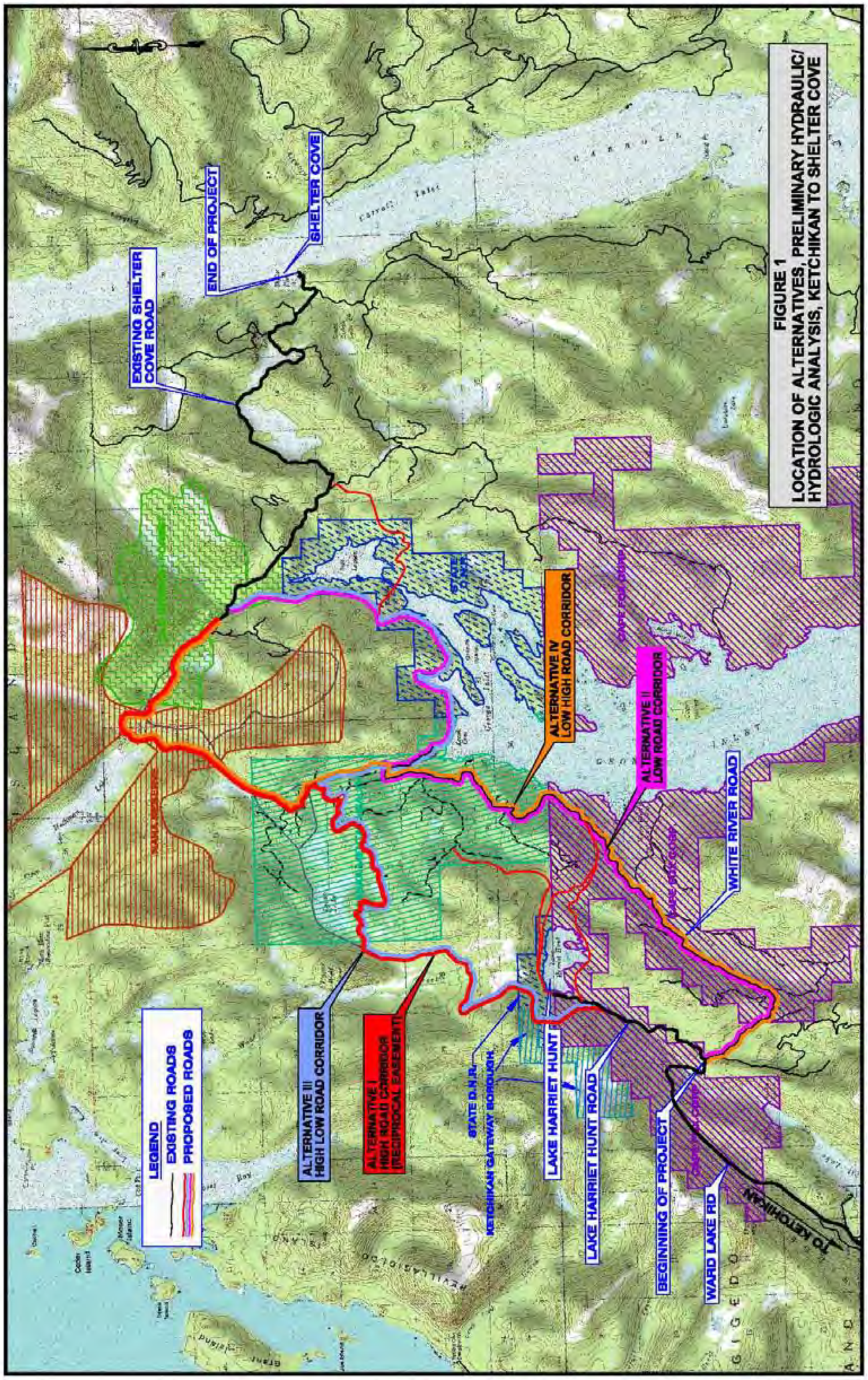

FIGURE 1
LOCATION OF ALTERNATIVES, PRELIMINARY HYDRAULIC/ HYDROLOGIC ANALYSIS, KETCHIKAN TO SHELTER COVE

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Table 1. Ketchikan Unit Area Annual Flow Frequency Analysis [(1)]

