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DRAINAGE STRUCTURES REPORT

KM70-SELIBABI

PROJECT NO. AFR-0214-C-00-3045-00

CONTRACT NO. 682-0214

USAID NOUAKCHOTT

ISLAMIC REPUBLIC OF MAURITANIA

NOVEMBER 1983

BY

MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS

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1. Introduction.

This report fulfills the requirements of the project agreement to prepare a drainage structures report for the section of the Mauritania Rural Roads Project between Km 70 of the UN constructed road and Selibabi.

The report describes the field investigations completed, analyzes and explains the methodology for determining the hydrology and hydraulic requirements, proposes alternative drainage crossing methods, recommends alternatives for each type of crossing, describes and provides typical details of radiers and pipe culvert installations and summarizes appropriate quantities and costs of the recommended alternatives.

The report should be used by those responsible for design and construction of the project as a guide to provide for the large quantities of runoff which cross the proposed roadway. As indicated above, typical details and recommendations are provided which should be applied with judgment at each particular drainage crossing.

Though the report is particularly directed at the Km 70 to Selibabi section of the project, many parts will also apply to and may be used for the Selibabi to Gouraye section and, to a lesser degree, the Mbout to Kaedi section.

The following are definitions of several French language words common at the project site and used throughout the report:

Oued - Refers to a large drainage channel with a drainage basin greater than 50 Km^2.

Marigot - Refers to smaller drainage channels with drainage basins less than 20 Km^2.

Radier - Ford, Irish bridge or submersible bridge designed to allow infrequent passage of flood waters over the roadway without damage to the roadbed.

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2. Field Work.

Field work for the Drainage Structures Report for the Km 70 to Selibabi Section was completed during a six-week period between 14 September and 26 October 1983 by Brad Peterson, a civil engineer with Morrison-Maierle, Inc.

During this period, five rains of eight millimeters or less and one rain of 70 millimeters occurred (See 3 - Hydrological Data) making it possible to observe the extensive flooding which occurred in and around the town of Mbout after even minor rainstorms. The character, duration, time of concentration and peak flows of several oueds and marigots were observed.

Though the storms made it possible to observe hydrological conditions near Mbout, they also caused water to flow in Oued Garfa at Km 48 of the UN Road making travel from Mbout south to the project site impossible for 23 days of the six-week period (See Figure 2-1). Actual field surveys and investigations at the project site were therefore conducted between 08 October and 26 October 1983.

The field survey and investigation for the Km 70 to Selibabi Section consisted of:

1. Re-establishment and completion of roadway centerline measurement and staking.

2. Complete, systematic drainage investigation of the entire alignment, walking and driving, including:

    a. Station, size and other characteristics of all oueds, marigots, drainage swales, flood swales and other features affecting roadway drainage.

V

b. Soil and vegetation types and characteristics.

c. Photogrpahs of important features.

3. Cross-sections and slope measurements of three of the major oued crossings.

4. Interviews with local residents about drainage and flooding charactertistics.

5. Meeting with Governor of Selibabi and Prefecte of Mbout to obtain recent and historical rainfall records.

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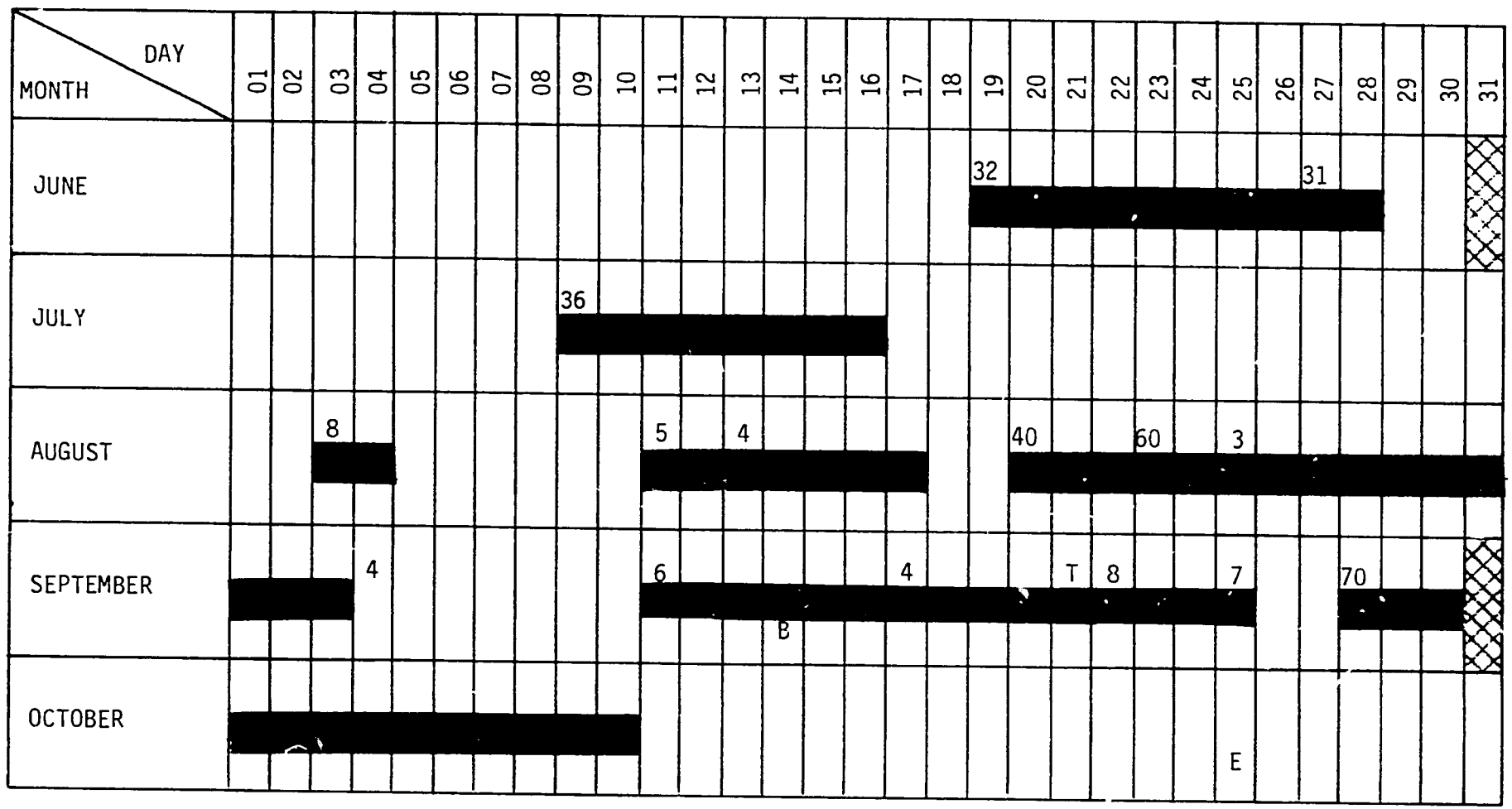
1983 HISTORY - OUED GARFA (KM 48)



Note: Bars indicate days when it was not possible to cross Oued Garfa.
B, E - Begin and end, respectively, field work for drainage structures report.
Numbers above bars indicate rainfall amounts in MM at Camp at M'bout.

FIGURE 2-1

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3. Design Flood Hydrology

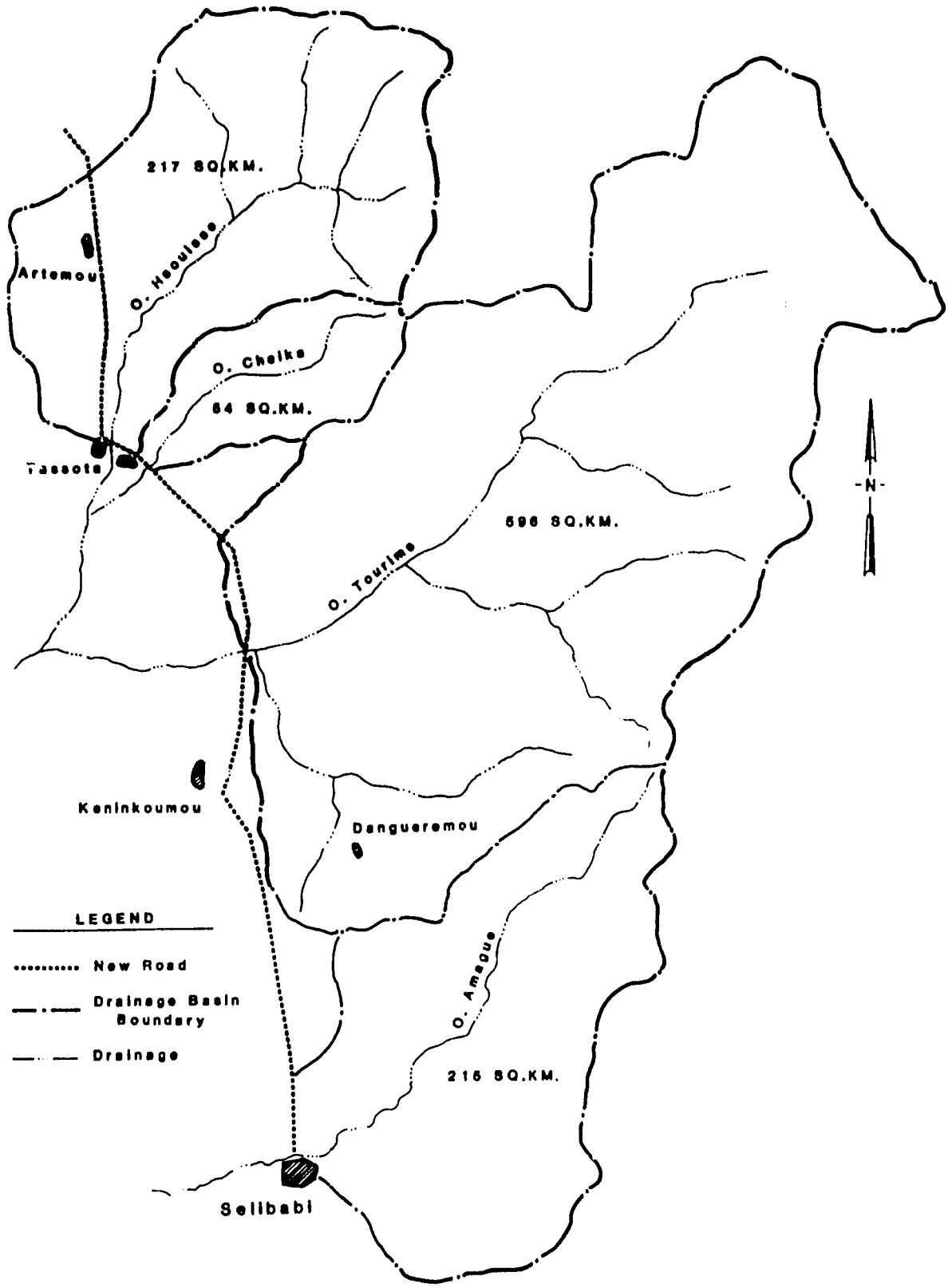
Roadways constructed under this project will cross drainage basins ranging from less than one square kilometer to nearly 600 square kilometers (The larger basins are shown on Figures 3-1 and 3-2). Adequate cross drainage structures need to be provided to allow passage of common runoff peaks without damage to the roadways. There are no streamflow records in the project area on which peak runoff characteristics could be based. Therefore, a rainfall-runoff analysis was performed to predict flood peaks at selected recurrence intervals. Field data was also collected to check the "reasonableness" of this analysis.

