APPENDIX II

Road Maintenance Technical Proposal

GRAVEL ROADS MAINTENANCE DESIGN

General

A basic engineering consideration in rural road maintenance is route location and design that fits the alignment sympathetically into the terrain. This will demand realistic horizontal and vertical geometric standards. Good location will also help to reduce the risks of soil erosion and side slope instability caused during the construction process and later with the dispersal of runoff.

1.1 LABOR-BASED CONSTRUCTION

The use of labor as the principal input in the construction process demands that longitudinal and borrow pit haul distances are kept to a minimum (we consider 200 meters as the maximum distance for wheelbarrow haulage). Careful selection of road alignments will often significantly reduce the need for excessive earthwork quantities, where possible, particularly in rock soils. Balancing of earthwork quantities is an important engineering factor. However, when using labor-based techniques, this balancing is achieved by shifting the road centerline laterally and not by moving soil longitudinally.

The success of any design is in its implementation and the benefits made available to the users. It is essential, therefore, that design standards to be adapted for use are easily understood by technical field staff responsible for minor road maintenance in Roads 2000 interventions. To this end we propose that the new standards should include sufficient flexibility to allow for safe and adequate accommodation of vehicles and efficient use of labor in its construction.

1.2 GRAVEL ROADS

The aim of the road designer is to provide safe all weather access for users at a minimum maintenance cost. Carriageway width therefore has a profound effect on maintenance cost. Carriageway widths depend on road alignment and the volume and type of traffic using the road. Due to traffic flows currently using minor roads in Kenya it is essential that there is provision for vehicles to pass which, in mountainous terrain, can be provided by the maintenance of passing places and/or building shoulders on which vehicles can travel during a passing

maneuver. From experience we recommended that a minimum carriageway width of 5.0 meters be adopted for minor roads.

Table 1.: General Terms.

(1.) *Construction*	The process by which a road is built according to established design standards.
(2.) *Rehabilitation*	Activities which improve the existing road and restore its geometric characteristics to the original recommended design standards.
(3.) *Upgrading*	The process by which the standard of an existing road is altered to allow the achievement of an increased capacity for safe use by a greater volume of traffic.
(4.) *Maintenance*	The work which is required to retain the original standard of the road.
(5.) *Routine maintenance*	Small operations with limited resource requirements usually performed once a year on a section of road.
(6.) *Periodic maintenance*	Needs to be carried out on a road or a section of a road after a number of years. This requires extra resources to implement.
(7.) *Emergency maintenance*	Is required from time to time on a section of road whenever a sudden or unforeseen damage occurs. In most cases this requires the deployment of additional resources.

(1.) STANDARDS

To avoid excessive wear and rutting to the carriageway and to provide for ongoing vehicles, shoulders are recommended for minor roads wherever possible. From experience in Kenya, the addition of shoulders should allow for a total roadway width of 6.00 m in lowland rolling/hilly terrain with a reduction to 5.00m in mountainous terrain, refer to figure 1 below.

In difficult mountainous terrain, the carriageway width may be reduced to a minimum of 3.5 meters where circumstances justify it. It is essential, for reasons of user safety, to ensure widening to full recommended standards on bends and summits. In mountainous terrain where heavy rock is encounterd, minimum roadway widths may be used for straight sections or where sight distance is adequate. However passing places must be constructed at regular intervals (determined by sight distance criteria) to ensure user safety.

Widening will also be essential on curves of minor roads constructed to minimum standard to ensure that vehicles can negotiate the curve safely within the roadway.

