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MINERAL MATERIAL EXPLORATION

AND

EXTRACTION

SPECIFIC CRITERIA AND METHODS OF HYDRAULIC EVALUATION

Prepared for

Northwest Alaskan Pipeline Company

by

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1.0 INTRODUCTION

1.1 Purpose

The following report presents the specific criteria for determining the hydraulic effects of extraction of mineral materials from the riverine environment on adjacent facilities, natural resources and river hydraulic parameters. Adjacent facilities or structures consist of permanent structures such as pipelines, bridges, spur dikes, revetments and roads. Either qualitative and/or quantitative evaluation will be made of all proposed sites to determine short term and long term effects. Methods for implementing these criteria are outlined in detail, and an example to demonstrate the evaluation method is included for a potential mineral mining site on the Sagavanirktok River.

1.2 Levels of Evaluation

Dependent upon the stream type and the location of the mining operation in relation to the thalweg of the stream, three levels of analysis will be utilized for considering potential hydraulic effects of mining upon the river morphology. In general, stream types may be classified into four basic patterns: braided channels, split channels, meandering channels, and sinuous channels. The split channel type may occur within the meandering or sinuous channel configurations. Figure 1 illustrates the four basic river channel patterns commonly delineated. In addition, mineral material site location may be divided into four areas: alluvial fans, terrace, active floodplain, and on-river. Figure 2 illustrates these four areas.

All proposed mineral material mining site evaluations will be assessed in relation to bank stability within the reach (whether banks are stable with regard to erosion, mass wasting, sluffing,

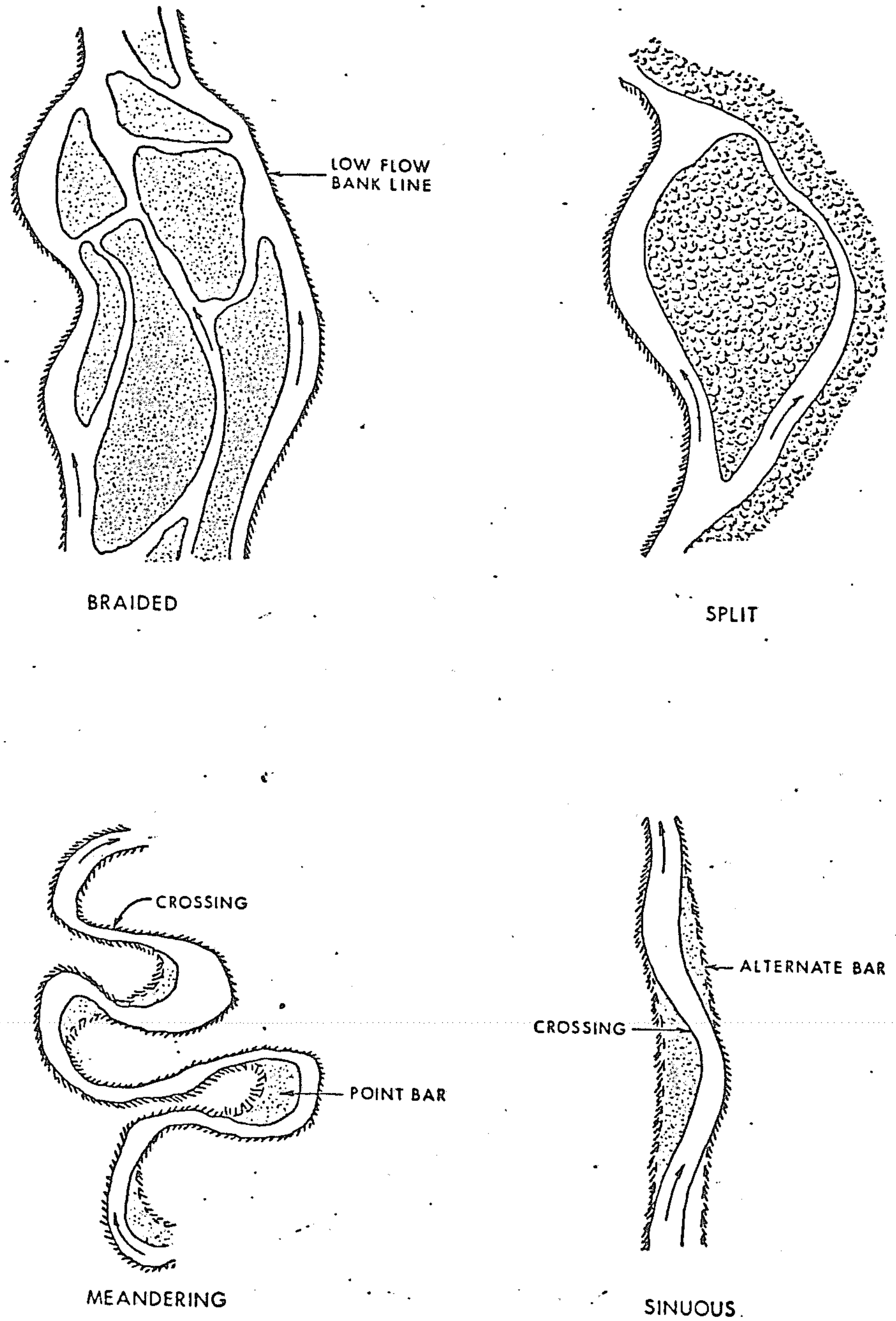

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FIGURE 1 RIVER CHANNEL PATTERNS

ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

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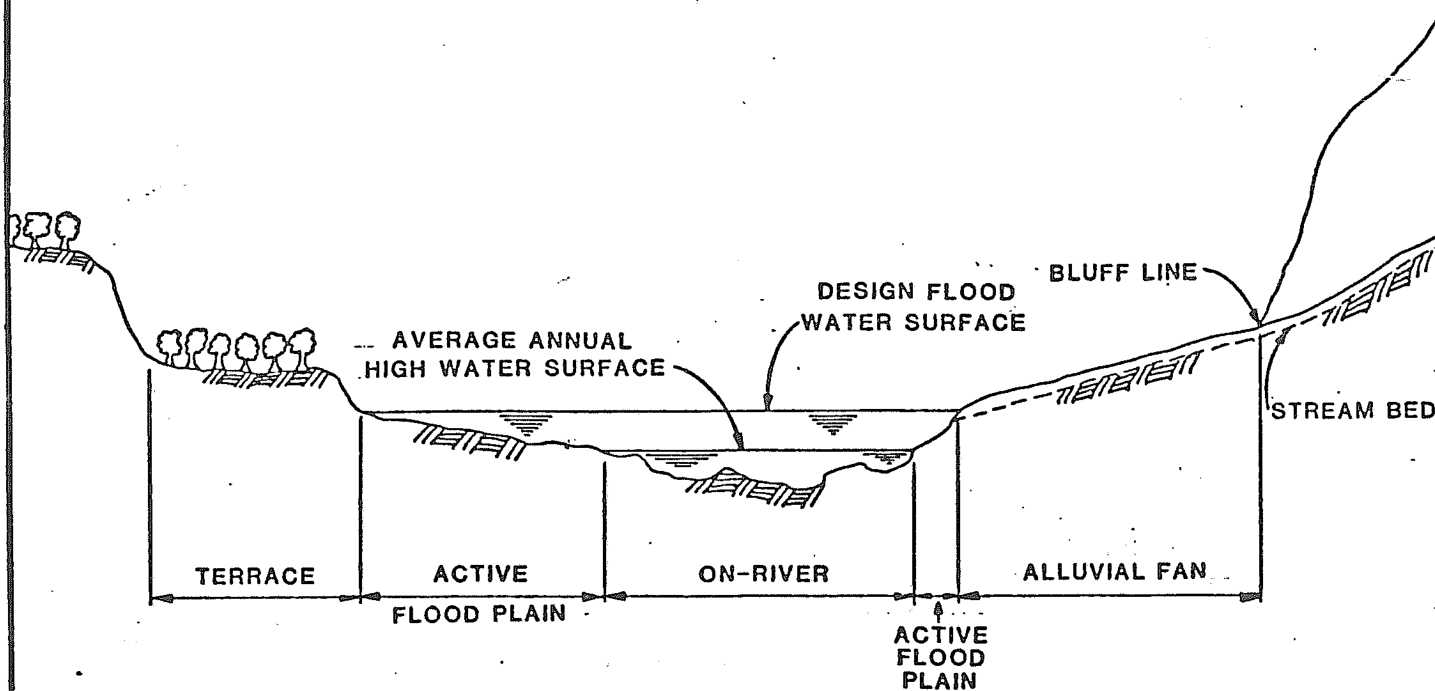