USGS PeakFQ (Pearson Log III) [(3)]								
USGS STATION NO	Drainage Name	Drainage Area (mi^2)	.5 RI 2 yr RP	.04 RI 25 yr RP	.02 RI 50 yr RP	.01 RI 100 yr RP	.005 RI 200 yr RP	.002 RI 500 yr RP
15059500	Whipple Creek near Ward Cove	5.29	1030	2840	3360	3910	4480	5280
15060000	Perserverance Creek near Wacker, AK	2.81	440	668	717	763	808	866
15067900	Upper Mahoney Lake outlet near Ketchikan	2.03	609	1130	1260	1390	1520	1700
15068000	Mahoney Creek near Ketchikan	5.70	1180	2540	2870	3210	3540	3990
15070000	Swan Lake near Ketchikan	36.50	3040	4940	5390	5830	6270	6850
15072000	Fish Creek near Ketchikan	32.10	2850	4500	4890	5270	5640	6140
15074000	Ella Creek near Ketchikan	19.70	1180	1720	1840	1960	2070	2230
15076000	Manzanita Creek near Ketchikan	33.90	2780	4490	4860	5210	5550	5980
15078000	Grace Creek near Ketchikan	30.20	2770	4150	4450	4740	5010	5370
AVG CFSM [(2)]			140	268	300	333	365	410

USGS Regression								
USGS STATION NO	Drainage Name	Drainage Area (mi^2)	Q_2 (cfs)	Q_{25} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)	Q_{200} (cfs)	Q_{500} (cfs)
15059500	Whipple Creek near Ward Cove	5.29	1120	2180	2440	2690	2940	3270
15060000	Perserverance Creek near Wacker, AK	2.81	396	696	769	841	912	1010
15067900	Upper Mahoney Lake outlet near Ketchikan	2.03	384	673	742	810	877	964
15068000	Mahoney Creek near Ketchikan	5.70	832	1440	1590	1740	1880	2070
15070000	Swan Lake near Ketchikan	36.50	4420	7620	8390	9150	9890	10900
15072000	Fish Creek near Ketchikan	32.10	2600	4530	5000	5480	5950	6570
15074000	Ella Creek near Ketchikan	19.70	1610	2830	3130	3430	3720	4120
15076000	Manzanita Creek near Ketchikan	33.90	3370	5780	6370	6950	7520	8280
15078000	Grace Creek near Ketchikan	30.20	3060	5250	5790	6310	6840	7530
AVG CFSM			130	231	256	280	304	336

Weighted Estimate of PEAKFQ and USGS Regression								
USGS STATION NO	Drainage Name	Drainage Area (mi^2)	.5 RI 2 yr RP (csfm)	.04 RI 25 yr RP (csfm)	.02 RI 50 yr RP (csfm)	.01 RI 100 yr RP (csfm)	.005 RI 200 yr RP (csfm)	.002 RI 500 yr RP (csfm)
15059500	Whipple Creek near Ward Cove	5.29	1040	2710	3160	3610	4070	4710
15060000	Perserverance Creek near Wacker, AK	2.81	439	671	722	772	821	884
15067900	Upper Mahoney Lake outlet near Ketchikan	2.03	593	1030	1140	1240	1340	1480
15068000	Mahoney Creek near Ketchikan	5.70	1170	2410	2700	2990	3280	3660
15070000	Falls Creek near Ketchikan	36.50	3070	5110	5610	6100	6590	7230
15072000	Fish Creek near Ketchikan	32.10	2850	4500	4890	5270	5650	6150
15074000	Ella Creek near Ketchikan	19.70	1190	1800	1950	2100	2240	2430
15076000	Manzanita Creek near Ketchikan	33.90	2790	4580	4970	5350	5720	6190
15078000	Grace Creek near Ketchikan	30.20	2790	4280	4630	4960	5290	5720
AVG CFSM			140	259	288	317	346	385