It should be noted that the sizing of cross drainage structures on some existing projects in the area have either underestimated or chosen to ignore the runoff potential which has resulted in frequent damage to roadways and drainage structures.

The project area is situated just north of Selibabi which lies approximately 15 degrees north of the equater. Rainfall records at Selibabi[1/] indicated that 91 percent of the average annual precipitation falls during the period from June to September. The months from December to April average less than 10 millimeters of rainfall. August receives 35 percent of the annual rainfall which averages 570 millimeters at Selibabi. Thunderstorms account for 70 percent[2/] of the rainfall events in the Selibabi area. Extremely high rates of runoff result from the combination of intense thunderstorm events (normally less than 24 hours in duration) and poor hydrologic soil conditions.

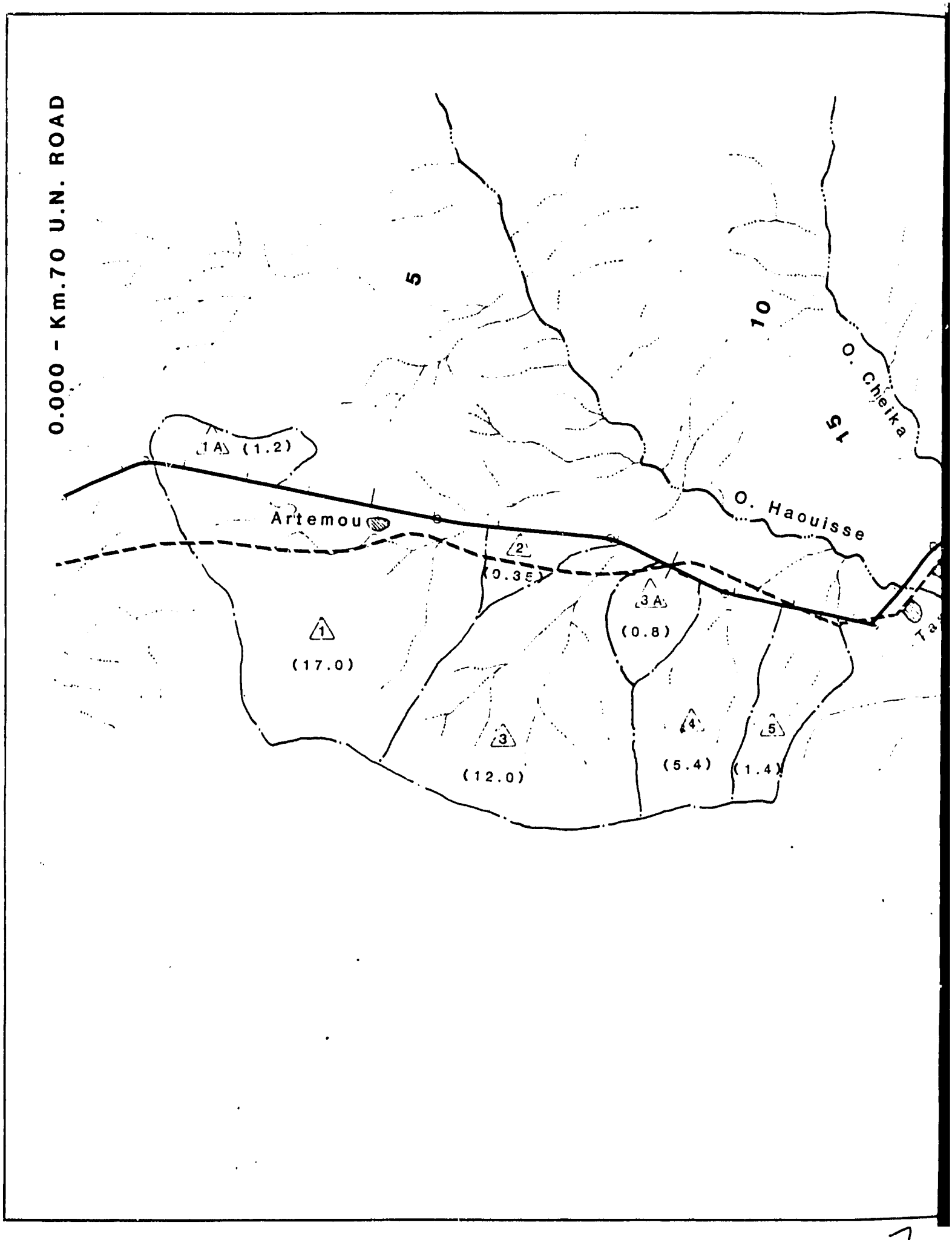
1/ Agency for International Development, Unclassified Project Paper 682-0214, Mauritania Rural Roads Improvement, September 14, 1982. Rainfall records in the Project Paper were supplemented and verified by more recent precipitation records available in Selibabi and Mbout.

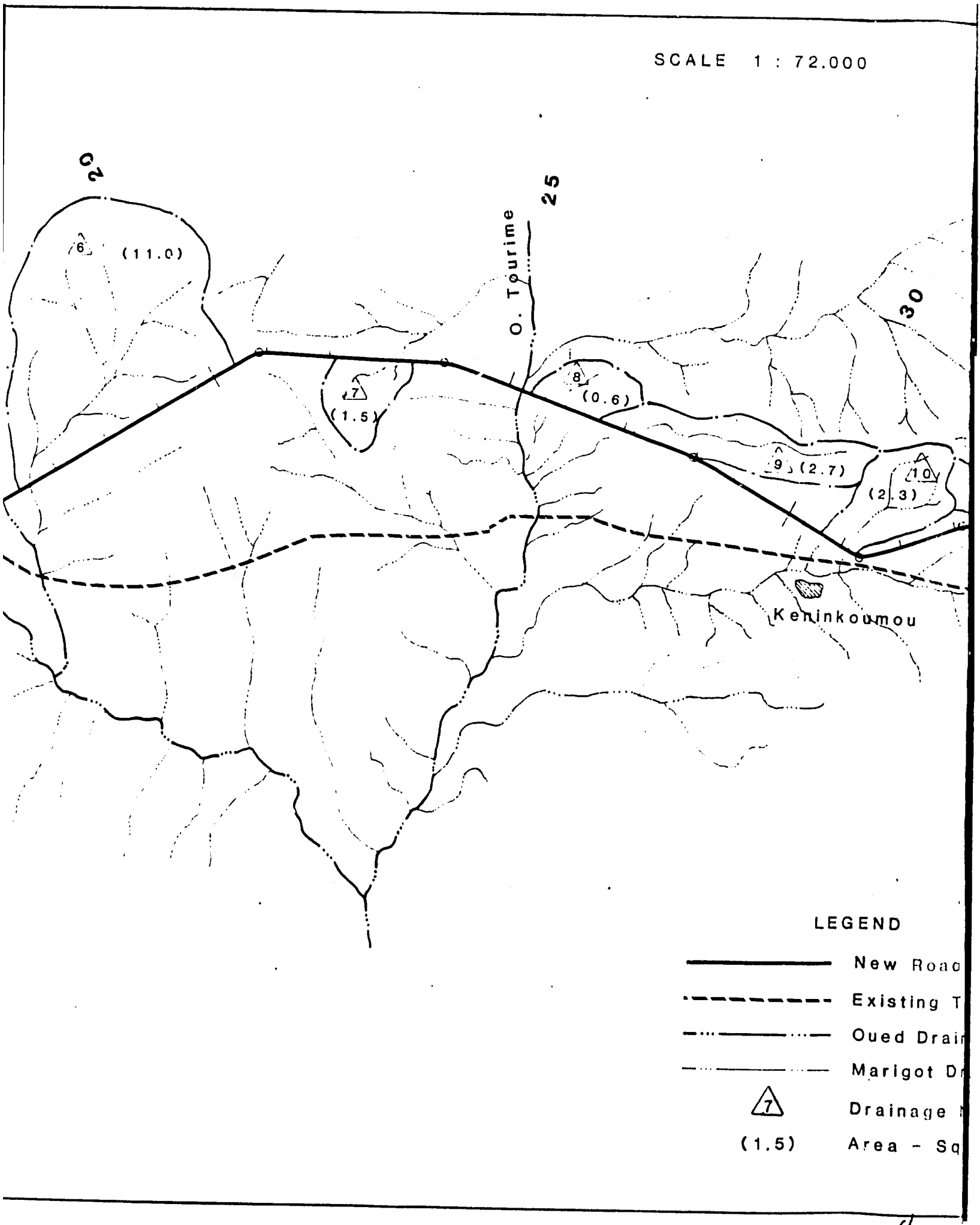
2/ Ibid.



MAJOR OUED DRAINAGE BASINS

FIGURE 3-1


0.000 - Km.70 U.N. ROAD
5
10
15
O. Cheika
O. Haouisse
Artemou
1A (1.2)
1 (17.0)
2 (0.35)
3 (12.0)
3A (0.8)
4 (5.4)
5 (1.4)


SCALE 1 : 72.000
20
25
30
O. Tourime
6
(11.0)
7
(1.5)
8
(0.6)
9
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10
(2.3)
Keninkoumou
LEGEND
New Road
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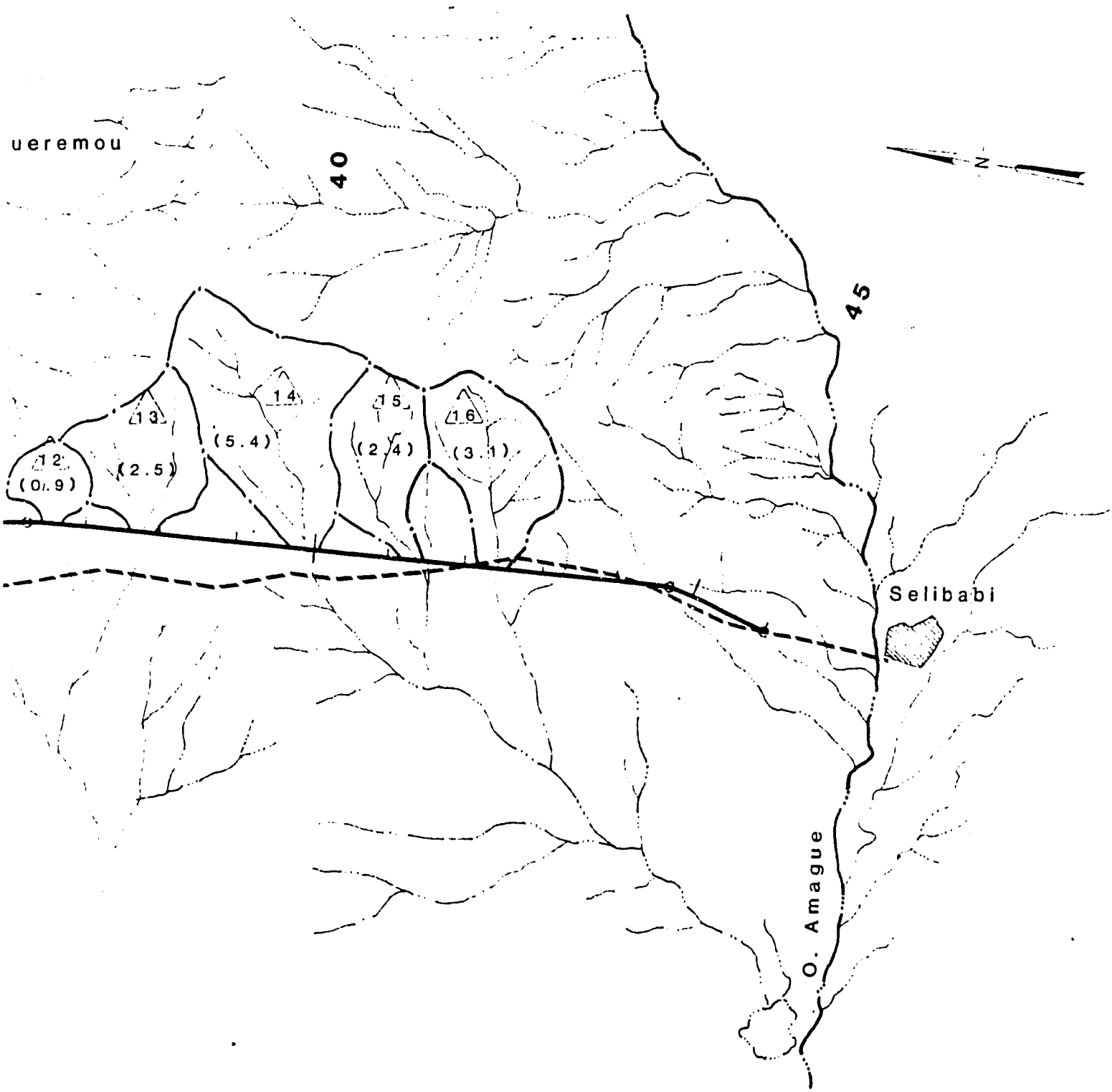
Oued Drai
Marigot D
7
Drainage
(1.5)
Area - Sq