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FIGURE 2. AREAS FOR POTENTIAL MINERAL MATERIAL SITE LOCATIONS

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or undercutting); existing buffer strip protection against lateral migration (whether banks are protected by well established vegetation, indicated by the age of the vegetation); the possibility of development of new main channels (whether low areas exist within the active floodplain that may become active channels following passage of the design flood); and the associated potential changes in thalweg elevations (the effect of upstream or downstream tributary inflows that may deposit large sediment loads during the design flood).

All levels of evaluation will consider the presence of icings and/or aufeis and the hydraulic analysis shall be conducted under observed conditions of maximum ice build-up. This information can be found in References 1, 2, 3, 4, 5, 6, 7, and 8. Dependent upon the quantity of material to be mined at the site and the anticipated removal schedule, the location and size of stockpiles shall be considered within the analysis, in conjunction with the existence of temporary access roads during the advent of the design flood. Stockpiles, if necessary, shall be located and designed to ensure that flood flows are diverted away from banks and adjacent structures, and shall be considered on a site-specific basis.

A summary of three levels of evaluation follows:

1.2.1 M_1 Evaluation

This basic level of evaluation will be applied to all potential material sites and will be the only initially required evaluation on terrace sites where the lowest excavation level is above the design flood maximum stage.

1.2.2 M_2 Evaluation

This level will involve the quantitative evaluation of the principal hydraulic parameters and sediment discharge computation. For potential sites where mining operations may noticeably change the physical cross sectional parameters (depth, top width, bottom width, or bed slope) within a reach, average and peak velocities will be computed for the pre- and post-mining conditions for the design flood discharge. Velocity or bed slope changes which occur between pre- and post-mining conditions will be evaluated with regard to upstream, downstream, and bank stability changes. The extent of the changes will be evaluated to determine if permanent regime changes will occur in the upstream or downstream reaches. Bed material loads for the pre- and post-mining conditions will also be computed at each site. Percentage changes which occur in the hydraulic parameters will be evaluated to determine if they are greater than 25 percent.

?

sounds substantial

how defined?

1.2.3 M_3 Evaluation

This level will involve the quantitative evaluation of potential scour along with the principal hydraulic parameters and sediment discharge. Using the design flood discharge, scour depth computations will be conducted for the pre- and post-mining conditions. An evaluation of the bed slope and morphological changes will be conducted for the two conditions. A comparison of the bed material load (for the peak of the design flood discharge) for the pre- and post-mining conditions will be conducted at selected cross sections within the proposed mining areas.

1.3 Application of Evaluation Levels

A flow chart for delineating the required level of analysis is given in Figure 3.

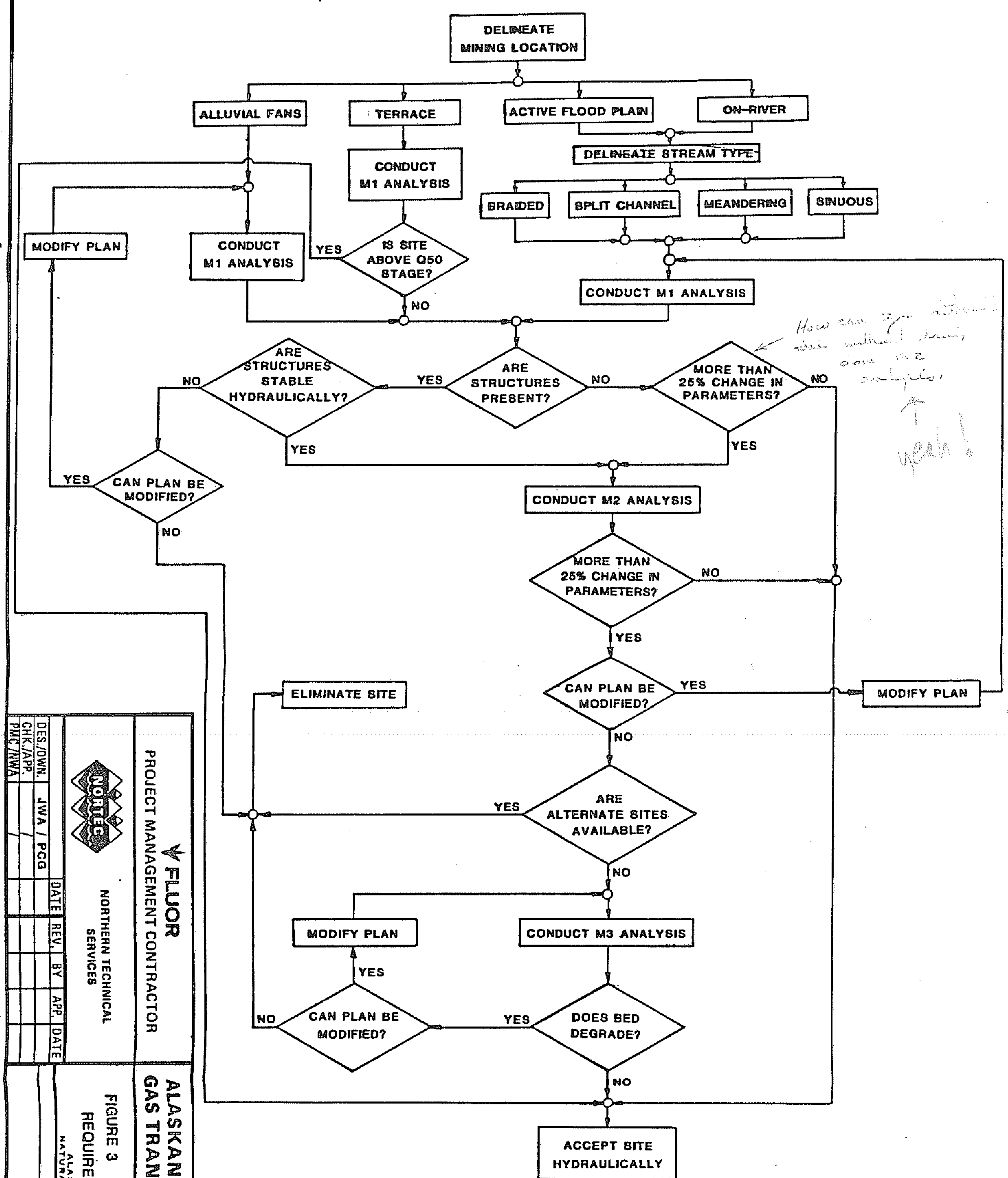

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FIGURE 3 SELECTION OF REQUIRED ANALYSIS

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The basic level of evaluation (M_1) will be applied to all potential mineral material sites, while the second (M_2) and third (M_3) levels of evaluation will be applied at locations where permanent hydraulic parameter changes may be induced. Irrespective of the stream type and site location, the second level of evaluation shall be used if permanent structures exist in the vicinity of the proposed sites and sufficient data are available at the site. The stability of the structures shall be evaluated in relation to possible permanent morphological changes induced by the mining activity.