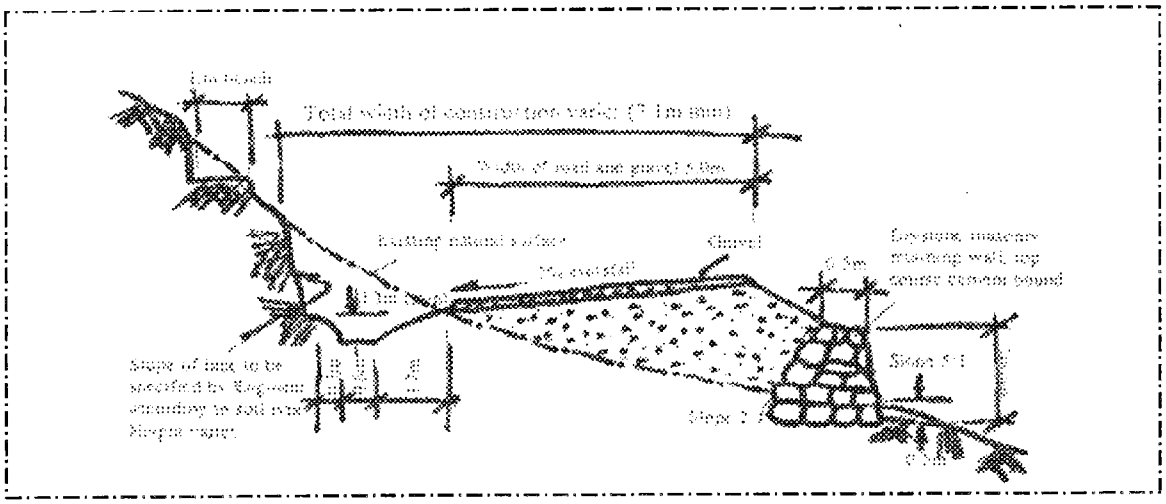


Figure 1: Minor road Cross Section on Mountainous Terrain.

(II.) RELAXATION OF DESIGN STANDARDS

Minor road standards should not be absolute, and sensibly applied relaxation can result in substantial maintenance cost savings, with little additional accident risk. Such relaxations or local reduction in standards should therefore be permitted, provided that they are not introduced in such a way as to be unexpected by the driver and thus lead to possibility hazardous situations. This aspect requires detailed study.

In many situations the reduction in maintenance cost by the relaxation of design standards may be more than offset by an increase in vehicle operating and maintenance costs. The minimum total cost solution always should be adopted. Here, use of 'Operation Research' is desirable to obtain an engineering compromise which yields maximum benefit among a number of constraints.

(III.) GRAVEL SPECIFICATION FOR MINOR ROADS

Gravel pavements for minor roads consist of formed subgrade, usually comprising in situ material obtained from excavation of side drains and a gravel base which acts as the running surface or wearing course. Since traffic volumes on the roads are relatively low, no structural design of the pavement is necessary. Based on the extensive pavement design studies undertaken in

Kenya by S. R. Manga and Associates, a minimum compacted thickness of 150mm of gravel is always recommended.

Rural roads works procedures do not involve mechanically frush or screening of murram material. The assessment of oversized material must be done by eye. We propose that the officer in-charge should have a specimen on hand of the largest permissible rock size in order to give laborers a rule to go by. Owing to the nature of labor-based quarrying (particular in hard, unweathered quarries), sticking rigidly to this specification may cause an undue loss of material due to rejection. In this case, we shall guidelines on how the supervisor may use discretion to increase the absolute maximum size of material.

- **California Bearing Ratio (CBR)**

The CBR is a measure of the strength of the pavement after compaction. The desirable minimum CBR for the gravel pavement at optimum moisture content is 35%, while the absolute minimum is 25%. The CBR is a characteristic of the particular type of gravel used.

- **Plasticity index (PI)**

The PI is the range of moisture content in which the gravel is in a plastic state. The clay content in the gravel is necessary to bind it together. Compaction is best achieved when moisture content is within the PI range. If the PI is high it indicates low bearing capacity. However, a low PI means that stringent control of moisture content is necessary during compaction. The acceptance range of PI for labor-based construction will have to be formulated.

- **Optimum moisture Content (OMC)**

This is the moisture content of the gravel at which the minimum amount of roller passes are required in order to achieve the specified minimum compaction. A practical field test of OMC will have to be devised to assist the field supervisor.

- **Minimum Compaction**

The required minimum compaction of the subgrade is 90% mod AASHTO[α] and of the gravel wearing course 95% mod AASHTO. The mod AASHTO

[α] AASHTO: American Association of State Highway and Transportation Officials

specification relates to the relative density of the compacted material and is tested after compaction has been completed.