8



MARIGOT DRAINAGE BASINS

FIGURE 3-2

A rainfall-runoff analysis was used to estimate flood peaks for a range of drainage basin sizes and selected recurrence intervals. This information was used to select the design flood recurrence interval and help size all drainage structures.

The hydrologic parameters required for the analysis included:

Drainage area size
Time of concentration
Unit hydrograph
Design storm
Infiltration loss rate

Drainage area size was determined from topographic maps at a scale of 1 to 200,000 developed by L' Institut Geographique National[3/] and 1 to 50,000 developed by the United Nations.

The time of concentration is described as the time required for runoff from the most distant location in a given basin to reach to the point of interest. The Kirpich equation[4/] is commonly used to predict the time of concentration and requires the parameters of longest watercourse length and elevation difference. The equation in metric units is presented below:

$$T_c(\text{hours}) = [(0.87)(L^3)/(H)]^{0.385}$$

L = longest stream length, kilometers
H = difference in elevation, meters

3/ L' Institut Geographique, Maps of Selibabi and Kankossa, Mauritania, Paris, France, 1969.

4/ U.S. Bureau of Reclamation, Design of Small Dams, Engineering Research Center, Denver, Colorado, 1977, 816 pp.

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Unit hydrographs were constructed using standard procedures developed by the U.S. Soil Conservation Service and found in the National Engineering Handbook[5/]. These procedures use the basin time of concentration to establish the time to peak of the hydrograph, the overall time of the hydrograph base and the peak of the hydrograph for a given unit of runoff.

A design storm depth-duration relationship was constructed from rainfall records at Selibabi[6/]. This curve shows the 100-year 24-hour point rainfall approximately equal to 207 millimeters, a 9.5 hour total equal to 183 millimeters and a one-hour rainfall of 125 millimeters. Multipliers for lesser recurrence intervals are shown below:

Recurrence Interval	Multiplier
100-year	1.00
50-year	0.75
25-year	0.58
10-year	0.45
2-year	0.33

The rainfall amounts reported above were considered to be point rainfalls, i.e., they would not apply directly to larger drainage basins. Areal reduction factors developed by the National Weather Service[7/] were used to account for the reduction in intensity which occurs when a storm is applied over a large area.

Design storms were developed for drainage areas of 1, 54, 215 and 586 square kilometers. These storms were arranged in a thunderstorm distribution found in Reference 4. A plot of the accumulated storm precipitation depth versus time follows an "S" pattern where the early

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5/ Soil Conservation Service, National Engineering Handbook, Section 4 Hydrology, Washington, D.C., January 1971.

6/ See Note 1.

7/ National Weather Service, Precipitation of Western United States, NOAA Atlas 2, Silver Spring, Maryland, 1973.

periods of the storm have a light rainfall intensity, followed by a period of heavy intensity and then tapering off to zero intensity.

Infiltration losses were based on field observations of actual storm events during the period September to October 1983 and estimation of the soil characteristics. Soil types in the project area range from clays and silt clays to sandy textures.[8/]. These soils lack organic matter and consequently have poor infiltration and soil structures. Reference 1 notes that a 10 mm/hour precipitation intensity will cause runoff. Based on further investigations, it is estimated that infiltration rates vary from 2.5 to 10 mm/hour. A sensitivity analysis was performed and showed that a reasonable variation of infiltration values causes only a very small difference in runoff rates. An infiltration rate of 5 mm/hour was used for the final analysis.

It should be noted that clay soils with poor organic content will "puddle" during extreme rainfall events. This phenomenon occurs when the impact of the rain drops is not intercepted by vegetation and strikes the soil surface. The clay materials are suspended and then tend to seal the surface of the soil and prevent infiltration. Loss rates under this condition would drop to nearly zero and account for tremendous runoff rates.

Data described in the preceeding discussion was used as input to the Army Corps of Engineers Flood Hydrograph Program HEC-1[9/]. This program processed the input data and provided the flood peak output for five storm recurrence intervals and four drainage sizes.

Results of the rainfall runoff analysis are shown on Figure 3-3 for drainages from 0.1 to 1,000 square kilometers and 2-, 10-, 25-, 50-, and 100-year recurrence intervals.

8/ Louis Berger International, Inc., Report on Aggregate and Water Surveys for the Rural Road Development Project, Washington, D.C., May 1980.

9/ U.S. Army Corps of Engineers, HEC-1 Flood Hydrograph Program, Hydrologic Engineering Center, Davis, California, 1981.

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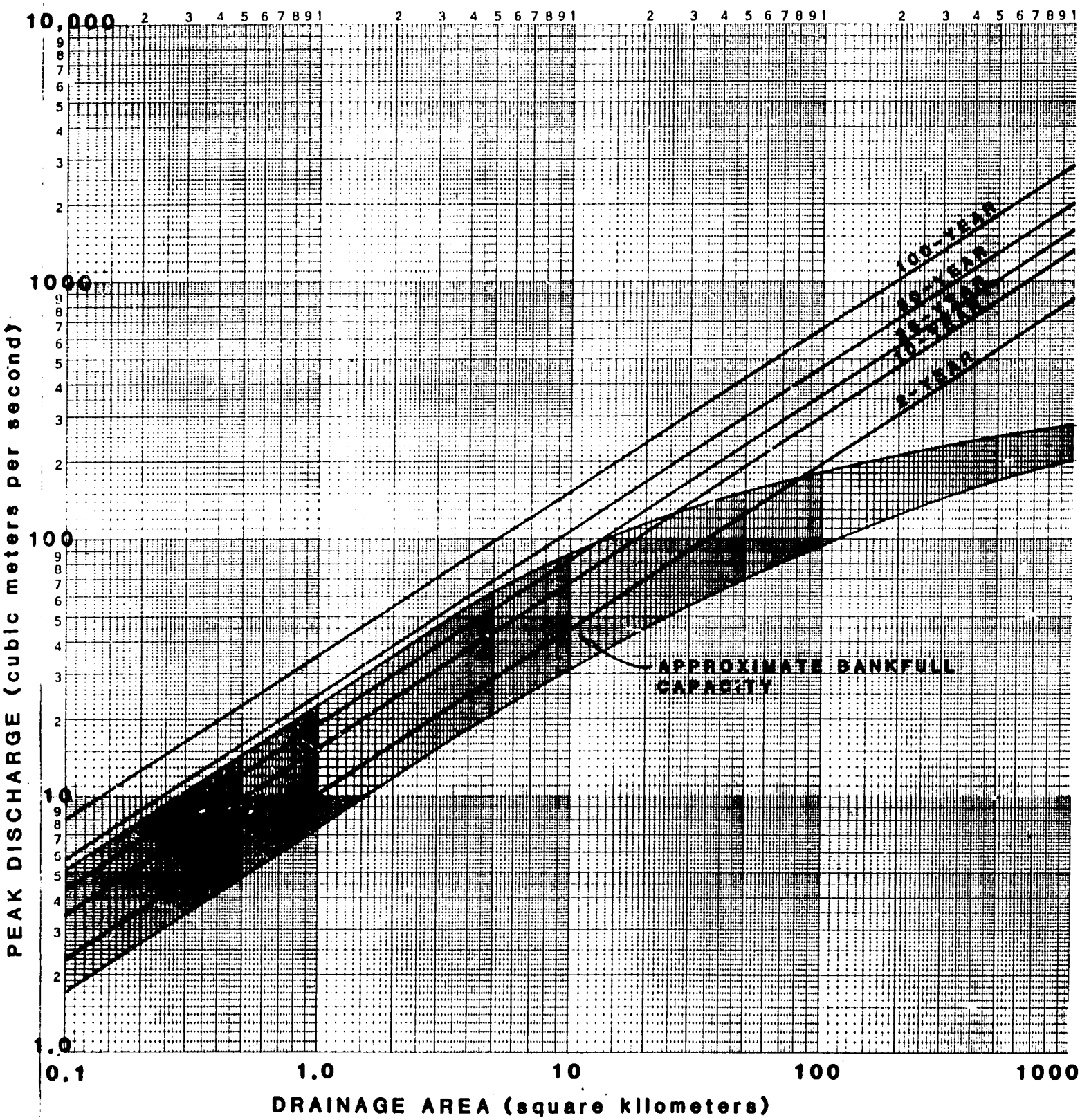

SELIBABI AREA REGIONAL HYDROLOGY

FIGURE 3-3

Reasonableness of these flood peaks were checked by several methods. The first method involves a check of the bankful capacity of channels with contributing drainage areas ranging from 0.8 to 586 square kilometers. Capacities were computed from field survey data obtained during September to October 1983. The range of bankful capacities is shown as a shaded area on Figure 3-3 and shows the bankful capacity ranging from a 25-year event at one square kilometer to less than a two-year event on drainages larger than 20 square kilometers.

Floodplains for both large and small basins are characterized by a central channel which can be approximated by a rectangular shape and bordered by a broad shallow overbank which can be up to 500 meters wide at the larger oueds.

Observations at the larger oueds conclude that the channel capacity is exceeded at least once a year which agrees well with Figure 3-3. Channel slopes in these areas are generally less than 0.1 percent and result in slow velocities. Most of the major flood flows are carried outside of the channel in the overbank area where a great deal of cross sectional area exists. Major floods are reported to inundate the overbank areas for one to two days. As the runoff recedes the overbanks dry out, however, the recession will continue to fill the channel for periods up to five days. Therefore, the disruption of traffic may last up to five days following a major storm on the larger oueds. Recession characteristics of the larger oueds which have been observed are presented below.