1.3.1 M_1 Evaluation

yeah!

This level of evaluation will be applied to all material sites as indicated in Figure 3. If, with the basic analysis, the maximum stage of the design flood is below the excavation level on terrace sites, no additional hydraulic analysis will be conducted, and the site shall be recommended for acceptance. If the excavation level is below the maximum design flood stage and the site is hydraulically unacceptable, the following remedial measures will be taken.

A. The site will be revised and re-evaluated at this level until acceptable.

B. The site will be rejected.

C. The next level of analysis will be used to better define the changes in hydraulic parameters if the site is required, but is not acceptable following Step A.

1.3.2 M_2 Evaluation

This evaluation method will be applied when:

A. The site is hydraulically unacceptable based on the M_1 level and the site cannot be revised or deleted.

B. Multiple mining sites are proposed.

C. The proposed site is adjacent to an existing site, or an existing structure.

If changes to hydraulic parameters are excessive, the measures listed in Section 1.3.1 will be taken.

1.3.3 M_3 Evaluation

This level of evaluation will be applied when:

A. The site is hydraulically unacceptable based on the M_2 level and the site cannot be deleted.

B. More than 25 percent change in hydraulic parameters is computed within the M_2 analysis.

C. A number of sites are located adjacent to each other in the direction of flow.

If the analysis shows that permanent changes to hydraulic parameters will occur, one of the following measures will be taken:

A. Modifications will be made to eliminate the detrimental effect of the permanent change on the river regime and the environment.

B. The site will be deleted.

1.4 Potential Mineral Material Sites Evaluation Designations

Tables 1 and 2 list the potential mineral material sites and the level of evaluation proposed. The level of effort will be directly dependent upon the actual site location, the presence of existing structures and their hydraulic stability, and existing data availability. The example shown in Section 3.0 illustrates the effects that material excavation will have upon the natural hydraulic parameters of streams such as the Sagavanirktok River.

TABLE 1

POTENTIAL MINERAL MATERIAL SITES

MS#		MS#		MS#		MS#		MS#	
A 4-1	(S)	18-1.1	(S)	35-3.1	(D)	48-1	(OR)	66-1	(OR)
4-2	(S)	A19-1	(S)	35-4	(D)	48-2A	(OR)	66-2	(OR)
4-3A	(S)	A19-1.1A	(S)	36-1	(D)	48-2B	(J)	67-1A	(OR)
4-3B	(S)	19-1.1B	(S)	36-2	(D)	48-4	(J)	A67-1B	(OR)
5-1	(S)	21-1	(EMS)	36-3	(D)	49-1.1	(OR)	67-3.1	(OR)
5-2	(S)	A21-2	(EMS)	36-4	(D)	49-3	(J)	68-1	(OR)
6-1	(S)	22-2	(OR)	36-5	(D)	50-1	(EMS)	68-3	(OR)
6-2	(S)	23-1	(OR)	A37-2	(D)	50-2	(OR)	68-4	(H)
7-1	(S)	24-1	(EMS)	37-3A	(D)	51-2	(OR)	69-3	(OR)
8-1	(S)	25-1	(EMS)	37-3B	(D)	51-2.1	(OR)	70-3	(OR)
10-3	(S)	A29-2	(A)	43-1	(MFK)	53-1.2	(OR)	73-2	(OR)
11-1	(S)	29-3	(OR)	43-4	(OR)	54-2	(OR)	73-3	(OR)
11-2	(S)	30-1	(A)	44-1	(MFK)	55-1	(OR)	73-4	(OR)
12-1	(S)	A30-2	(A)	44-2	(OR)	55-2	(OR)	74-2	(EMS)
12-2A	(OR)	A30-3	(A)	44-3	(OR)	56-1	(OR)	74-3	(OR)
12-2B	(OR)	30-5	(OR)	44-4	(MFK)	58-1	(OR)	75-1	(OR)
12-3	(OR)	31-1	(A)	45-1	(MFK)	58-1.1	(OR)	75-2	(OR)
14-1	(S)	32-1	(OR)	45-2	(OR)	59-2	(OR)	A76-3	(OR)
14-2	(S)	A33-1	(D)	46-1	(EMS)	60-2	(OR)	77-1	(OR)
14-3	(S)	33-2	(EMS)	46-2	(EMS)	61-1	(OR)	78-1	(OR)
15-2	(S)	34-3	(D)	46-3	(OR)	62-1	(OR)	78-2	(OR)
16-1	(S)	34-4	(D)	46-4	(OR)	62-3	(OR)	78-4	(OR)
16-3	(S)	35-2	(D)	47-1	(OR)	63-3	(OR)	79-5	(OR)
18-1	(EMS)	35-2.1	(D)	48-0	(OR)	65-2	(OR)	80-1	(OR)

TABLE 1 (Continued)

MS#		MS#		MS#		MS#	
80-2	(OR)	94-1.1	(T)	A104-3	(T)	118-2	(OR)
82-3	(OR)	94-2	(T)	105-1	(OR)	119-1	(OR)
82-4	(OR)	95-0	(T)	106-1	(RMS)	119-2	(EMS)
83-4	(OR)	95-1	(T)	107-1	(OR)	A120-3	(OR)
85-2	(M)	95-1.1	(OR)	108-1	(OR)	122-1	(OR)
86-1	(M)	95-3	(T)	109-1	(OR)	122-2	(OR)
A86-3	(OR)	96-1	(DE)	109-2	(OR)	123-3	(OR)
87-2	(OR)	96-2	(OR)	A110-1A	(OR)	124-3	(OR)
88-2	(OR)	97-2	(DE)	A110-1B	(OR)	A125-2	(OR)
88-4	(OR)	98-1	(OR)	110-2	(OR)	125-3	(OR)
89-2	(OR)	98-2	(OR)	111-1	(OR)	126-2	(OR)
89-2.1	(SA)	99-1	(OR)	111-2	(OR)	127-1	(OR)
89-3	(SA)	100-1	(OR)	A114-1A	(OR)	128-1	(OR)
89-4	(OR)	101-2	(OR)	114-AB	(OR)	129-1	(OR)
90-2	(OR)	102-1	(OR)	114-2	(RMS)	A129-2	(OR)
91-1	(RMS)	A102-3A	(G)	115-1	(OR)	130-1	(OR)
91-2	(OR)	A102-3B	(G)	116-1	(OR)	131-1A	(OR)
92-1	(OR)	103-1	(OR)	116-2	(OR)	131-1D	(RMS)
93-1	(OR)	103-2	(T)	117-2	(OR)		
93-2	(OR)	A104-1	(T)	118-1	(OR)		

A = Alternate Site
(OR) = Off River
(RMS) = Reconnaissance Material Site
(EMS) = Exploration Material Site
(P) = Putuligayuk River
(S) = Sagavanirktok River
(D) = Dietrich River
(J) = Jim River
(M) = Moose Creek

(T) = Tanana River
(G) = Gerstle River
(A) = Atigun River
(R) = Robertson River
(MFK) = Middle Fork Koyukuk River
(H) = Hess Creek
(SA) = Salcha River
(DE) = Delta River

Note - The total number and location of sites will be subject to change pending further investigation.

TABLE 2

TOTALS OF ON-RIVER and ACTIVE FLOOD PLAIN
POTENTIAL MINERAL MATERIAL SITES

	Stream	Number of Sites	Preliminary Level of Effort
(S)	= Sagavanirktok River	30	M_1
(A)	= Atigun River	6	M_1, M_2 or M_3
(D)	= Dietrich River	15	M_1, M_2 or M_3
(MFK)	= Middle Fork Koyukuk	5	M_1 and M_2
(J)	= Jim River	3	M_1, M_2 or M_3
(H)	= Hess Creek	1	M_1
(M)	= Moose Creek	2	M_1
(SA)	= Salcha Creek	2	M_1
(T)	= Tanana River	8	M_1, M_2 or M_3
(DE)	= Delta River	2	M_1
(G)	= Gerstle River	2	M_1, M_2 or M_3
(R)	= Robertson River	1	M_1, M_2 or M_3

How come only M_1?