1.3 MINOR ROAD ELEMENTS

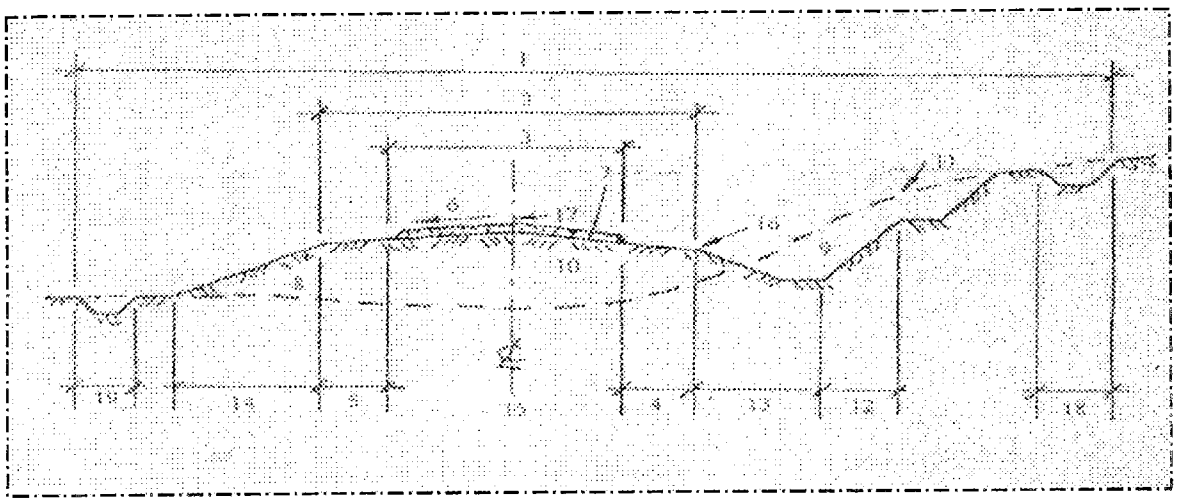


Figure 2.: Minor Road Elements (see Table 3 for definitions).

Figure 2.: Terrain Types in Kenya.

Mountainous (Over 65% crossfall)	Rugged, hilly and mountainous with substantial restrictions in both horizontal and vertical alignment; such roads will generally require larger amounts of cut and fill (greater than 26 No. Twenty-five-meter ground contours per kilometer).
Hilly (35% to 65% crossfall)	Hilly terrain with significant levels of rise and fall including restrictions on vertical alignment. Application of minimum standards will generally enable ground contours to be followed, however, cut and fill quantities will be significant. (15 to 26 No. twenty-five-meter ground contours per kilometer)
Rolling (105 to 35% crossfall)	Rolling terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment. Whilst lower standard roads will be able to follow the ground contours with small amounts of cut and fill, use of the higher standards will required more substantial quantities. (5 to 14 No. twenty-five meter ground contours per kilometer)
Lowland (up to 10% crossfall)	Level or gently sloping terrain with largely unrestricted horizontal alignment. Minimum values of alignment will rarely be necessary. Roads will for the most part follow the ground contours and amounts of cut and fill will be small (0 to 4 No. twenty-five-meter ground contours per kilometer)

Table 3.: Minor Road Elements (see Figure 2).

(1.) *Construction Width*	width of all earthworks carried out in constructing the road.
(2.) *Roadway*	width of a minor road inclusive of shoulders for vehicular use
(3.) *Carriageway*	paved width of a minor road
(4.) *Inside shoulder*	unpaved width of a minor road next to the edge of the carriageway adjacent to a cut slope.
(5.) *Outside shoulder*	unpaved width of a minor road next to the edge of the carriageway adjacent to an embankment slope.
(6.) *Camber*	lateral slope of the cross section of a straight section of a carriageway/shoulder.
(7.) *Pavement*	running surface of suitable graded material with full design thickness over entire carriageway
(8.) *Embankment*	constructed earthworks below the roadway
(9.) *Cutting*	excavation in the natural ground usually with graded slopes
(10.) *Subgrade surface*	upper layer of soil (this soil may be imported fill) supporting the roadway including embankment slopes.
(11.) *Original ground level*	the natural surface of the cross section prior to construction
(12.) *Cut slope*	a natural or artificially constructed soil (natural material) plane at an angle to the horizontal.
(13.) *Ditch and inside slope*	as for (12.)
(14.) *Embarking slope*	as for (12.)
(15.) *Minor Road Centerline*	line running along the Centre of the road (important in surveying and setting out the road alignment
(16.) *Shoulder break point*	the junction of the carriageway shoulder with the drainage ditch
(17.) *Crown*	peak or highest point of the camber
(18.) *Cut off drain*	drain to drain water from higher catchment areas
(19.) *Outside drain*	