Oued	Drainage Area (Square Kilometers)	Days of Inundation	
		Overbank	Channel
Garfa*	2,000	2-3	12-14
Tourime	586	1-2	4-5
Haouisse	217	1	2
Cheika	54	½	1

* Not on this project

Bankful capacity of oueds with less than 10 square kilometers of drainage area tend to lie between a two-year and 25-year flooding event. This appears to be reasonable because the channel slopes of these basins

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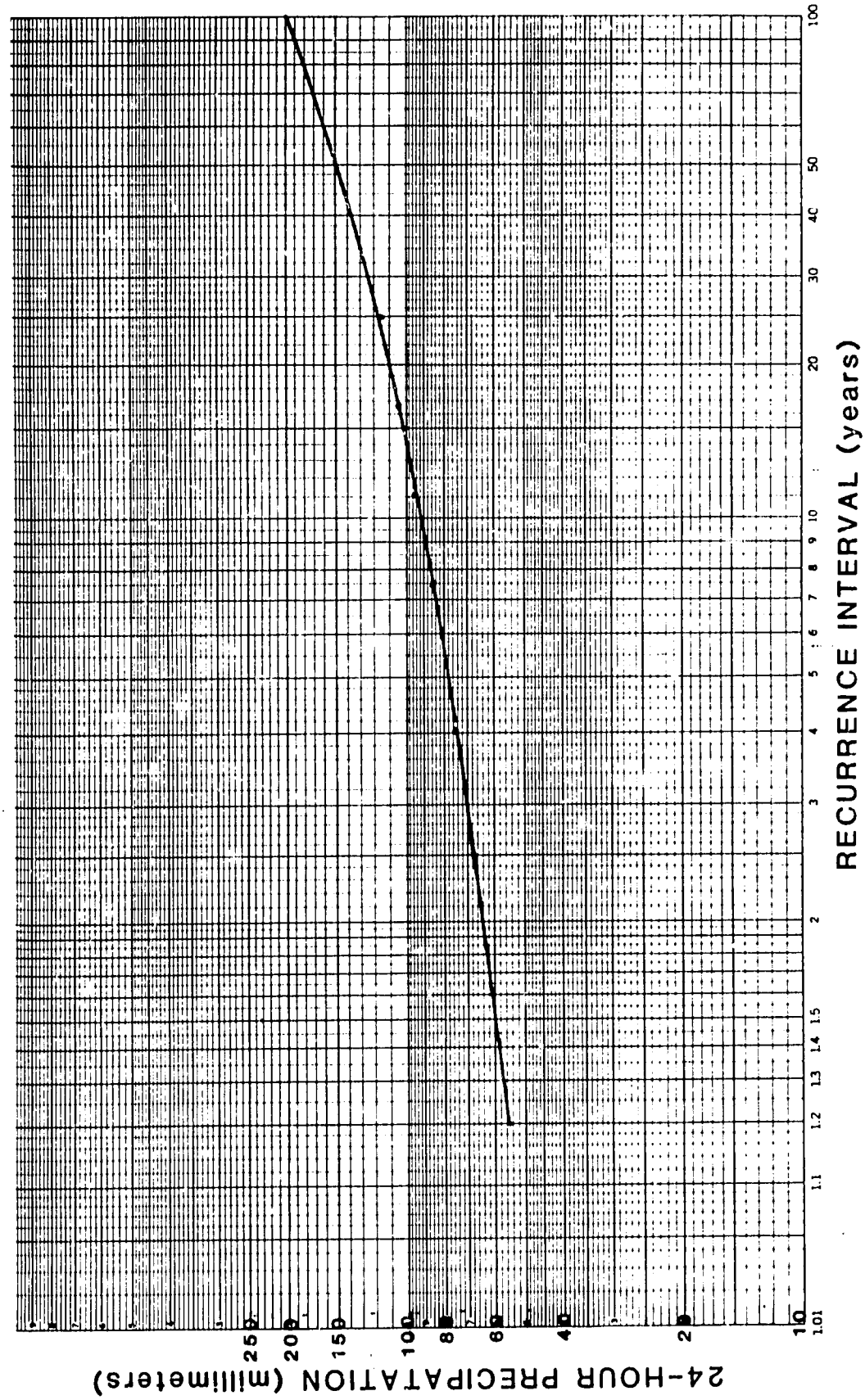
average approximately 1 percent which results in velocities during common flooding events sufficient to cut a deep channel. Therefore, only an infrequent flood of great magnitude will exceed the bankful capacity and spread into the overbank areas.

There is a large spread in the bankful capacities of the basins with less than 10 square kilometers drainage. Therefore, site specific data and judgment must be used. Some may have fairly broad overbanks (up to 100 meters total width) and relatively small channel capacities (two-year event). Other small drainage basins with well defined channels of considerable capacity will carry a large flow at a high velocity.

The second method for checking the reasonableness of flood peaks involves the observation of several rainfall events and the resulting flows in the larger oueds. A 24-hour total rainfall of 50 to 65 millimeters would be expected to occur more than once a year (see precipitation versus recurrence interval relationship on Figure 3-4). From Figure 3-3 we would expect storms of this magnitude to fill the channel past backful capacity. This condition was observed at Oueds Garfa (2,000 square kilometers) crossing the 70 Km UN Road, Tourime (586 square kilometers) and Haouisse (217 square kilometers) during the period from September to October 1983.



SELIBABI AREA RAINFALL RECURRENCE

FIGURE 3-4

4. Hydraulics of Roadway Crossings.

Drainage structure requirements and sizes were determined using the follow procedures:

1. During the field investigation, each drainage channel was inspected and, based on observed channel size and characteristics, preliminary estimates were made of the type, size and number of culverts, radiers, bridges or other drainage structures required.

2. The cross-sectional area of each drainage channel based on field measurements and the size and number of pipe culverts, bridges or radiers required to cross the channel without decreasing the bankful capacity were determined[10/]. This information was then compared with information from Step 1 above and the required adjustments were made.

3. Using methods outlined in Section 3, Design Flow Hydrology and based on approximately a 25-year design storm, design flows were determined for each channel. The number and size of required drainage structures required to pass these flows were determined and compared with Steps 1 and 2 above. Generally, Step 3 was the step which indicated the greatest flows and therefore the largest culvert, radier or bridge requirements. In a few cases, however, Step 2 indicated larger crossing requirements.

Using the procedures outlined above, the following general requirements for drainage structures were indicated:

1. Major Oueds. This type of drainage crossing is characterized by large drainage basins (greater than 50 Km^2) and

10/ U.S. Department of Transportation, Hydraulic Charts for the Selection of Highway Culverts, Washington, D.C., December 1965, Reprinted April 1977.

resulting large runoff peaks (greater than 200 M^3/sec.) and a large, well defined channel with a significant flood plain on either side. Field observations and hydrology indicate that the channel banks may be over-topped several times per year causing flow throughout the floodplain. Protected roadways or radiers will be required to allow passage of these flood flows over the roadway. Large bridges may also be used to cross the deepest part of the channel with the longest flow duration.

2. Marigots. This type of drainage crossing includes drainages with basin areas of 1 to 20 Km^2 with well defined channels. The flows are generally too great to be accommodated by pipe culverts. Crossings will require radiers or small bridges or a combination of the two. If radiers are constructed, it is estimated that traffic will be interrupted for less than one day after each significant storm.

3. Small Marigots. Drainage crossings with basin areas of less than 1 Km^2 and design flows less than 20 M^3/sec. are included in this group. The expected flows can be accommodated using from one to four 90 cm or 150 cm diameter corrugated steel pipe, properly installed.

4. Cross Drainages. There are many areas where, though there are no well defined marigots or channels, small drain pipes should be installed. These areas include long sections of roadway with no oued or marigot crossings where it is desirable to provide periodic opportuntiy for storm water collected along the roadway to cross before it accumulates sufficiently to cause erosion. They also include dips and low areas where, though no significant flows are indicated, cross drains are desirable to prevent ponding of water against the roadway. Cross drainages will usually be accommodated using 90 cm and sometimes 150 cm corrugated steel pipe.

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5. Flood Areas. In many cases it will be desirable to raise the roadway even higher above the existing terrain than the 60 cm required by the design typical section[11/]. In areas where frequent flooding is indicated, the roadway finished grade should be raised 60 cm above the indicated high water level. Cross drainage pipe should be incorporated as described above.

Locations, sizes and design recommendations for the five types of drainage features described above are provided in Sections 5 thru 8 of this report.

11/ Morrison-Maierle, Inc., Project Work Plan and Schedule, Mbout-Selibabi, Selibabi-Gouraye, Mbout-Kaedi, June 1983, Pg 14.

5. Major Oued Crossings.

Table 5-1 is a summary of the major oueds on the Km 60 to Selibabi section:

As indicated in Section 3 - Design Flow Hydrology, very large flows occur in the major oueds causing flow throughout the flood plain several times per year. During most of the year, however, the oueds are completely dry and flows which would disrupt traffic occur only a few days per year as indicated in the table above. Design for these crossings therefore requires not only consideration for the massive flood flows which occur, but also consideration that the very low traffic volumes projected to use the road will only be affected by storm runoff a few days per year. The following alternatives are proposed.

1. Extended Radiers consisting not only of the protected radier roadway through the main channel, but also through the floodplain to a point on each side above the expected high water level. This extended radier (throughout the floodplain) is necessary to protect the roadway during periods of flooding. Investigations of the Oued Garfa and Oued Boudame crossings on the UN constructed Mbout to Km 70 section where radiers were constructed through the main channel only indicate that the extended radier would have been desirable. After only one rainy season, the roadway for several hundred meters each side of the main channel is badly eroded and will require extensive yearly repair and maintenance to avoid complete destruction of the roadway.

   Figures 6-1 and 6-2 show two methods of constructing the protected roadway for the radiers.