Note - The total number and location of the sites will be subject to change pending further investigation.

2.0 METHODS OF HYDRAULIC EVALUATION

The specific methods for evaluating the potential hydraulic impacts upon the delineated river types as a result of material extraction operations are outlined in the following sections. All levels of evaluation will be based upon available data using aerial photographs, field inspection notes, existing topographic data and any available hydrologic and hydraulic data from the site.

Following individual evaluations using all available data, acceptance or elimination of the site will be based on a decision-making process which includes the following:

A. Engineer's knowledge and experience in river mechanics.

B. Engineer's knowledge and experience in Arctic rivers and streams.

C. Existing field conditions.

D. Past history of the stream.

2.1 M_1 Evaluation

The initial level of analysis at each site will involve primarily qualitative assessment based on observed general arctic morphological conditions and specific historical conditions observed at the prepared site. A flow chart of the prepared analysis is given in Figure 4, and a description of each of the segments follows.

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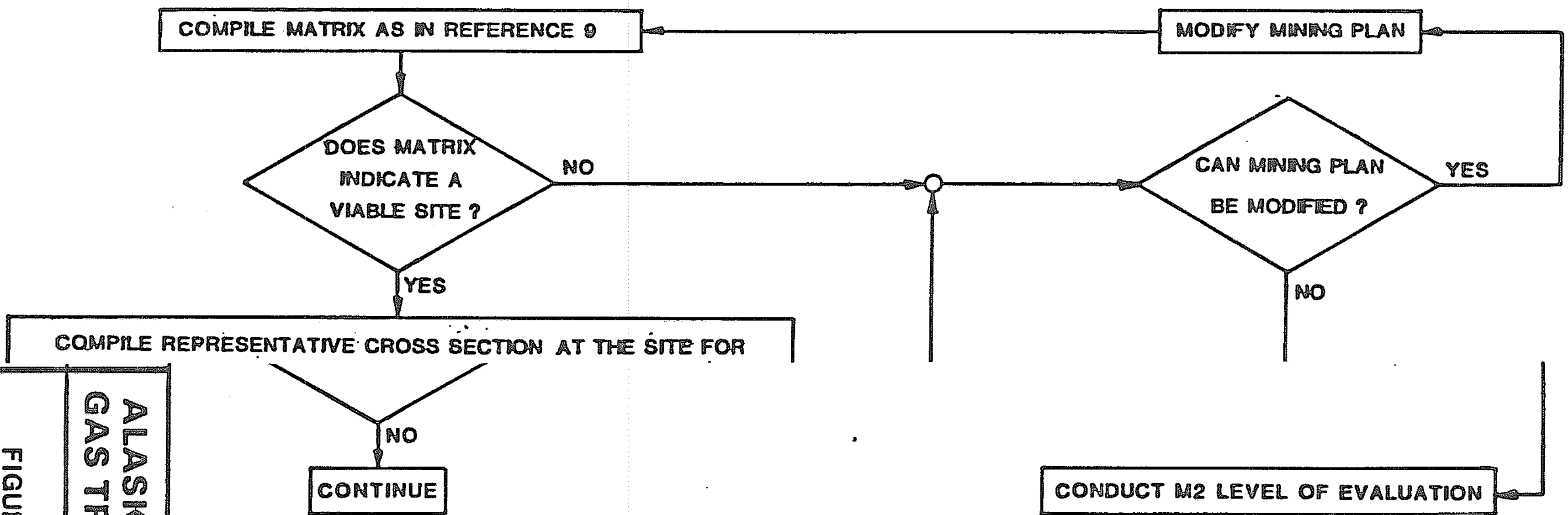

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FIGURE 4 M1 ANALYSIS FLOW CHART

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- Matrix Formulation

  Initial evaluation of the site shall be conducted using the procedures developed in Section VI of Reference 9. If this matrix does not indicate a viable mining site, the mining plan shall be modified to ensure a viable site, or eliminated.

- Cross Section Compilation

  From the mining plan, a cross section of the stream shall be compiled using existing data, for both the pre- and post- mining conditions.

- Hydraulic Parameter Comparison

  For the pre- and post-mining conditions, percentage changes in the hydraulic parameters shall be computed. If any of the observed parameter changes are greater than 25 percent, one of the measures outlined in Section 1.3.1 will be taken. The proposed level of excavation, in relation to the existing thalweg shall also be determined.

- Channel Switching

  From the proposed excavation depths, ascertain if the channel within a braided or split stream location will divert a majority of the flow to the post-mining location. If the stream has the propensity to switch channels and the resulting flow redirection would be detrimental to existing structures or presently unstable banks, modify the mining plan if possible, and begin re-evaluation of the site.

- Aufeis and Icings

  At each location ascertain from aufeis, pre-breakup and breakup surveys, the possibility of ice buildup, and its consequential effect upon the stream following mining. If severe ice formation has been observed at the site, the location and extent of this constriction will be included within the cross-sectional analysis. If mining will induce aufeis problems, the mining plan will be modified if possible.

- Groundwater

  Any observed groundwater problems at the site shall be assessed with regard to the effects of mining increasing or decreasing groundwater surcharge or recharge. If mining will induce groundwater problems, the mining plan will be modified if possible.

- Bank Stability

  Bank stability and lateral stream migration shall be assessed at each site if the proposed mining activity will shift or redirect the main channel towards a bank, or the mining site is immediately adjacent to a bank. In field observations and aerial photography shall be used to ascertain whether the mining will induce or enhance any erosion, mass wasting, sluffing or undercutting occurring adjacent to the site. Lateral stream migration estimation shall be conducted through comparative aerial photograph interpretation and in-field observations. If mining will induce bank stability problems, the mining plan will be modified.

o Headcutting

For proposed deep mining operations, and all mining operations on alluvial fans, the possibility of headcutting occurring through changes in the bed slope of the stream shall be evaluated. If mining will induce headcutting problems, the mining plan will be modified if possible.

2.2 M_2 Evaluation

This evaluation method involves computation of the flow cross sectional areas; average and maximum velocities; average and maximum flow depths; wetted perimeters, and bed material loads for the pre- and post-mining conditions. Figure 5 gives the flow chart for this analysis and a description of the segments follows.

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o Design Flood Discharge

From available data, determine the design flood discharge (Q_D), in cfs, for the site. The design flood discharge at locations in the vicinity of existing pipelines or structures will be the pipeline design flood discharge provided in Reference 10. At other locations, the 50-year flood discharge will be used as determined using procedures outlined in Reference 11.

o Cross Section Compilation

From survey notes and all available data sources, compile the cross section of the river in the vicinity of the proposed sites, as generalized in Figure 6. If cross sectional surveys are not available at the material sites, cross sections will be compiled from upstream and downstream cross sections, available topographic contour maps and aerial photographs.