Ketchikan Area Small Watersheds USGS PEAKFQ (Pearson Log III)								
USGS STATION NO	Drainage Name	Drainage Area (mi^2)	Q_2 (cfsm)	Q_{25} (cfsm)	Q_{50} (cfsm)	Q_{100} (cfsm)	Q_{200} (cfsm)	Q_{500} (cfsm)
15059500	Whipple Creek near Ward Cove	5.29	195	537	635	739	847	998
15060000	Perserverance Creek near Wacker, AK	2.81	157	238	255	272	288	308
15067900	Upper Mahoney Lake outlet near Ketchikan	2.03	300	557	621	685	749	837
15068000	Mahoney Creek near Ketchikan	5.70	207	446	504	563	621	700
AVG CFSM			215	444	504	565	626	711

Mean (all estimates except small drainages)						
AVG CFSM	137	253	281	310	338	377

Notes: *(1) Water Resources Invetigations Report 03-4188*
(2) CSFM = Cubic feet per second per square mile of watershed
(3) Per Bulletin 17-B

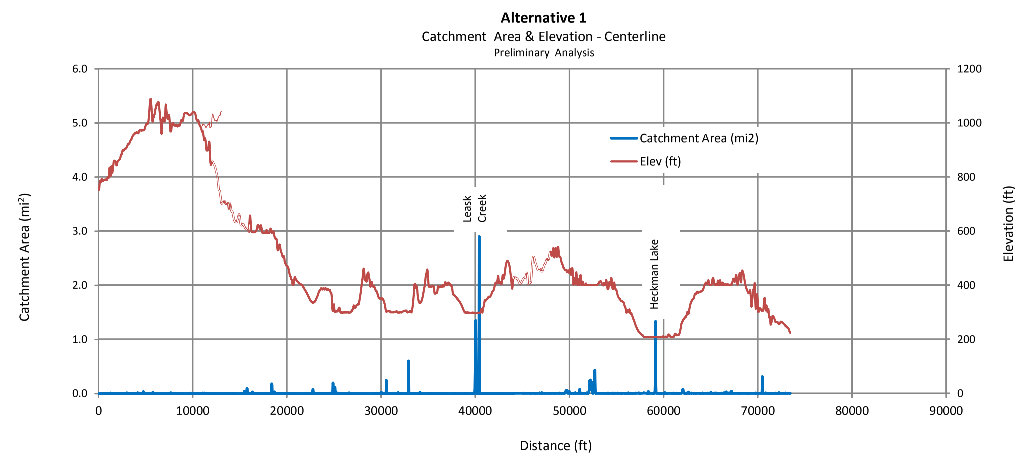

Figure 2. High Road Corridor (Reciprocal Easement)