1.4 PROPOSED MINOR ROADS DRAINAGE STANDARDS

Adequate drainage of minor roads in Kenya is essential to ensure attainment of the principal function of the road (all weather access), minimize maintenance and vehicle operation costs and protect local environment from erosion and other adverse effects resulting from the maintenance process. We intend to undertake research with a view of evolving a maintenance procedure which promotes for adequate drainage of the minor roads. Our endeavor will be to design road drainage that fulfils the following: -

(i.) Prevent saturation of the upper layers of the pavement structure

(ii.) Disperse surface water runoff away from the road

(iii.) Pass water under or across the road with minimum disturbance to its natural flow

(iv.) Ensure protection of the local environment from drainage discharge

(v.) Prevent the pooling of water on the road surface

We propose to design drainage structures for a two-year return period, that is they be designed to handle the largest flood that could reasonably be expected in any two years period, as computed from hydrological data. These structures will also be designed to safely overtop in the event of any flood larger than this one.

In mountainous areas it is important to ensure that the maintenance or rehabilitation of roads does not impede the natural drainage of upland water catchments. These catchments often provide important water sources for mountain villages. Adequate cross drainage structures will be provided to allow, as far as possible, the free passage of water. Care will be taken in selection of sites as marshy areas and small streams may not be evident during the dry season.

Minor roads maintenance experience indicates that a slope of 1:1 for embankments will provide the necessary structural support for the roadway and will be stable under prevalent weather (rainfall) conditions. To protect the exposed face from erosion, the planting of suitable grasses is strongly recommended and should be done immediately after maintenance of the embankment.

The major consideration in the design of drainage channels will be the prevention of erosion, whether to the road structure or to the channel itself. Both side and longitudinal slopes ought to be flat to avoid scouring velocities being reached. Where flow velocities are likely to be high due to the terrain, we

will propose that channels be lined with stone pitching. Scour checks may also be introduced to reduce the effective slope of the channel invert. A minimum slope of 1:200 for unpaved drains is desirable to avoid silting in flat terrain.

Table 4.: Drainage elements.

(i.)	Ditch	Along narrow flat bottomed excavation designed to collect and drain away surface runoff water.
(ii.)	Culvert	A structure constructed entirely below the roadway that allows water (mainly from ditches) to be safely dispersed away from the road.
(iii.)	Drift	A low level crossing over which perennial or intermittent water collected from the ditches and/or natural watercourses can flow.
(iv.)	Vented Ford	A medium level piped stream or river crossing through which the normal flow of water can pass but which is designed to be over topped during periods of heavy rainfall.
(v.)	Bridge	A designed structure that allows all water including runoff during periods of high rainfall to pass below the roadway elevation, but which may be overtopped for rainfalls of higher intensity than the design rainfall.