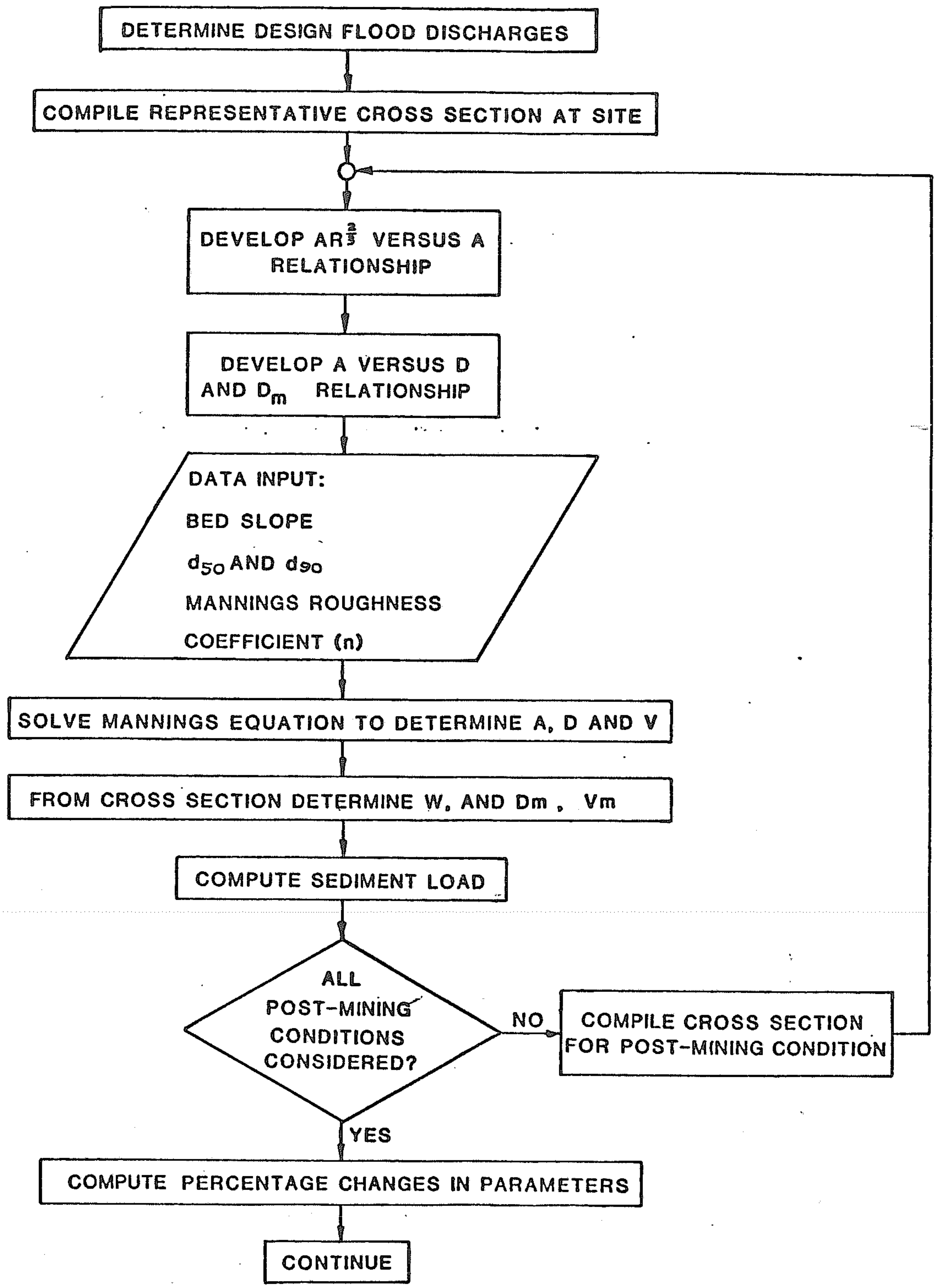

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FIGURE 5 M2 ANALYSIS FLOW CHART

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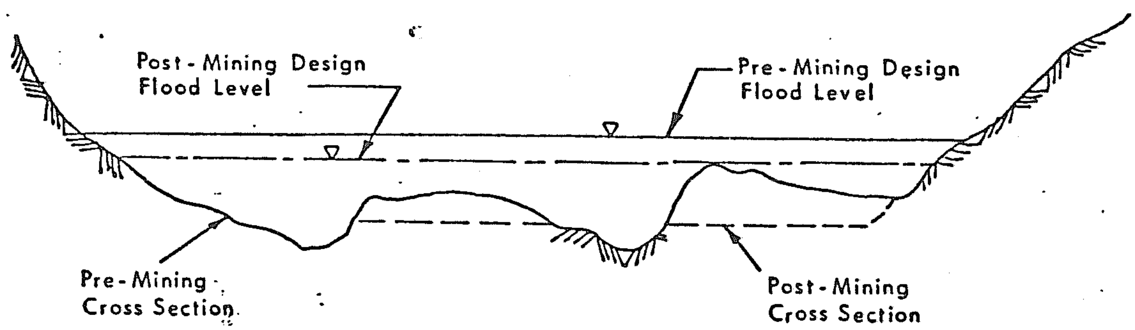

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FIGURE 6 TYPICAL RIVER CROSS SECTION

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- Cross Sectional Parameter Relationships

  From the compiled cross section, plot the following relationships:

  a) $AR^{2/3}$ versus A

  b) A versus D

  c) A versus D_m

  where A = Area, in square feet,
  P = Wetted perimeter, in feet,
  R = Hydraulic radius = A/P, in feet,
  D = Average Depth = A/W, in feet,
  D_m = Maximum depth, in feet,
  W = Water surface width, in feet.

- Data Input

  From survey notes and/or topographic contour maps, determine the approximate bed slope, S, at the proposed site.

  From field observations and tables presented in Reference 12, estimate the roughness coefficients (n) for the main channel and overbanks within the reach.

  Determine the median bed material size, d_m, and the d_{90} bed material size. These data are obtained from sieve analysis of samples collected at the sites, where

  d_{90} = bed material size, in mm, 90% of which is finer,

  d_m = representative diameter, in mm, of bed material, assumed here equal to d_{50}, and

d_{50} = bed material size, in mm, 50% of which is finer.

Solve Manning's equation for $AR^{2/3}$ from the equation

$AR^{2/3} = \dfrac{nQ_D}{1.486\ S^{\frac{1}{2}}}$, and determine A from the $AR^{2/3}$

versus A relationship

From the cross sectional plot, determine W.

From the A versus D and D_m relationships, derive D, and D_m.

Compute the average velocity, V, in feet per second, from the equation $V = \dfrac{Q_D}{A}$

and the maximum velocity, V_m, in feet per second from the equation

$$V_m = \frac{1.486}{n} (D_m)^{2/3} S^{\frac{1}{2}}$$

o Sediment Load

The pre-mining total bed material load at the site is determined using the most applicable computational procedure. For silts to medium sands, the Modified Einstein method will be adopted; for medium to coarse sands, the Colby method; and for coarse sands to gravel, the Meyer-Peter Mueller equation. The latter method would be the most applicable for a majority of rivers in Alaska. The basic Meyer-Peter Mueller equation is given by

$$q_b = 1.606\ [3.306 \frac{Q_b}{Q_D} \left[\frac{d_{90}^{\frac{1}{6}}}{n_b}\right]^{\frac{3}{2}} DS - 0.627 d_m]^{3/2}$$

where,

q_b = bed material load, in tons/day/ft width,

and

Q_b = water discharge, in cfs, determining the bed load transport.

The quantity $\frac{Q_b}{Q_D}$ for rectangular channels is given by

$$\frac{Q_b}{Q_D} = \frac{1}{1 + \frac{2D}{W}\left(\frac{n_w}{n_b}\right)^{3/2}}$$

where

n_w = the roughness coefficient of the stream banks,

and

n_b = roughness coefficient of the stream bed

The quantity n_b for rectangular channels is given by

$$n_b = n_c\ [1 + \frac{2D}{W}\ (1 - \left(\frac{n_w}{n_c}\right)^{3/2})]^{3/2}$$

where

n_w = the roughness coefficient of the stream banks,

and

n_c = the roughness coefficient of the channel.