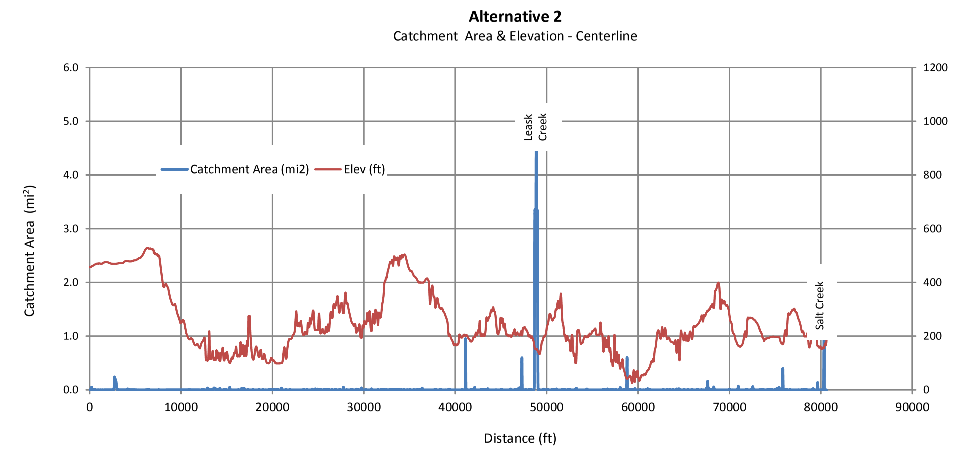

Figure 3. Low Road Corridor

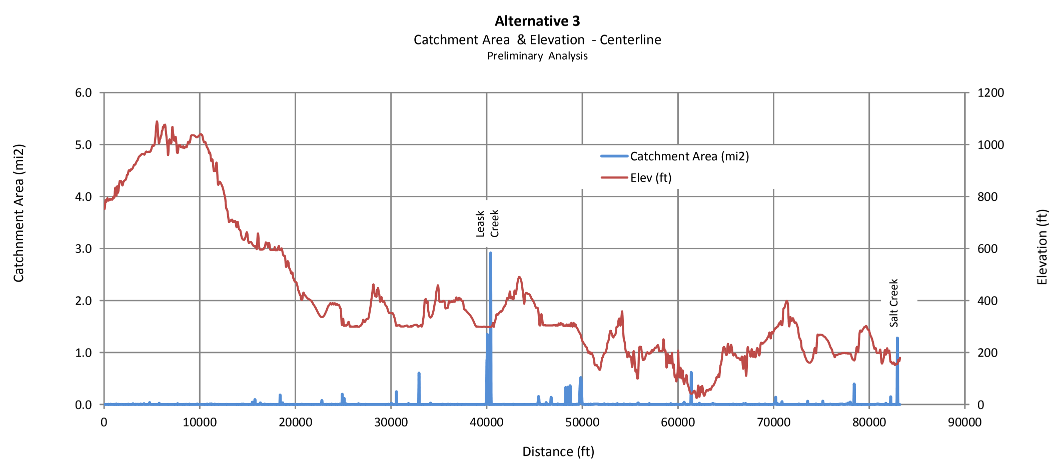

Figure 4. High-Low Road Corridor

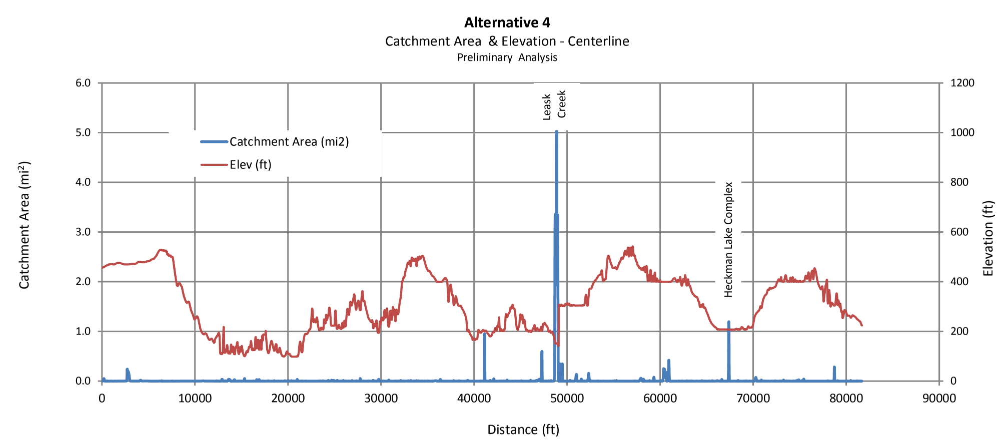

Figure 5. Low-High Road Corridor

Figures 2 through 5. Catchment Area and Elevation Plot, Alternatives 1 through 4, Ketchikan to Shelter Cove Road

Hydrology/Hydraulics

Upon the selection of a preferred alternative, various hydraulic tools, including HEC-RAS, HY-8, FishXing, CAD and GIS shall be used to further analyze major stream crossings and localized drainage requirements associated with stormwater runoff and other minor stream/drainage systems. Specific crossings that are large and/or are fish passage sensitive shall require additional topographic survey to adequately design these structures.

Detailed field evaluations will be required to verify hydraulic conditions along the preferred alignment including stream width assessment, the characterization and measurement of fluvial geomorphologic entities, evaluation of sediment/bedload conditions, assessment of debris flow potential and verification of fish passage requirements.