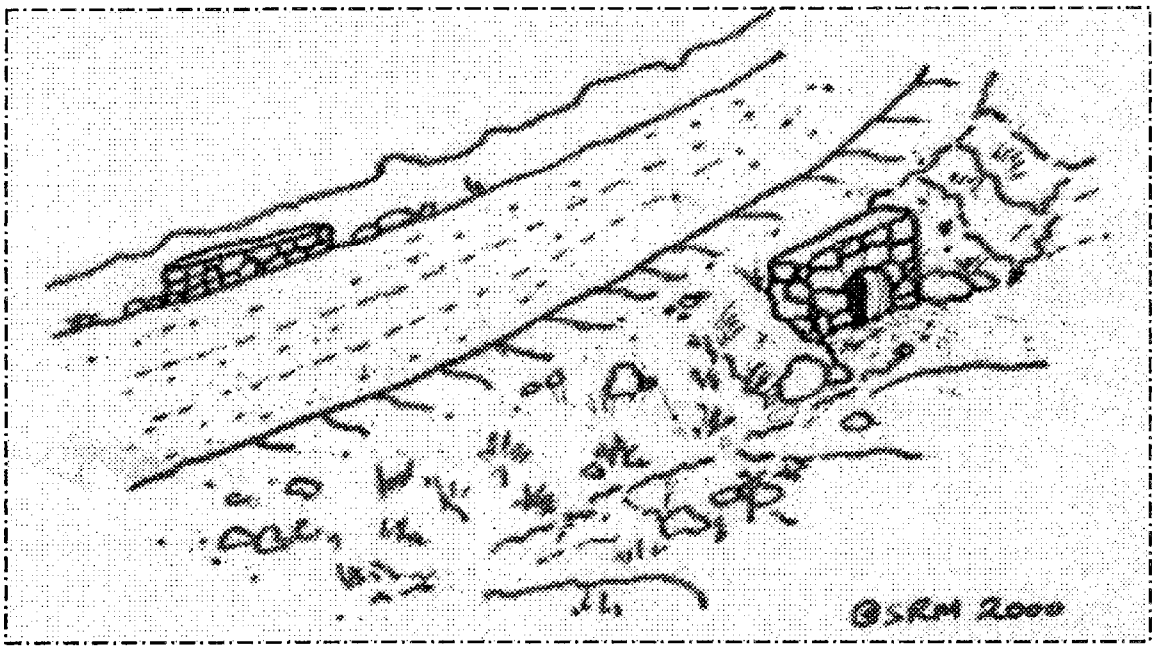


Figure 3.: Typical Pipe Culvert.