For a majority of the streams under consideration, Q_b/Q_D approaches unity, and therefore the Meyer-Peter Mueller equation may then be simplified to

$$q_b = 1.606 \left[3.306 \left[\frac{d_{90}^{\frac{1}{6}}}{n_b}\right]^{\frac{3}{2}} DS - 0.627 d_m\right]^{\frac{3}{2}}$$

o New Cross Section Compilation

From the mining plan, obtain the volume of material to be mined at each site, the area covered, and the maximum mining depth. Compile the new cross section for the post-mining condition as generalized in Figure 6.

o Parameter Comparison

Repeat the M_2 analysis to determine the hydraulic parameters and bed material loads for the post-mining conditions, and compute the percentage change in all hydraulic and sediment parameters. If any of the observed parameter changes are greater than 25 percent, one of the measures outlined in Section 1.3.1 will be taken.

2.3 M_3 Evaluation

This method will require a quantitive evaluation as outlined in Section 2.2, together with scour depth estimation.

Scour depths will be computed using the regime theory and/or a simplified water/sediment routing model, involving one dimensional, known discharge, steady state conditions. The water/sediment routing model is capable of predicting changes in cross sectional area for steady state discharge conditions, degradation or aggradation occurring through a reach, and resulting bed elevations following passage of a hydrograph.

The model is based upon satisfying the continuity equation for sediment, the continuity equation for momentum and the energy equation within a stream reach. Water surface profiles are determined using standard backwater analysis techniques, and the total bed material load is computed using either the Meyer-Peter Mueller method (for coarse sands to gravels), the Colby method (for medium to coarse sands), or the Modified Einstein method (for silts to medium sands).

Data requirements for such model operation include cross sections spaced at approximately 3 times the width of the river, for a distance of 12 times the width of the river upstream and downstream of the site, bed material sizes and a vertical bed material size gradation, the design flood hydrograph and any available stage-discharge data for the site. In conjunction with the above, an upstream or downstream control section is required that is adopted as a rigid boundary condition. A flow chart of the evaluation method is given in Figure 7, and complete documentation of the simplified water/sediment routing model may be found in Reference 13. Following is a brief description of the main elements of the flow chart.

- Data Input

  Data requirements and methods of compiling data are the same as for the M_2 evaluation level. An additional data requirement is a classification of the sediment size fractions of the bed material and a complete description of the data collection and analysis method is found in Reference 14.

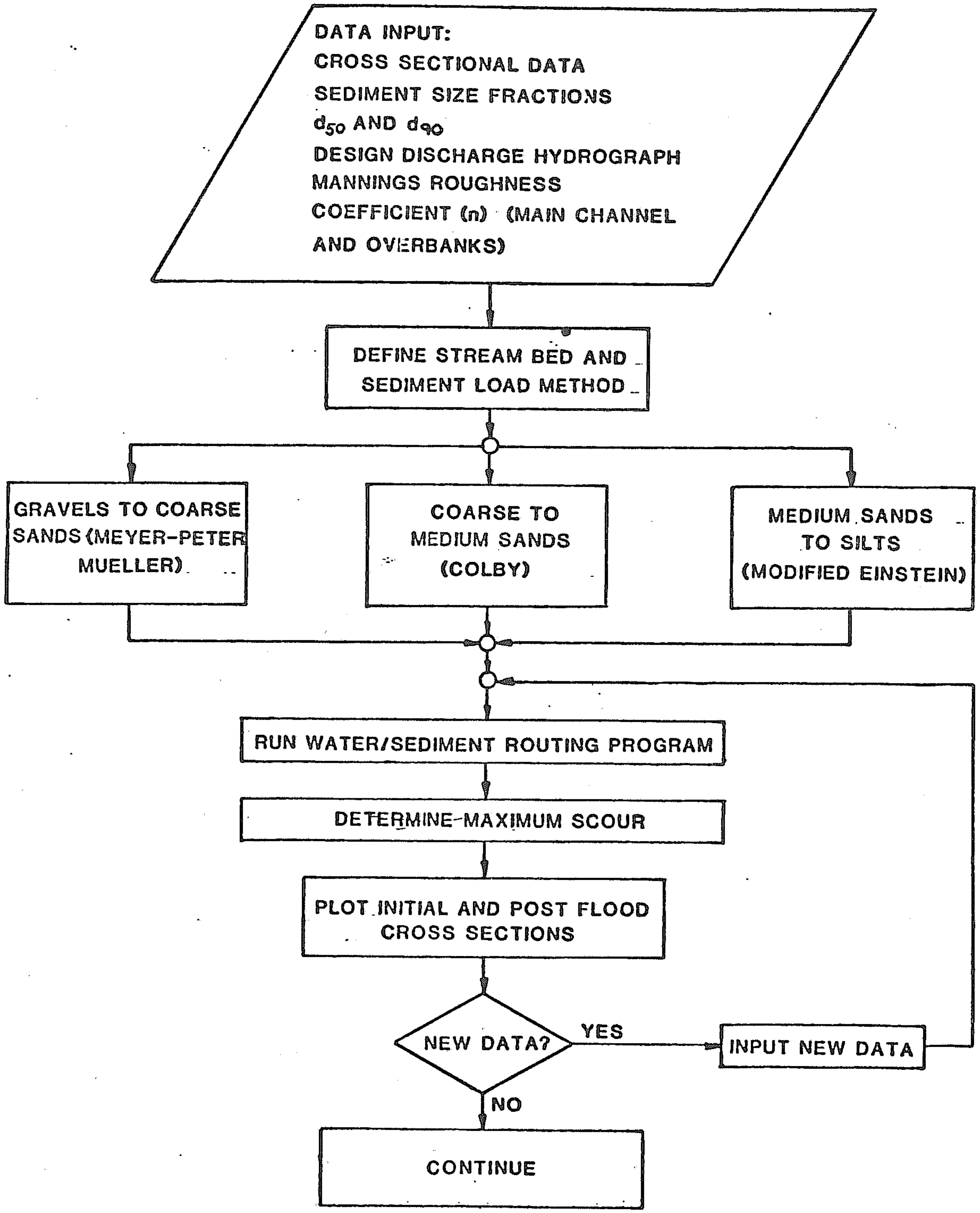

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FIGURE 7 M3 ANALYSIS FLOW CHART

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- Stream Bed Type

  Material in the stream bed is classified in accordance with the standard U.S. Geological Survey sieve size analysis, and is divided into the three main categories of gravels to coarse sands; coarse to medium sands; and medium sands to silts. The Meyer-Peter Mueller, Colby or Modified Einstein sediment load computation method is then adopted for the respective stream bed type.

- Routing Program Operation

  The water/sediment routing program is then operated with the as-is field condition data, with icing conditions in place under the worst case scenario.

- Maximum Scour Determination

  The maximum scour is determined from the most central cross section at the site under the worst case discharge condition.

- Cross Sectional Plotting

  The pre- and post-flood cross sections at the site are then plotted.

- Post-Mining Data

  Data shall be modified following the as-is routing to reflect post-mining conditions and the model re-operated to compute degradation or aggradation at the site. The post-mining conditions shall include any observed icing conditions at the site, and if the material is to be stockpiled on-site, it will be assumed that the stockpiles exist at the time of the flood event. However, this scenario will be dependent upon the quantity of material to be mined and the anticipated time of year for operations. If temporary access roads are to be constructed on the active flood plain these shall also be considered within the post-mining operation of the model.

- Parameter Comparison

  In conjunction with the aggradation/degradation evaluation a comparison of the hydraulic and sediment parameters shall also be conducted at the site. Based on pre- and post-mining degradation or aggradation, in conjuction with the hydraulic and sediment parameter changes, one of the measures outlined in section 1.3.1 will be taken.