Figures 2 through 5 represent plots of the roadway elevation and the corresponding catchment area for each alternative. The magnitude of the catchment area is directly proportional to the runoff potential at that point on the alignment. ‘Low’ elevation alternatives cross larger catchment areas, while the opposite is true for the ‘high’ elevation alternatives. This does not necessarily indicate that fewer bridge structures are required on high routes, or that more would be anticipated on lower ones. Local conditions will dictate the most suitable and practical structure required to cross a particular topographical and/or hydrological challenge, including muskeg, entrenched, intertidal and stream/river systems.

Three general types of hydraulic/hydrologic categories were developed in an attempt to determine a decision matrix for each of the four (4) alternatives. Land slope values were extracted from the projects digital elevation model (DEM) and analyzed utilizing GIS techniques at points along each alignment. These values were used as an indication of the general gradient of the hydrologic system. Muskeg and marsh type systems, as described below, were assumed to have localized land slopes of less than 1%, while entrenched stream systems used slope values between 1% and 10%. Slopes greater than 10% were considered ‘undifferentiated’, as no other criteria was available to further describe and characterize these hydrologic units.

The first category includes those systems which are characterized by the existence of defined streams systems, which are prominent in the lower portions of the watershed. They have moderate channel gradients, are typically entrenched and confined, and thus have narrow floodplains. Pool spacing is irregular, and in some cases, controlled by bedrock. Being low in the watershed, (larger catchment areas), these hydrologic systems may have higher energies and discharge rates. The symbol ‘***ES***’ (Entrenched Stream) is used to identify this category.

A second hydrologic category that may assist in characterizing the anticipated hydrologic conditions to be encountered by the proposed alignments was developed. This category largely impacts those alternatives that are considered ‘high’, or any combination of both ‘high’ and ‘low’ alignments. Stream types generally consist of multiple, highly interconnected channels with broad floodplains. Landforms are typical of marshes, with system base levels controlled by lakes. They are typically associated with the extensive muskeg environments that prevail in the project area. Such systems create unique hydrologic and construction challenges that are different from those found in the ***'ES'*** hydrologic system. The symbol '***M***' (Muskeg/Marsh) is used to identify this category.

A third category identifies those systems that cannot be reasonably defined within the filtering criteria used to define the other two categories defined above. Further hydrologic evaluation of the project area will more fully characterize the type of hydrologic/hydraulic conditions that are anticipated to be encountered once an alternative is selected. The symbol '***U***' (Undifferentiated) is used to identify this category.

Table 2 presents a summary of the physical parameters associated with each alternative. A hydrologic category, with the estimated percentage of the alignment being affected is presented for each alternative.

Table 2. Summary of Physical Attributes, Alternatives 1 through 4.

Alternative ID	Description	Alternative Length (ft)	Min Elev (ft)	Max Elev (ft)	Total Watershed Area (mi^2)	Hydrologic Category 'M' (1)	Hydrologic Category 'ES' (2)	Hydrologic Category 'U' (3)
1	'High'	73,440	208	1089	28	8%	21%	71%
2	'Low'	80,620	25	529	76	6%	18%	76%
3	'High-Low'	83,200	25	1089	36	5%	19%	75%
4	'Low High'	81,680	98	542	80	10%	23%	67%

Hydrologic Category Notes:

(1) ***ES****: Entrenched Stream System*

(2) ***M****: Muskeg/Marsh Stream System*

(3) ***U****: Undifferentiated Stream System*

The percentages shown in Table 2 appear to be essentially equal, indicating that there does not appear to be a preferred alternative based on hydrologic category.

Catchment Area

The size and number of watersheds or catchment areas which occur above any particular alternative were identified to better understand the nature of the hydrologic system, and subsequently, the character of the stream crossing which may be required.

Table 3 provides a summary of the estimated number of catchment areas for each of the proposed alignments. The size of the catchment area can be used as an approximation as to the relative frequency a road may encounter a significant stream crossing. As shown in the table, alternates traversing higher elevations generally encounter fewer and smaller sized catchment basins, (Alternative 1) than those which traverse the land at lower elevations, (Alternatives 2, 3 & 4).

Table 3. Catchment Area Summary.