   If this alternative is selected, it is estimated that the crossing will not be passable for the periods indicated in Table 5-1. The worst condition, at Oued Tourime, would involve road closure for four to five days after each signi-

Table 5-1

Sta.	Name	Drainage Area	25 Yr Flood	Main Channel Width	Flood Plain Width	Est. Days/Yr. with Significant Flow in Channel
14.130	Oued Hauoisse	217 Km^2	583 M^3/Sec.	28 M	450 M	6-8
16.037	Oued Cheika	54 Km^2	243 M^3/Sec.	30 M	100 M	3-4
25.250	Oued Tourime	586 Km^2	1,105 M^3/Sec.	34 M	550 M	12-20
27.500	Oued Amague	215 Km^2	580 M^2/Sec.	-	-	6-8

Table 5-2

Bridge and Radier Lengths

Mauritania Rural Roads

Km 70 - Selibabi

Crossing	Begin Floodplain	End Floodplain	Radier Length (M) w/o Bridge	Bridge Length (M)	Radier Length (M) With Bridge
Oued Haouisse	13.900	14.300	400	50	350
Oued Cheika	15.950	16.100	150	42	108
Oued Tourime	24.875	25.425	600	75	525
Oued Amague	--	--	--	50	--
		Totals	1,150	217	983

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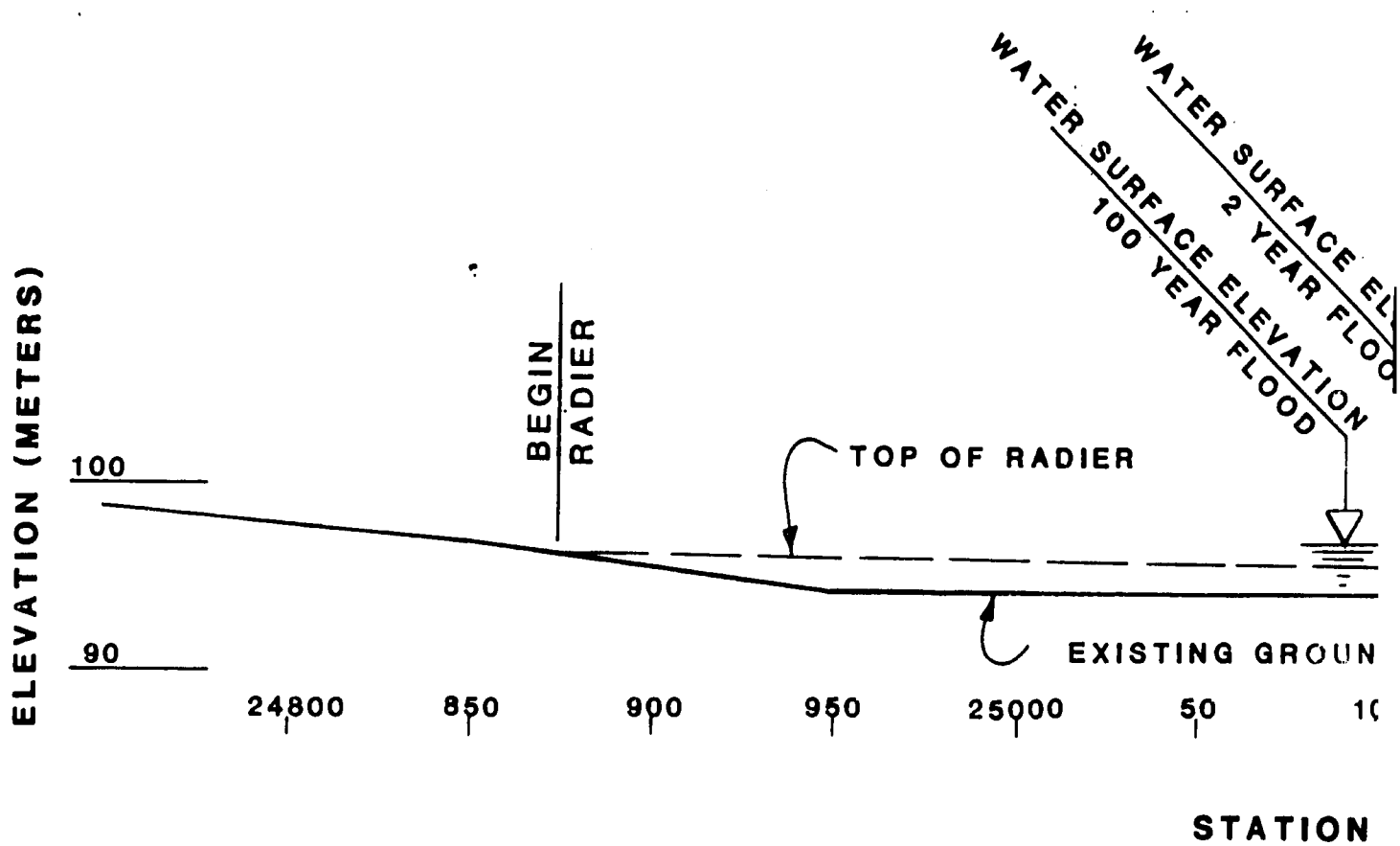
ficant storm (30 mm or greater) which would amount to a total of up to 20 days per year.

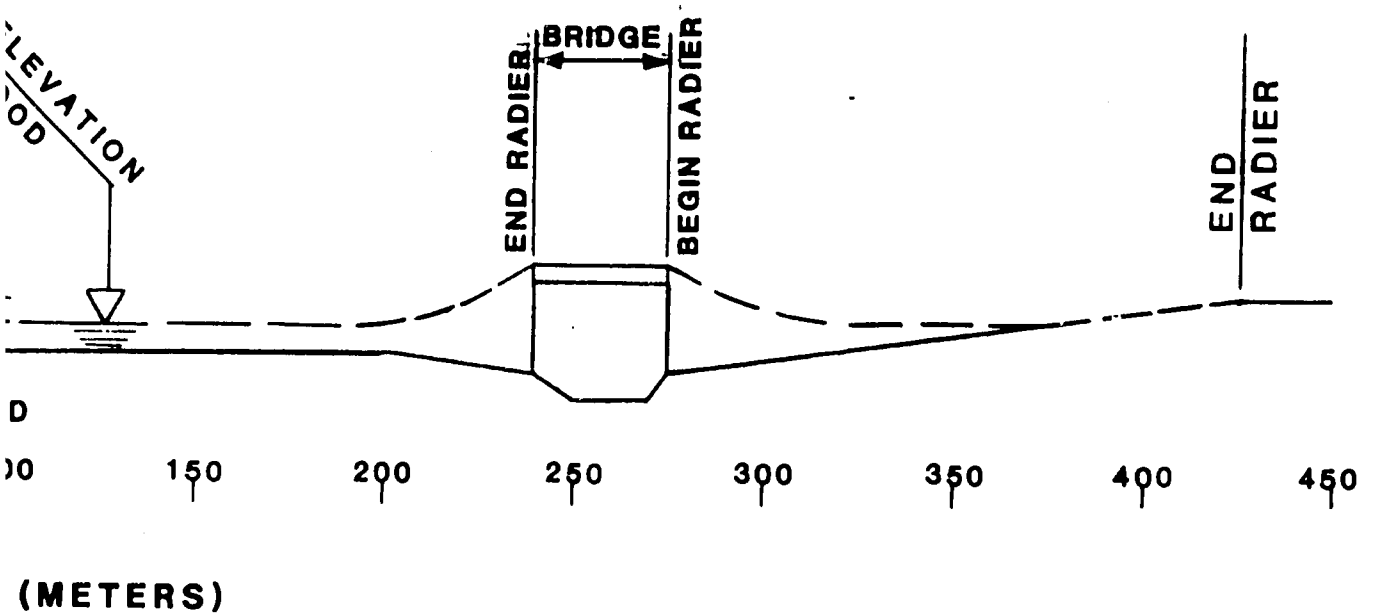
2. Combination Bridge and Radier (See Figure 5-1) designed to pass the large flood peaks under the bridge and over the radier and, after the first 24 hours, to pass the entire flow under the bridge. The alternative will significantly reduce the periods of road closures during runoff periods. For example, the time the road would be impassable after a significant storm would be reduced at Oued Tourime from four or five days to one day and the total days of closure per year would be reduced to three or four days. If this alternative is selected, additional field work will be required including more detailed flood analysis, complete topographic and bridge surveys and foundation investigations. Bridges will require complete engineering design.

   Because of the large flood flows and their unpredictability, it is recommended that bridges be "perched" above the expected high water levels with radiers constructed to allow passage of the flood peaks without reaching the bridge. Table 5-2 summarizes the bridge and radier lengths required.

Because of the high cost of bridge construction, and the very low expected traffic volumes, and the fact that bridge design and construction cannot be completed within the scope and scheduled duration of this project, it is recommended that the bridge/radier alternative not be used at this time. The gravel surfaced radier alternative is not recommended because it is believed that, after several rainstorms causing flow over the roadway, all fines and small gravel would be washed out leaving only large, five cm and larger, gravel and stone particles. This would create a rough driving surface, cause traffic to slow significantly and would therefore not meet the miniumum speed requirement desired.


WATER SURFACE EL
2 YEAR FLOO
WATER SURFACE ELEVATION
100 YEAR FLOOD
BEGIN
RADIER
TOP OF RADIER
EXISTING GROUN
ELEVATION (METERS)
100
90
24800
850
900
950
25000
50
STATION

- BRIDGE SHOULD BE CONSTRUCTED ABOVE 100 YEAR WATER SURFACE ELEVATION
- 70 METER BRIDGE WITH 10 PERCENT APPROACH ROADWAY GRADE
- VERTICAL CONCRETE WALL ABUTMENTS AND WINGWALLS
- APPROACH ROADWAY CONSTRUCTED AS RADIER AS SHOWN ON FIGURES 6-1 & 6-2.



EXAMPLE BRIDGE/RADIER CROSSING

OUED TOURIME

FIGURE 5-1

It is therefore recommended that an extended concrete radier be constructed through Oueds Haouisse, Cheika and Tourime. If at a later date it is decided that bridges should be constructed over the main channel as described above, they can easily be added and most of the concrete radier length can be retained and used with the bridge. A concrete radier which works reasonably well exists in Oued Amague at the edge of Selibabi. It appears to have been developed and constructed over years of construction and reconstruction and it is recommended that it not be disturbed until an adequate bridge can be constructed to replace it.

6. Marigot Crossings.

Table 6-1 is a summary of the significant marigots encountered on the Km 70 to Selibabi Section. The significant marigots, as shown by the table, are generally characterized by drainage basins between 1.0 and 20 Km^2 and flows of between 20 and 117 M^3/sec. They have well defined channels and are important drainages between the major oueds. They are too large and their flows are too great to be accommodated by corrugated steel pipe culverts because the large number of pipes required could not be placed in a hydraulically efficient manner and pipes have a greater tendency to become plugged creating significant problems and damage to the roadway. The following alternatives are therefore proposed for crossing significant marigots:

1. Box Culverts or Small Bridges designed to span the width of the channel or to pass at least the two year (average) storm along with dips in the profile (radiers) adjacent to the bridge. The dips would be designed to pass runoff greater than the two-year storm without damage to the bridge. Spans less than five meters should be avoided to prevent debris accumulations which would damage the bridge or its piers. Two types of bridges might be considered for these crossings including:

    a. Bailey Bridges or other prefabricated bridges may be economical if they can be purchased from the U.S. Government as excess equipment. The Bailey Bridge consists of a system of prefabricated truss panels which bolt together. They are quickly and easily installed using very little specialized equipment or labor. However, though there are cases where they have been used successfully as permanent structures, they are not designed as such.

Table 6-1

Significant Marigots

Mauritania Rural Roads

Km 70 - Selibabi

Station (Km)	Drainage Area (Km^2)	25-Year Flow (M^3/sec.)	Width (M)	Depth (M)	Est. Required Radier Length (M)*
3.143	1.2	22	2.4	1.3	39
6.612	17.0	117	8.0	0.9	34
9.248	12.0	94	9.3	3.8	81
10.370	1.0	20	8.4	0.6	29
11.248	5.4	56	59.0	0.3	75
12.675	1.4	24	13.5	1.4	47
12.835	1.4	24	15.0	0.5	34
16.602	11.0	88	16.0	1.5	51
23.122	1.5	25	8.2	1.0	35
27.143	2.7	36	11.3	1.9	53
31.136	2.3	33	9.5	1.5	45
37.852	2.5	35	5.2	2.2	52
39.861	5.4	56	14.0	1.0	41
41.366	2.4	34	9.1	2.0	52
42.476	3.1	40	3.0	1.5	38
				Total	705 Linear Meters

*Length = 4 + 16 (Depth + 0.45 M) + Width

Width not less than 6 meters

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b. Concrete Bridges or box culverts may be used if Portland Cement and reinforcing steel can be readily obtained. These structures will have a much longer, more maintenance-free life than the steel Bailey bridges and would probably be more resistant to collection of debris and damage from high water flow.