3.0 EXAMPLE HYDRAULIC COMPUTATIONS FOR MINERAL MATERIAL SITES

Cross sectional data are available for the Sagavanirktok River, approximately 1 mile downstream of proposed material site 17-2. The adopted site is situated on a center bar of the river. This example assumes that the bar will be scraped to within one foot of the existing water elevation. The example follows the basic flow chart given in Sections 1.3 and 2.0. Material site 17-2 is delineated as an on-river site and the Sagavanirktok River is a split channel stream at this location. The initial step is to conduct an M_1 level of hydraulic evaluation for the site, according to the flow chart given in Section 2.0.

how does existing relate to avg., etc.

1) Complete matrix as in Reference 2

TABLE NO. 3 INITIAL EVALUATION MATRIX

SPLIT CHANNEL RIVERS

	River size			Site location			Associated channel			Type of deposit								Comment No.2 is the only match for the four variables
	Small	Medium	Large	Active floodplain	Inactive floodplain	Terrace	Active channel	High-water channel	Abandoned channel	Bed	Point bar	Lateral bar	Mid-channel bar	Inside meander	Outside meander	Vegetated island	Vegetated bank	Comments
MS 17-2			x	x			x						x					
		x	x	x			x			x								1. Gravel may be available by scraping or dredging.
		x	x	x			x				x	x	x					2. Gravel available by scraping.
		x	x	x	x	x	x	x						x	x			3. Some gravel may be available by scraping or pit.
	x	x	x	x	x	x	x	x								x		4. Generally should not be mined.
	x	x	x	x	x	x	x	x									x	5. Banks should not be mined.
		x	x	x	x	x		x		x	x	x	x					6. Gravel available by scraping.
	x			x			x			x	x	x	x	x	x	x		7. Should not be mined.
	x			x	x	x		x		x	x	x	x	x	x			8. Generally avoid, not much available.
	x	x	x		x	x			x	x	x	x	x	x	x	x	x	9. Gravel available by scrape or pit.
		x	x			x		x		x	x	x	x	x	x	x		10. Gravel available by scraping.

Comment No. 2 - Gravel is available by scraping gravel deposits to near the low summer flow, maintaining appropriate buffers, or no lower than the water level present during the mining operation. Refer to Scraping Guidelines. (Reference 2, Section VI).

2) As the matrix indicates a viable site, proceed to step 3.

3) Compile a representative cross section of the site, for pre- and post-mining conditions, from the mining plan (See Figure 9).

4) Hydraulic Parameter Comparison

The maximum depth of excavation anticipated is to within one foot of the water surface at the time of mining. Table 4 lists the hydraulic parameters for the pre- and post-mining conditions, for the fifty year design flood conditions.

TABLE 4

Discharge	Hydraulic Parameter	Pre-Mining	Post-Mining	Percentage Charge
36,800 cfs	average depth, ft.	5.7	5.7	0.0
	maximum depth, ft.	9.9	8.8	-11.1
	average velocity, fps	7.9	7.9	0.0
	maximum velocity, fps	11.2	10.4	- 3.6

5) Evaluate possibility of main channel switching.

The channel is split at this location and the potential for main channel switching is minimal.

6) Evaluate the effects of aufeis and icings.

No significant icings or aufeis have been observed at this location. Maximum ice thickness observed has been one foot.

7) Evaluate potential groundwater problems of site.

The site should be scraped to provide positive drainage and not create a fish entrapment problem. No potential groundwater problems are anticipated at this site.

8) Conduct bank stability evaluation.

The banks at this location are very stable. Detectable erosion over the 20-year period from 1949 to 1969 is minimal.

9) Evaluate headcutting potential.

Scraping the center bar to within one foot of low summer flow will not induce or reduce the potential for headcutting as no bed slope changes are created in the main channel.

Steps 1-9 complete the M_1 level of hydraulic evaluation. There are no structures present and Table 4 indicates that there is less than 25% percent change in the hydraulic parameters. The M_1 analyses indicates no detremental hydraulic effects, therefore, as such, the proposed mining operation is acceptable hydraulically and no further analysis is required. However, as an example of the M_2 evaluation method, the following analysis has been included.

1) Determine the design flood discharges.

From the flood frequency analysis, the following flood peaks were determined for the various return periods.

Q_2 = 17,000 cfs
Q_5 = 26,100 cfs
Q_{10} = 28,100 cfs
Q_{25} = 34,500 cfs
Q_{50} = 36,800 cfs

For this example, approximate flood hydrographs were constructed for each of the above peak discharges. These hydrographs were constructed from typical storm hydrographs recorded by the U.S.G.S. gaging station at Sagwon. The hydrographs are given in Figure 8.

2) Compile representative cross section at the site.

This has been completed in the M_1 level of hydraulic evaluation. (See Figure 9).

3) Develop the $AR^{2/3}$ versus A relationship.

4) Develop the A versus D and D_m relationship. These data are given in Table 5 following.

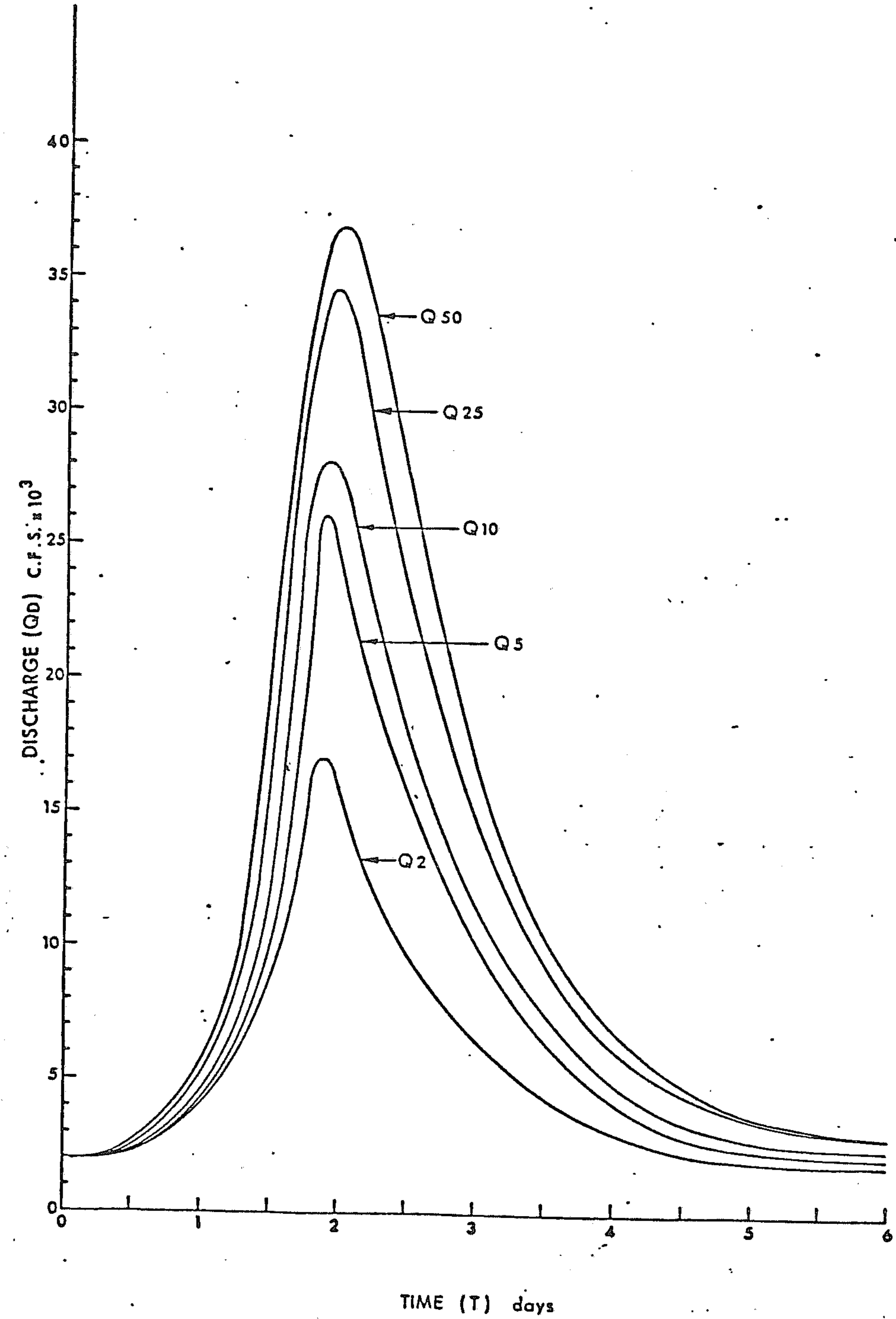

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FIGURE 8 ADOPTED FLOOD HYDROGRAPHS : SAGAVANIRKTOK RIVER NEAR SAGWON