	Catchment Area, mi^2								Total
	< 0.25	**< 0.50**	**< 1.00**	**< 2.00**	**< 3.00**	**< 4.00**	**< 5.00**	**> 5.00**	
Alternative ID	**Estimated Number of Catchment Areas**								
1	3654	6	6	5	1	0	0	0	**3672**
2	3999	6	6	6	5	5	3	1	**4031**
3	4128	16	10	5	1	0	0	0	**4160**
4	4044	11	4	6	5	5	3	1	**4079**

It should be noted that over 99 percent of all catchment basins for all alternatives appear to be less than ¼ square mile in size. Since the total number of catchment areas extracted from the data is considered to be theoretical, they are likely overstated. However, Table 3 provides a reasonable, relative representation of the general basin characteristics for comparison purposes.

Using a catchment area threshold value of 3.0 mi^2 to indicate that a 'significant' crossing may required, (such as a bridge or large culvert structure), it appears that 'low' route Alternatives 2 and 4 have the greatest potential in this respect. Although not qualitatively obvious, it appears the hydrologic/hydraulic challenges for those alternatives that have a 'high' alignment component associated with them appear to be essentially equal to those for the lower alternatives.

Bridges

The number of bridges that may be required can only be crudely estimated for each of the alignments. It is intuitive that more bridge structures would be required on alternatives; 1) with the highest number of catchment basins, and 2) with catchment basins that are greater than three (3) square miles. Based on these criteria, it was anticipated that more bridges would be required on the 'low' routes.

However, multiple bridge-type crossings may be required in more complex hydrologic regimes, such as found in the Leask Lake and Heckman Lake Tributary Complexes, which are located along 'high' routes. For 'low' routes, the nature of the terrain may require the utilization of bridges even for smaller streams that are deeply entrenched. Large fills may be warranted in lieu of bridges for any alternative. The hydrologic combinations that ultimately determine bridge configurations are complex, necessitating field reconnaissance to ascertain bridge crossings along any one alignment.

For planning purposes, it is anticipated that several major bridge structures (greater than 80-ft in length) will be required regardless of which alternative selected. Identifying spans shorter than 80 feet is beyond the scope of this report. The number and the estimated length of these bridge structures was estimated by selecting those catchment areas that were relatively large. A bridge summary, representing the minimal requirements for each alternative, is presented in Table 3. *It must be stressed that these findings are considered reconnaissance level and the actual number of bridges required and their length are very likely to be understated*.

Table 4. Preliminary Bridge Summary, Ketchikan to Shelter Cove Road.

Alternative ID	Bridge ID	Estimated Length (ft)	Hydrologic Description
1	1-1	180	Leask Creek Complex, Muskeg-Marsh, (1)
	1-2	80	Leask Creek Complex, Muskeg-Marsh
	1-3	140	Heckman Lake Tributary Complex, Muskeg-Marsh, (1)
	Total	***400***	
2	2-1	100	Leask Creek, Entrenched Stream
	2-2	100	Salt Creek, Entrenched Stream
	Total	***200***	
3	3-1	180	Leask Creek Complex, Muskeg-Marsh, (1)
	3-2	80	Leask Creek Complex, Muskeg-Marsh
	3-3	100	Salt Creek, Entrenched Stream
	Total	***360***	
4	4-1	100	Leask Creek, Entrenched Stream
	4-2	140	Heckman Lake Tributary Complex, Muskeg-Marsh, (1)
	Total	***240***	

(1) The estimated length does not necessarily reflect the need for a single bridge span with a length equal to 180-ft. A series of bridges, (or significant sub-excavation and fill), is likely required in these muskeg-marsh zones. The total span length (180-ft) may reflect the need for two bridges, one with a span of at 100 ft, the other 80-ft.

Bridge installations shall be evaluated and designed by the Bridge Section. The Southeast Region hydraulics engineer shall provide support in identifying and evaluating these structures as requested.

Culverts

Table 1120-1 AK DOT&PF Preconstruction Manual, identifies design flood frequencies to be used when sizing hydraulic structures. The Shelter Cove Road is anticipated to be a very low volume, local road with an average daily traffic volume of less than 400 vehicles.

Based on this classification, Table 4 provides a summary of applicable criteria that may apply.