Should bridges or box culverts be selected as the alternative to construct, additional field work beyond the scope of this report will be required including additional flood flow analysis, topographic surveys of the bridge site and foundation investigations. A complete engineering design will also be required for each bridge or box culvert.

2. Radiers crossing the main channel as shown in Figure 6-1 and 6-2 may be constructed. It is estimated that flows will be great enough to prevent crossing after significant storms for less than 24 hours. This should present little problem given the very light traffic volumes expected. The following two precautions should be taken to properly install radiers:

a. The driving surface of the radier should be higher than the flowline of the channel as shown on the "Drainage Longitudinal Section" on Figure 6-1.

b. Where sides of the natural channel are cut back to allow the construction of the roadway creating a notch in the side of the channel, a smooth transition should be constructed from the radier back to the natural

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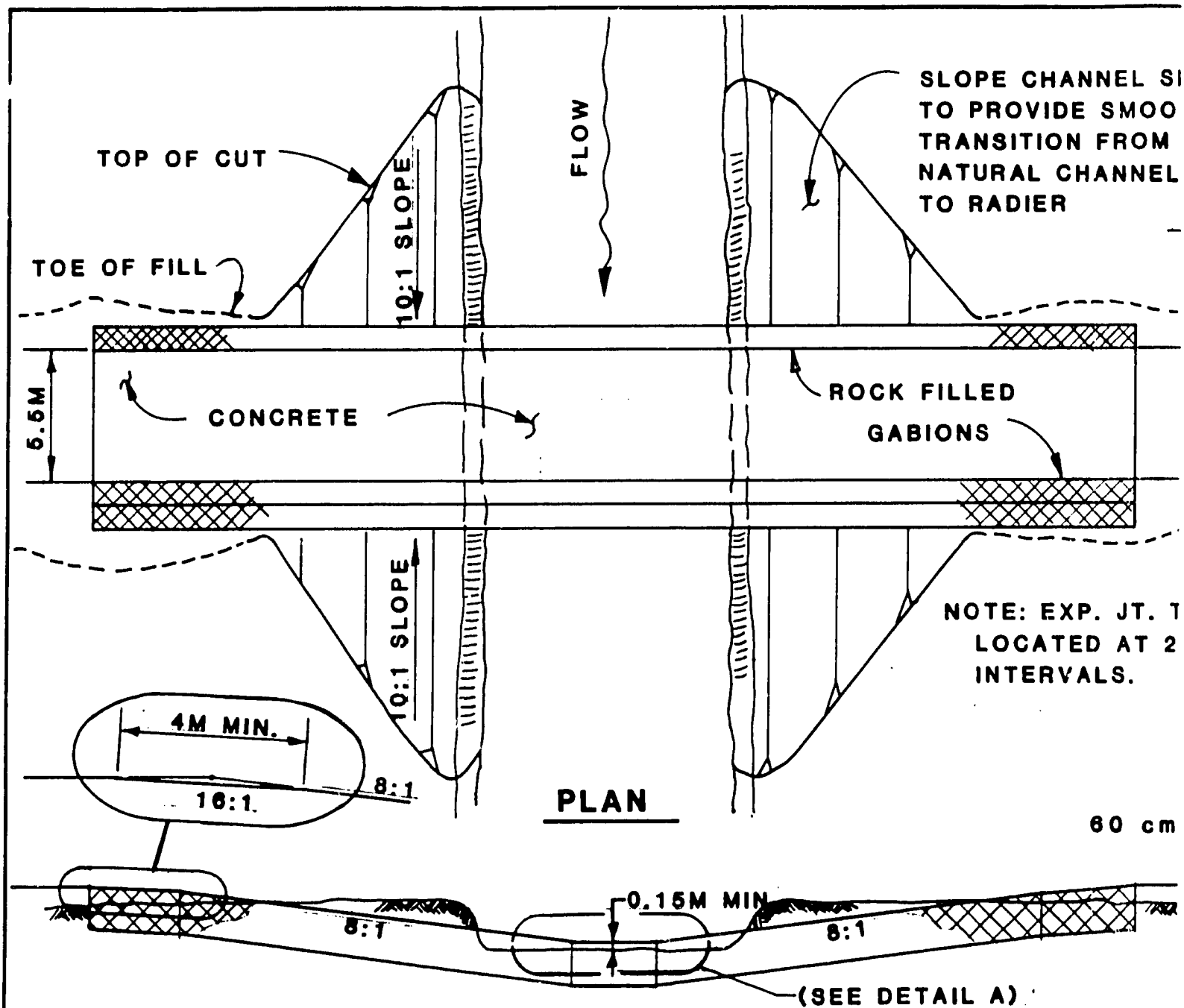
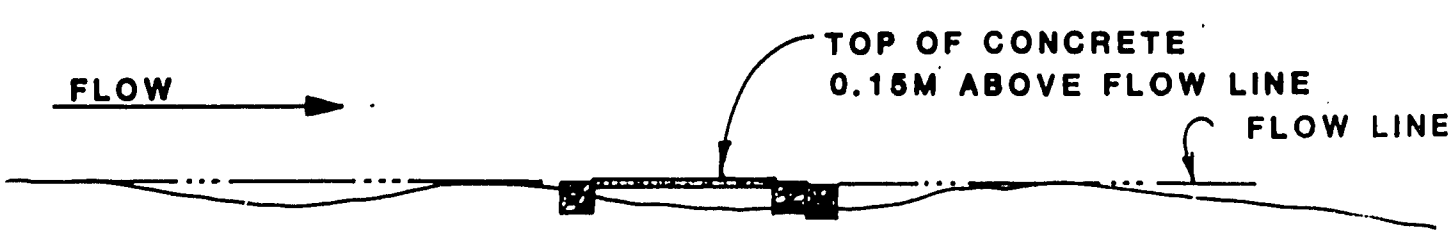
channel to help avoid creating pockets where stream sediment load may be deposited. See Figure 6-1.

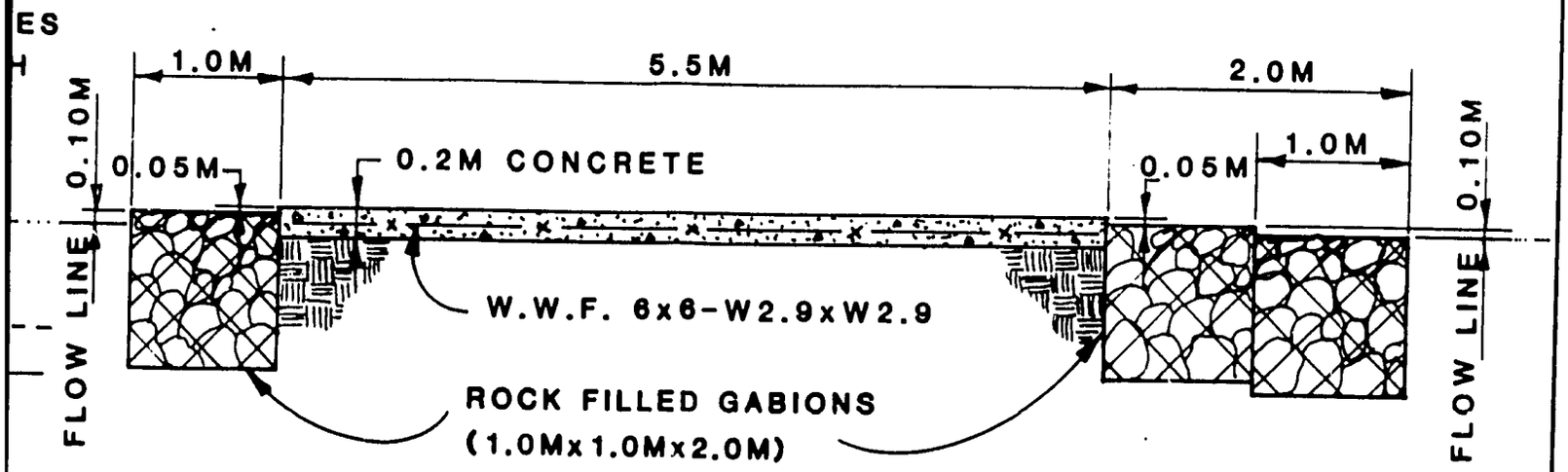
The alignment and profile should be checked and necessary adjustments made to ensure that the radiers will be visible for a sufficient distance for drivers to make the necessary speed adjustments. Advance warning signs should also be considered.

Concrete radiers, instead of bridges, box culverts or gravel radiers, are recommended because of their lower cost and because they will be much less likely to become clogged with debris and/or damaged during periods of high flood flows. Because of the additional field work and design required for bridges, radiers will also be much easier to complete during the scheduled duration of this project.