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TABLE 5

Cross Sectional Parameters: Sagavanirktok River near Sagwon

A	$AR^{2/3}$	D_{max}	D	W
46	32	1.2	0.6	76
415	567	3.2	1.6	259
1,126	2,025	5.2	2.4	469
2,466	5,307	7.2	3.2	771
4,075	11,915	9.2	5.0	815
5,714	20,779	11.2	6.9	828
7,330	31,197	13.2	8.7	849

5) Data Input

Bed slope = 0.0024 ft./ft

d_{50} = 10 mm

d_{90} = 24 mm

Manning's roughness coefficient = 0.030.

6) Solve Manning's equation to determine A, D, and V.

This is done by a normal depth computational program.

7) From the cross-section determine W, D_m and V_m.

This is also done by a normal depth computational program.

8) Compute sediment load.

The pre-mining bed material load was computed for each half-day time period of the hydrograph and then summed over the duration of the storm. Table 6 lists the total bed material loads for the adopted flood hydrographs, together with the normal depth computation parameters.

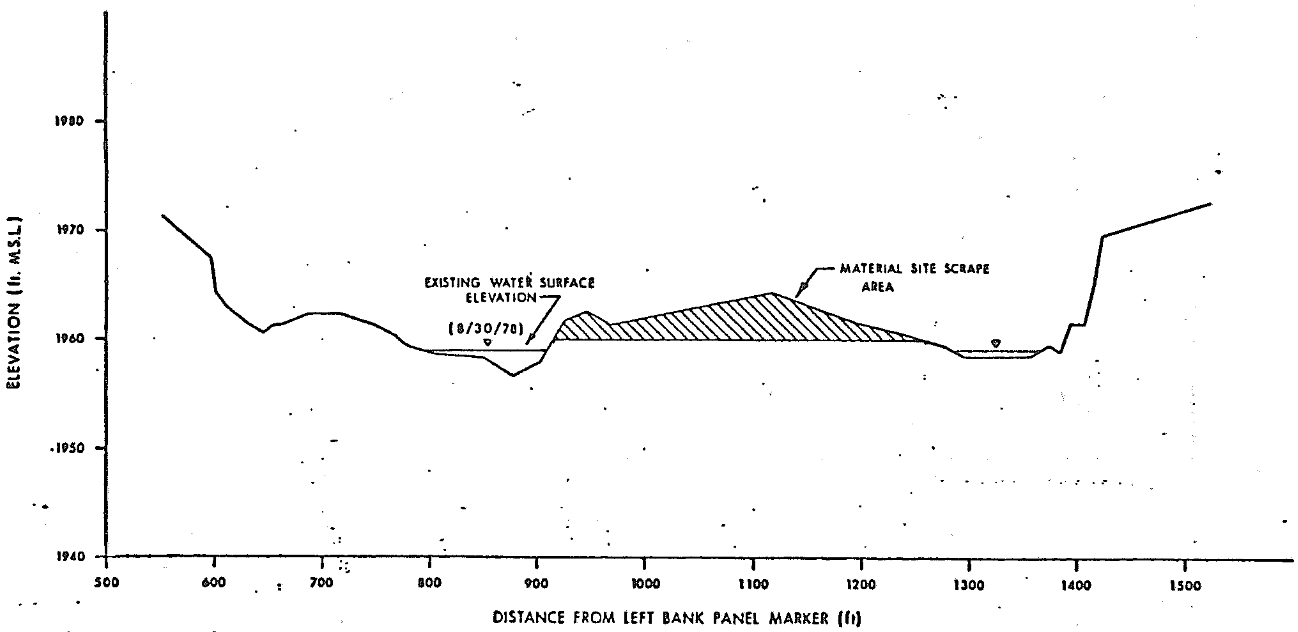

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FIGURE 9 CROSS SECTION:
SAGAVANIRKTOK RIVER NEAR SAGWON

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9) New channel geometry is then prepared and steps 3-8 repeated for post-mining conditions.

10) Compare percentage change in parameters.

For this example, the percentage change for the parameters is less than 25%, therefore the material site can be accepted hydraulically. Table 6 lists the pre- and post-mining parameters together with the percentage changes. Approximately 24,000 cubic yards of material would be removed from this site, with a maximum scraping depth of 4.5 feet and an average depth of 1.2 feet. This material would be scraped and removed within a 14 day work period.

For all hydrographs, a reduction in the bed material load is observed for the post-mining conditions, with this reduction decreasing for increasing discharges. For the 2-year flood event, there is approximately a 15% reduction in the total bed material load following mining operation, and approximately a 4% reduction for the 50-year event. Computed hydraulic parameters for the pre- and post-mining conditions indicated similar small changes.

Since under natural conditions, the bed elevation is changing consistently both upstream and downstream of the cross section due to degradation, the bed material load immediately upstream of the site will be approximately the same as for the pre-mining conditions. As such, deposition will occur at the site following the mining operation, and it is not anticipated that scraping of bars in braided or split channel rivers will induce any long term post-operation hydraulic effects.

TABLE 6

Comparison of Hydraulic Parameters
For Pre-Mining and Post-Mining Conditions

Flood Frequency	Discharge	Hydraulic Parameter	Pre Mining	Post Mining	Percentage Change
2	17,000 cfs	average depth, ft.	3.7	3.6	2.7
		maximum depth, ft.	7.7	6.6	14.3
		average velocity, fps	5.9	6.0	1.7
		maximum velocity, fps	9.5	8.6	9.5
		Bed material load, tons	16,900	14,300	15.4
5	26,100 cfs	average depth, ft.	4.7	4.6	2.1
		maximum depth, ft.	8.8	7.7	12.5
		average velocity, fps	6.9	6.9	0.0
		maximum velocity, fps	10.4	9.5	8.7
		Bed material load, tons	36,100	33,900	6.1
10	28,100 cfs	average depth, ft.	4.9	4.8	2.0
		maximum depth, ft.	9.1	7.9	13.2
		average velocity, fps	7.1	7.1	0.0
		maximum velocity, fps	10.6	9.6	9.4
		Bed material load, tons	45,900	42,900	6.5
25	34,500 cfs	average depth, ft.	5.5	5.5	0.0
		maximum depth, ft.	9.7	8.6	11.3
		average velocity, fps	7.7	7.7	0.0
		maximum velocity, fps	11.1	10.2	8.1
		Bed material load, tons	69,000	66,300	3.9
50	36,800 cfs	average depth, ft.	5.7	5.7	0.0
		maximum depth, ft.	9.9	8.8	11.1
		average velocity, fps	7.9	7.9	0.0
		maximum velocity, fps	11.2	10.4	7.1
		Bed material load, tons	83,500	80,500	3.6

4.0 REFERENCES

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11. Northern Technical Services, "Flood Frequency Determinatins for the Alaska Segment of the Alaska Natural Gas Transportation System (ANGTS)", March 19, 1981.

12. Chow, V.T., Open Channel Hydraulics, John Wiley and Sons Inc., New York, New York 1959.

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