Table 4. Design Flood Frequency Criteria (1)

Type of Structure	Design Frequency Exceedance Probability (2)
Culverts in designated flood hazard areas	100 years / 1%
Culverts on secondary highways with high average daily traffic volumes	50 years / 2%
Culverts on secondary highways of less importance	10 years / 10%
Channel changes in designated flood hazard areas	100 years / 1%
Channel changes for less important secondary highways	25 years / 4%
Side ditches	10 years / 10%
Bridges in designated flood hazard areas	100 years / 1%
Bridges on all highways	50 years / 2%

(1) Source: Alaska Preconstruction Manual, January 1, 2005
(2) The exceedance probability is the chance in any given year that the flood event would occur.

These criteria indicate that culverts installed along this route would likely qualify using the 10 year criteria; however, due to the remoteness of culvert locations, lack of alternate routes and the significant costs associated with culvert failure due to overtopping, it is recommended that culvert structures be designed to the 50 year event. It should be noted that all bridges require the design to accommodate a design frequency of 50-years.

Preliminary culvert recommendations along the proposed alignments and existing roadways shall be identified once the primary alignment is selected. Culvert material type will be assessed at all culvert crossings. It is recommended that drainage systems utilize HDPE pipe up to 48-inches. Material type for crossings requiring the culvert rise to be greater than 48-inches, hydraulically complex drainage systems, and fish passage pipes, will be evaluated on a case by case basis. Recommended materials are aluminum of various configurations, including circular, pipe arch and structural multi-plate. Depending on stream gradient and other hydraulic considerations, baffle systems may be required to promote fish passage.

The discharge rate for a particular catchment area can be *estimated* by multiplying the unit area flow frequency value for a given recurrence interval by the catchment area. From Table 1, the average unit area flow for a 50-yr event is 281 CSFM. Applying this factor to a catchment area of ¼ mi^2, the anticipated flow rate is estimated to be 70 cfs. Excluding accommodation for fish passage, this *approximately* equates to a minimum culvert size of 60 inches. The calculation only serves as an indication that most culvert structures may be large.

Tidal Influence

The vast majority of stream crossings are not anticipated to be under tidal influence. The extreme high water elevation (EHW) and mean higher high water elevation (MHHW) are 21.3 and 15.4 feet, respectively.

Floodplain

There are no jurisdictional floodplains within the project. The design of all culvert and bridge structures will consider the hydraulic character of flood flows associated with recurrence intervals of 2, 25, 50, 100, 200 and 500 yrs.

Fish Passage

Streams catalogued by the Alaska Department of Fish and Game will be identified and evaluated based on criteria implemented through the memorandum of agreement between the Alaska Department of Fish and Game and DOT&PF, 2002. A current catalog of anadromous fish streams is provided in Section 3.8.7 of the Reconnaissance Report.

Additional fish streams may be identified during the reconnaissance phase of the hydrologic study that have not been previously catalogued. The presence of fish, along with the quality and of habitat upstream of the culvert, will affect the design of culverts and bridges in designated fish streams. Other factors required to properly address and design for fish passage include;

- The design fish species and fish length(s),
- Habitat type,
- Time of year fish passage is required,
- Type of stream (840 or 870). ***840*** streams refer to the evaluation of resident fish streams (AS 16.05.840) and uncatalogued anadromous fish streams. ***870*** streams are cataloged anadromous fish streams and,
- Qualification of the stream as an anadromous spawning and high-value rearing site.

Bibliography

Alaska Department of Transportation and Public Facilities, Highway Drainage Manual, 1995 1st Edition; Updated 2006.

Alaska Department of Transportation and Public Facilities, Preconstruction Manual, January 2005.

Alaska Department of Transportation, Materials Section, *Preliminary Geotechnical Reconnaissance Report*, March 2008.

FHWA Culvert Hydraulics Program HY-8, Version 7, March 2007.

FHWA Hydraulic Design of Culverts, HDS #5, Revised May 2005.

Watershed Modeling System, V8.0, Build Date 8/7/07 www.emrl.byu.edu/wms.htm

Curran, J. H., Meyer, D. F., and Tasker, G.D. *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada*. USGS 2003, 101 pgs