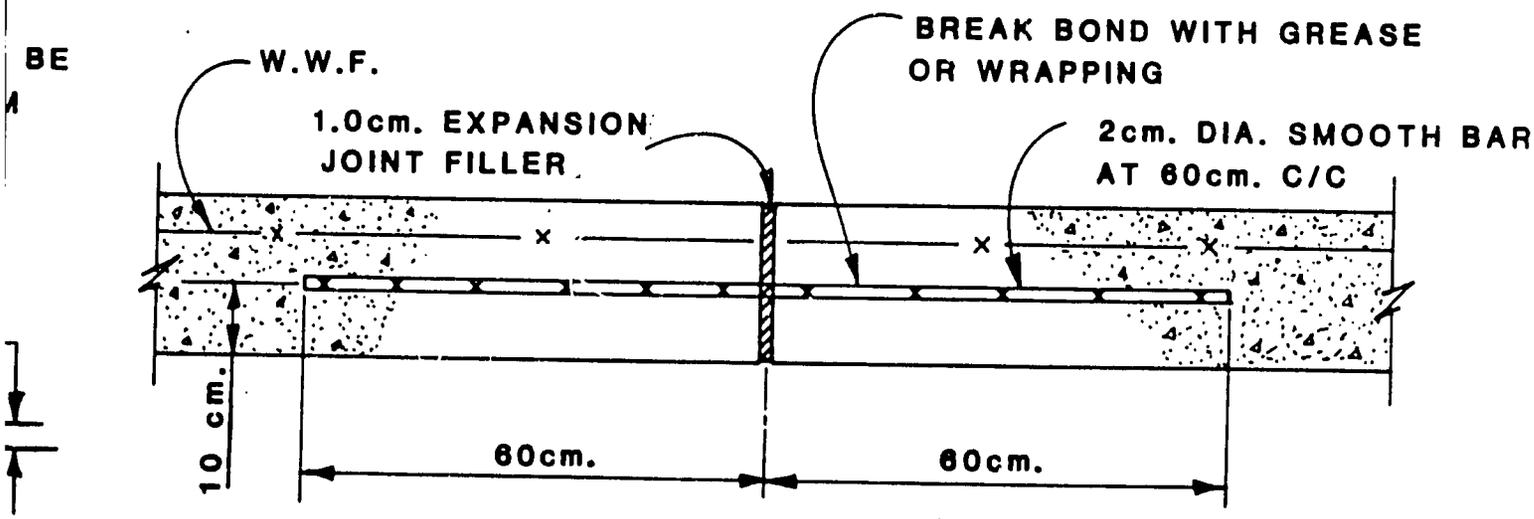




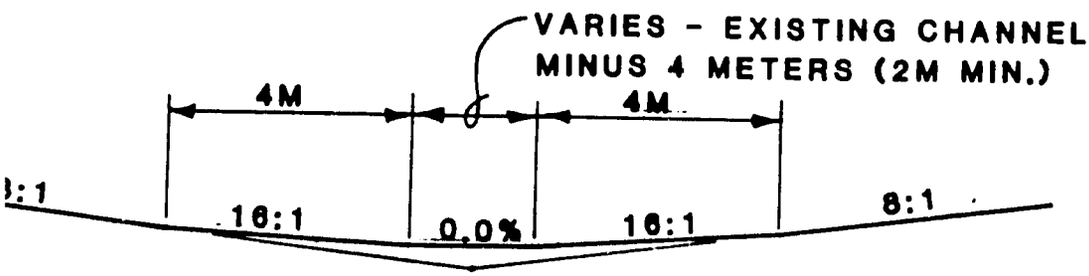
DRAINAGE LONGITUDINAL SECTION



CROSS SECTION



EXPANSION JOINT DETAIL



DETAIL A

TYPICAL RADIER DETAILS

FIGURE 6-1

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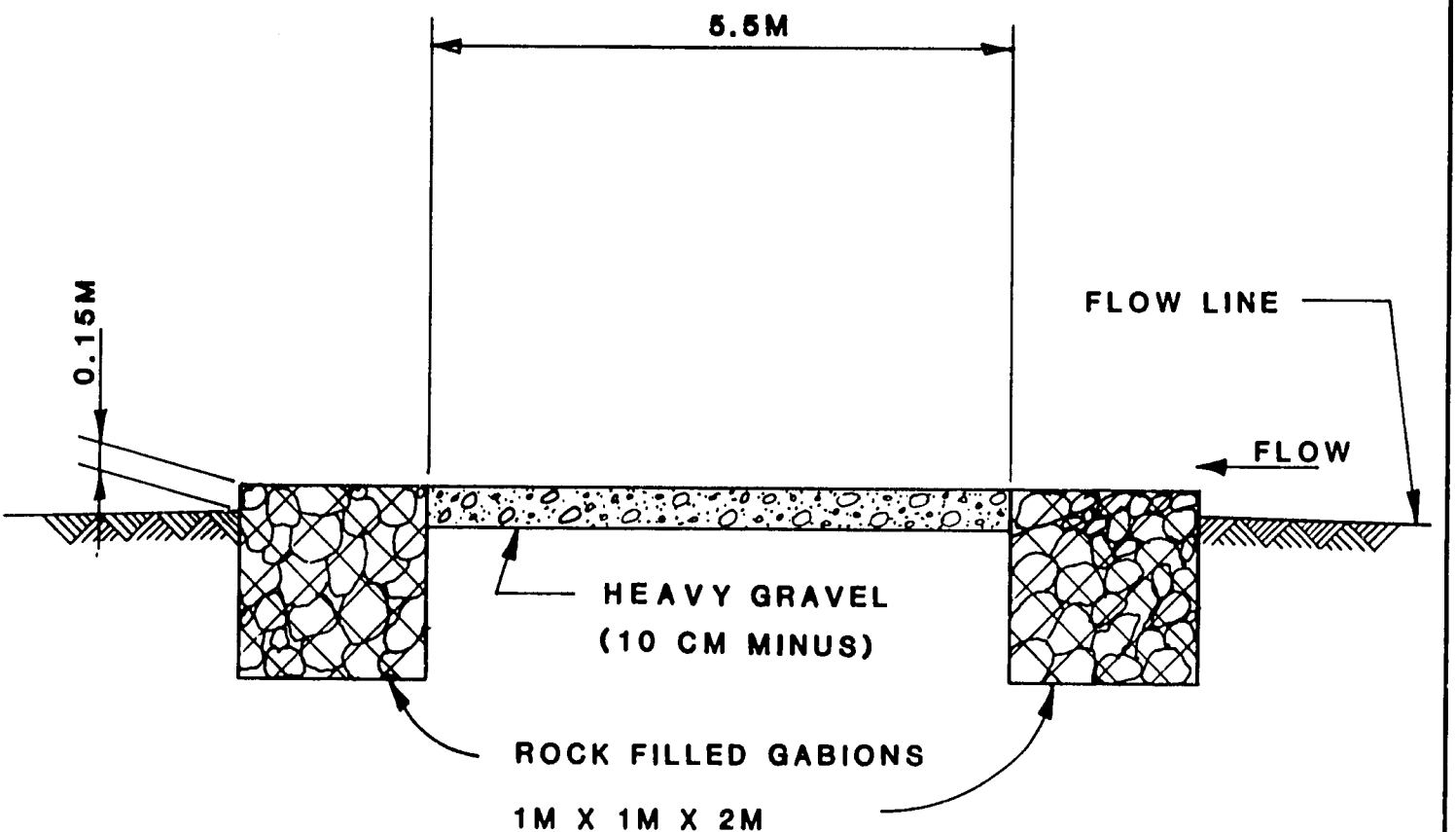

ALTERNATE RADIER

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FIGURE 6-2

7. Small Marigot Crossings

Table 7-1 lists small marigot crossings encountered between KM 70 and Selibabi and indicates the recommended pipe sizes and quantities required. These crossings include those marigots with defined channels and with flows of less than 20 m^3/sec or less. They are minor drainages and are the most numerous type of drainage crossing encountered. Pipe culverts were selected instead of concrete raiders or bridges for the following reasons:

1. The large number of small marigots (more than 1 crossing/km), if crossed by the dips of numerous radiers, would make driving the road uncomfortable, slow and perhaps unsafe.

2. Flows do not require anything larger.

3. Corrugated steel pipe should be less expensive than radiers or bridges.

One disadvantage to the use of culverts will be their tendency to become blocked more rapidly than radiers and will therefore require regular maintenance (debris should be removed from the entrance after every significant storm).

The culverts should be installed as indicated in Figure 7-1. Minimum cover should be 30 cm and 60 cm is desirable. The flow line of the culvert should have a minimum slope of 1% and should be level with or above the channel flow line. Placing any part of the culvert below the flow line will cause it to immediately begin to fill with sand and gravel. A level circuit should be completed downstream of the culvert to make sure the channel slopes away from the culvert to avoid ponding or siltation. A one percent slope away from the culvert is desirable. The adjacent roadway should be constructed to an elevation at least equal to 30 cm above the top of the pipe to assure that the full design capacity of the pipe can be used before water overtops the road.

Table 7-1
Small Marigot Crossings
Mauritania Rural Roads
Km 70 - Selibabi

Station	Discharge (M^3/Sec)	No. of 90 cm CSP Required	No. of 150 cm CSP Required
2.200	12.0		3
3.116	9.0		2
3.464	18.0		4
5.500	6.9		2
5.866	11.0		3
6.645		3	
6.811			4
7.130	9.9		2
7.159	9.9		2
7.672		3	
7.850			1
7.994	9.9		2
8.232	9.9		2
9.425		2	
9.778	17.0		4
9.891	4.5	3	
11.350		2	
11.393		2	
11.450		2	
12.985		1	
13.600		2	
15.998			3
16.710		2	
21.922	6.9		2
23.070		3	
25.600	9.0		2
25.850	14.0		3
26.990	4.5		2
27.085			1
27.693			2
28.073			2
28.572			2
29.612			1
30.050			1
30.200			1
30.640	14.0		4
32.000			1
32.190			1
32.530			1
32.735			1
32.940	14.0		3
33.387	14.0		3
33.699	14.0		3

Table 7-1 (Cont.)
Small Marigot Crossings
Mauritania Rural Roads
Km 70 - Selibabi

Station	Discharge (M^3/Sec)	No. of 90 cm CSP Required	No. of 150 cm CSP Required
34.185			2
35.590	11.0		3
35.800	6.9		2
36.529	18.0		4
36.700	3.9		1
37.117	3.9		1
37.435	3.9		1
37.525	3.9		1
38.066	11.0		3
39.500	6.9		2
39.946			3
40.633			1
41.299			2
41.596	17.0		4
42.493			3
42.978	14.0		4
42.825			2
	Totals	25	109

Required Length per 90 cm CSP = 12 M

Required Length per 150 cm CSP = 15 M

Total Length 90 cm CSP = 300 Meters

Total Length 150 cm CSP = 1,635 Meters

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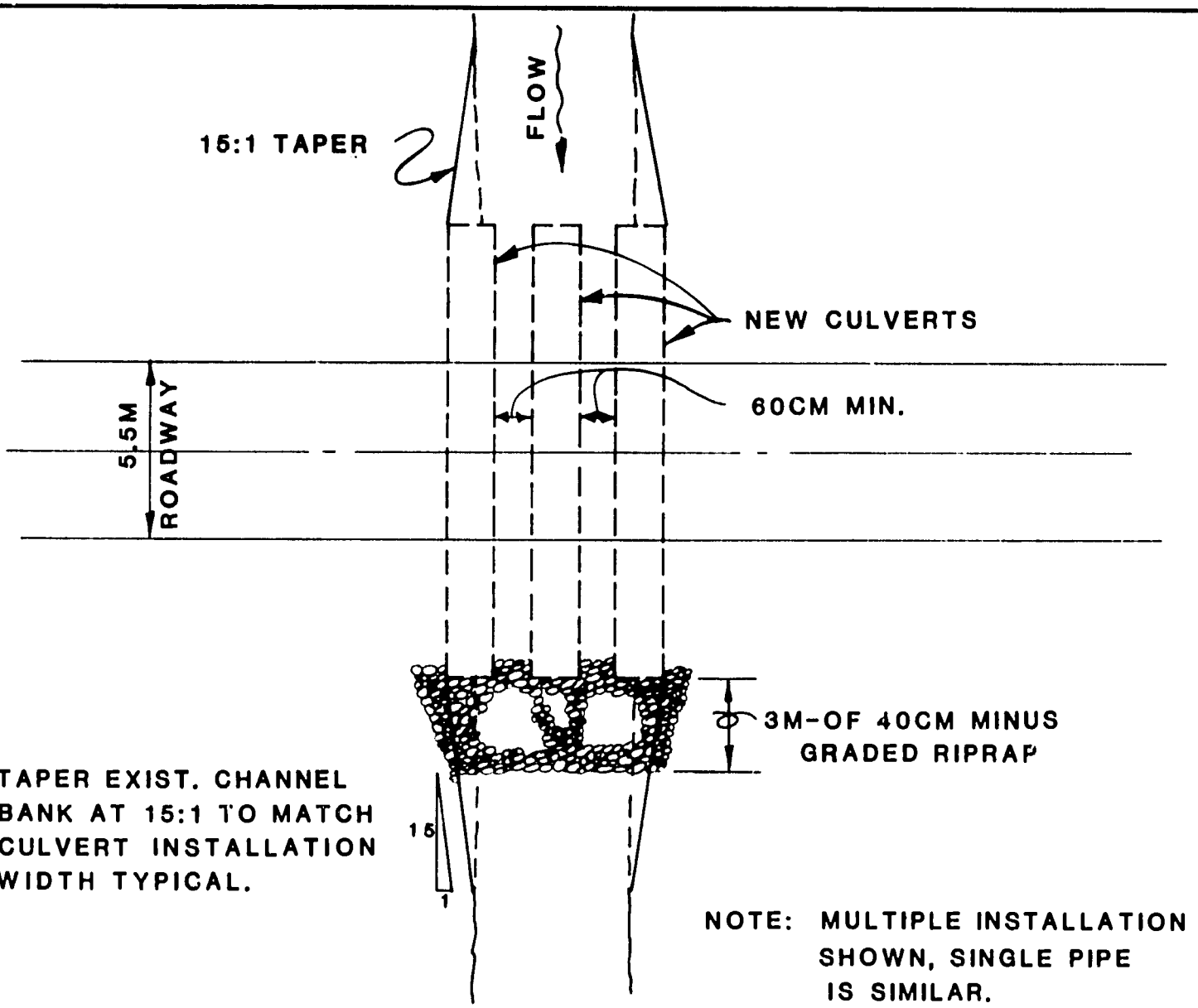
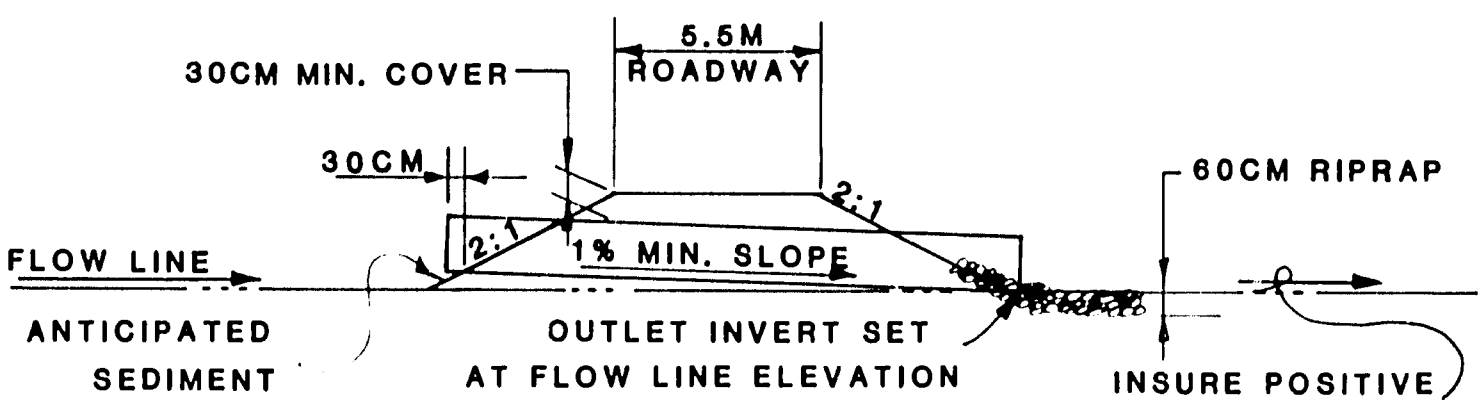


PLAN



SECTION

TYPICAL CULVERT INSTALLATION

FIGURE 7-1

Corrugated steel pipe shall meet the requirements of AASHTO M36-82. Culvert wall thickness, assuming nestable two piece pipe is used, shall be 14 gauge for 90 cm pipe and 12 gauge for 150 cm pipe or heavier if recommended by the manufacturer. The pipe shall be designed to withstand HS-20-44 loads with a minimum of 30 cm cover over the top of the pipe.

There are several methods and types of pipe assembly and connection. It is recommended that before pipe is shipped, the assembly and connection methods be ascertained and the necessary tools and materials, including spares, be purchased. For example, some methods use large quantities of steel bolts and nuts for assembly. Because of the many culvert installations required, several heavy duty air wrenches with compressors and a large quantity of spare sockets and other parts would be required. The project construction superintendent and the master mechanics should be consulted. It is also recommended that before the pipe is shipped, it be inspected to ascertain it meets the requirements of the specifications.

8. Cross-Drainage and Flood Areas.

Table 8-1 lists stations, locations and quantities of pipe recommended for cross drainage pipes desirable for the Km 70 to Selibabi Section. Cross-drainages include areas where, though there are no well defined marigots or channels, it is evident that some surface flow occurs across the roadway alignment and small drain pipes should be installed. These areas also include long sections of roadway where no oued or marigot crossings occur and it is therefore desirable to give surface drainage an opportunity to cross the roadway before it accumulates sufficiently to cause erosion or damage to the roadway. Cross-drainage pipe should also be placed in profile dips, low areas and periodically along the raised roadway through flooded areas as described below.

Cross-drainage culverts will be corrugated steel pipe as described in Section 7 - Small Marigot Crossings. Because cross-drainage pipes are not required to carry a specific flow, it may be acceptable, if necessary, to place the flowline of the pipe slightly below the flowline of the channel to reduce the elevation of the roadway over the pipe.

Table 8-1

Cross-Drainage Culverts

Mauritania Rural Roads

Km 70 - Selibabi

Station	No. of 90 cm CSP Required	No. of 150 cm CSP Required	Station	No. of 90 cm CSP Required	No. of 150 cm CSP Required
0.500±	1		26.000±	1	
0.980	1		26.200±	1	
1.100	1		26.350±	1	
1.550±	1		26.530±	1	
2.750±	1		27.500	1	
3.585	1		27.850	1	
3.960		1	28.700	1	
4.400±	1		29.200	1	
4.800		1	29.725	1	
5.200	1		30.300	1	
6.150		1	31.068	1	
8.700±	1		31.650	1	
10.500	1		31.820	1	
11.575	1		32.795	1	
11.665	1		34.130	1	
12.100±	1		34.550±	1	
12.600	1		34.900±	1	
13.200	2		35.250±	1	
13.300	1		38.300	1	
15.000	1		38.700		1
15.350	1		38.920	1	
16.200	2		39.025	1	
16.400	2		40.300		1
17.100±	1		40.900		1
17.500±	1		42.320		1
17.800±	1		43.500±	1	
18.200±	1		43.750±	1	
18.600		1	44.000	2	
18.828		1	44.520	2	
19.100±	1		44.950	1	
19.400±	1		44.250	1	
19.731		1	44.550	1	
20.150±	1		44.970	1	
20.600±	1				
21.050±	1				
21.500±	1				
22.600	2				
23.330		1			
23.510	1				
24.000	1				
24.200	1				
24.590	1		Total	70	11

The total pipe lengths required are:

90 cm = 70 Each @ 12 Meters/Each = 840 Meters

150 cm = 11 Each @ 15 Meters/Each = 165 Meters

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Table 8-2 is a summary of some of the areas where it may be desirable to raise the roadway above the water level in areas where flooding occurs. Table 8-2 is not complete and does not include all areas which might be encountered because a complete accurate profile, existing or designed, has not been completed. As the roadway is designed and constructed through these areas, it should be raised at least 60 cm above the average high water elevation in flood areas as determined from the profile survey to be completed. Cross drainage pipe should be incorporated as described above.

Table 8-2

Flood Areas Where Profile Should be Raised

Mauritania Rural Roads

Km 70 - Selibabi

Station (From - To)
2.000 - 2.350
2.800 - 3.525
6.525 - 7.180
11.200 - 11.475
12.500 - 12.900
15.720 - 16.800
22.550 - 22.650
28.650 - 28.750
33.600 - 33.750
39.900 - 40.150
42.300 - 42.550
43.950 - 44.100

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9. Quantity and Cost Summary.

Tables 9-1 and 9-2 summarize the quantities and material needed to complete the required drainage structures for the Km 70 to Selibabi section using the alternatives recommended by this report. Costs are estimated based on information gathered and calculations performed by Overseas Construction Company, a subcontractor for this project. A copy of a portion of their report is included on following pages.

The prices shown on the tables include direct labor, equipment and materials costs. For information, the following materials only costs, delivered on-site are provided:

Item	Quantity	Unit Price ($)	Total ($)
Concrete & Steel	1,265 M^3	83.00	$105,000
Gabions	3,450 M^3	28.50	98,300
90 cm CPS	1,140 Linear Meters	96.00	109,400
150 cm CPS	1,800 Linear Meters	195.00	351,000
			$663,700

The quantities shown on Tables 9-1 and 9-2 are actual estimated quantities with no contingencies added. It is recommended that when the materials are purchased the quantities indicated plus 20 percent be ordered to allow for skew and any changes, problems or other unforeseen circumstances. Should the 20 percent not be required for Km 70 to Selibabi, the excess can easily be applied to the next section, Selibabi to Gouraye.

Table 9-1
Quantities and Costs
Including Labor, Equipment and Materials
Concrete Radiers
Mauritania Rural Roads
Km 70 - Selibabi

Item	Quantity Per Linear Meter	Unit Cost ($)	Total Linear Meters	Total Price
Major Oued Crossings (Concrete Radiers):				
Concrete (incl. steel)	1.1 M^3	$160.00	1,150	$202,400
Gabion Baskets	3.0 M^3	45.50	1,150	157,000
			Subtotal	$359,400
Marigot Crossings (Concrete Radiers):				
Concrete (incl. steel)	1.1 M^3	$160.00	705	$124,100
Gabion Baskets	3.0 M^3	45.50	705	96,200
			Subtotal	$220,300
			Total	$579,700

Table 9-2
Quantities and Costs
Including Labor, Equipment and Materials
Corrugated Steel Pipe
Mauritania Rural Roads
Km 70 - Selibabi

Item	Linear Meters	$/Meter	Total Cost($)
Small Marigots:			
90 cm CSP	300	124.00	$ 37,200
150 cm CSP	1,635	237.00	387,500
		Subtotal	$ 424,700
Cross Drainage:			
90 cm CSP	840	124.00	$ 104,200
150 cm CSP	165	237.00	39,100
		Subtotal	$ 143,300
		Total	$ 568,000
		Add Radier Costs	$ 579,700
		Total Cost	$1,147,700

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OVERSEAS
CONSTRUCTION SERVICES COMPANY
800 West Madison Street
Mt. Pleasant, Iowa 52641
319/385-7611
Cable OCSINC
P. O. Box 238
TLX 230199 SWIFT UR OCS

November 28, 1983

Mr. Brad Peterson
Morrison-Maierle, Inc.
P. O. Box 6147
910 Helena Avenue
Helena, Montana 59604

Dear Brad:

Cost estimate spread sheets are attached for the nestable culvert pipe, gabions, and Irish Bridge. Direct costs are as follows:

Item 1.	Irish Bridge (Excavate, pour, clean-up)	US$160.00M^3 Concrete
Item 2.	36" Culvert 14 gauge (Excavate, Place, Backfill)	US$123.54/M.L Culvert
Item 3.	60" Culvert 12 gauge (Excavate, Place, Backfill)	US$237.40/M.L Culvert
Item 4.	Gabions (Furnish & Place)	US$113.30/Meter Cube

Direct costs for single span country bridges should be in the following ranges:

Excavations for footings	Dry US$ 13.00/M^3
	Wet US$ 42.50/M^3
Footing & abutment concrete (in place)	US$140/M^3
Beams & slabs (in place)	US$285/M^3
Reinforcing steel (provide & place)	US$ 0.92/kg.

Regards,

Ken

Ken Rogers
President

Revised to $45.50 per conversation w/ Dave Paulsen on 01 Dec 83.
BGP

WKR:vkb

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