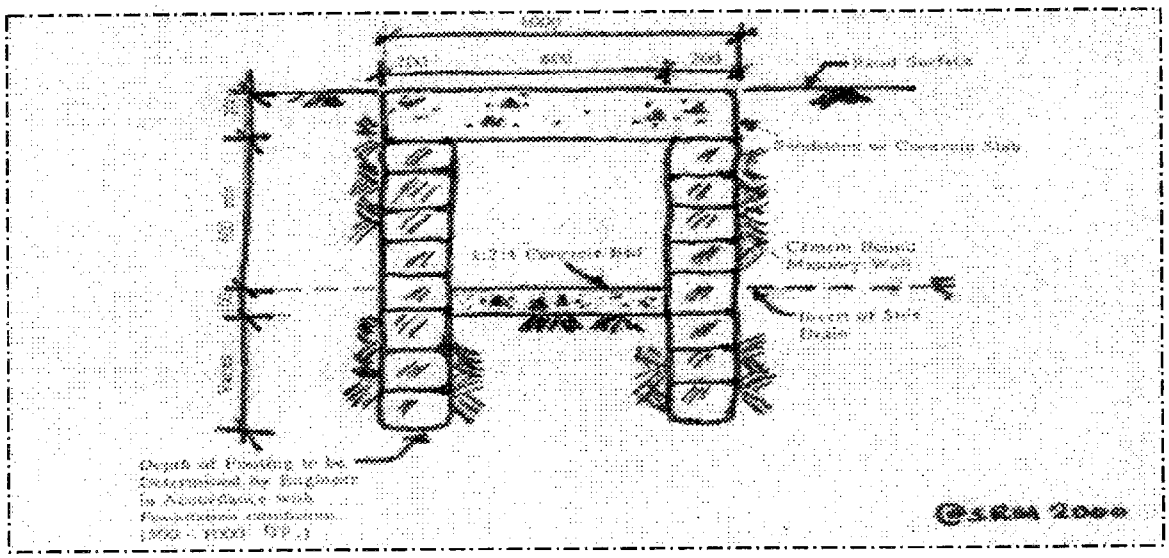


Figure 4.: Slab Culvert

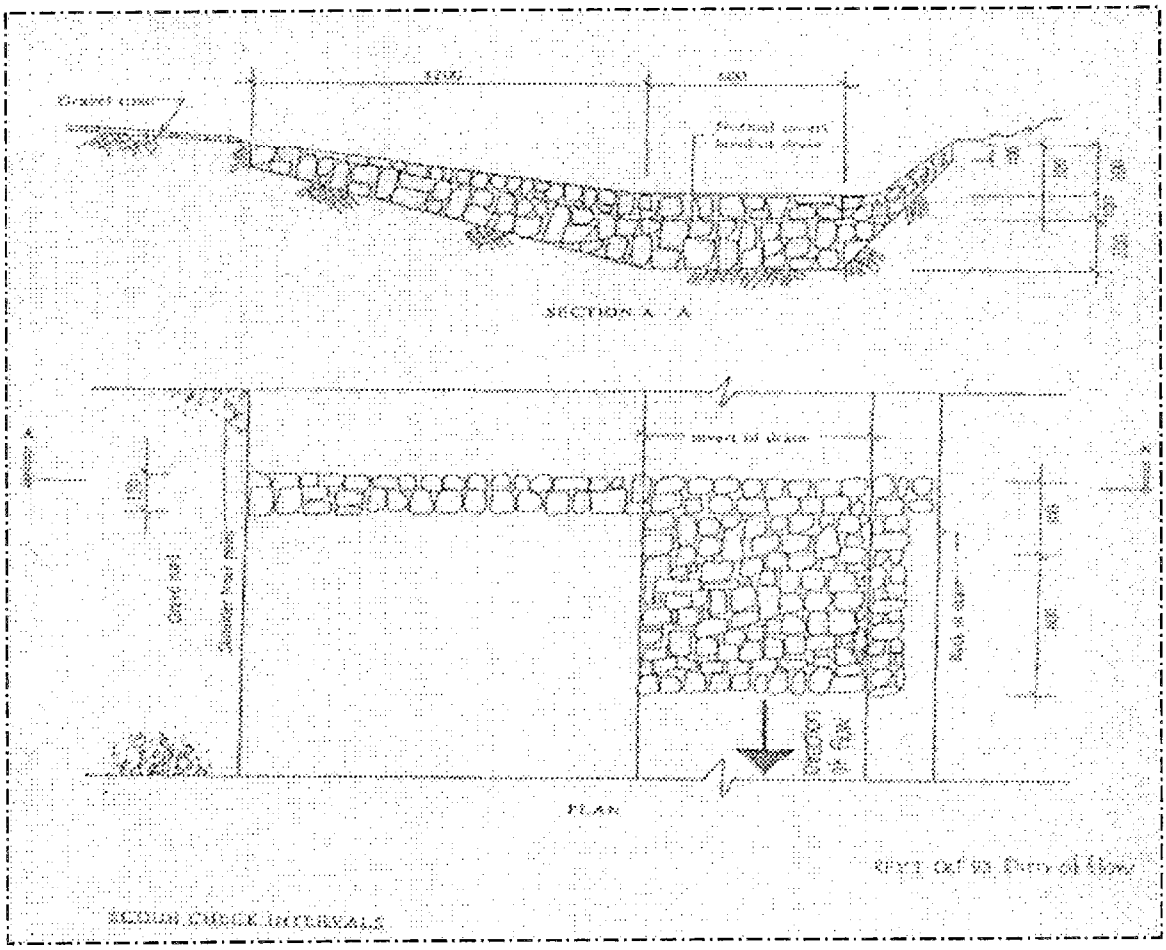


Figure 5.: Proposed Masonry Scour Checks.

APPENDIX III

Qualified Roads Contractors (Kenya)

Table I: List of Qualified Civil Engineering and Road Contractors.

(Source: Architectural Association of Kenya Newsletter, 1992)

(1.) Broadways Construction Ltd, P.O. BOX 46695, Nairobi. Tel. 221535/221967	(2.) Sarajevo General Engineering C P.O. BOX 48331, Nairobi. Tel. 722277/79
(3.) Capital Construction Co. Ltd, P.O. BOX 30604, Nairobi. Tel. 557433/303604	(4.) G. Issaias & Co.Ltd, P.O. BOX 43500, Nairobi. Tel. 725095/5989/6656
(5.) Come-Const.Africa Ltd, P.O. BOX 18429, Nairobi. Tel. 588933	(6.) Twiga Construction Co. P.O. BOX 43151, Nairobi. Tel. 214955/57/58
(7.) Carpentocraft Building & Civil, Engineering Contractors, P.O. BOX 28138, Nairobi. Tel. 334854	(8.) H.Z. & Co.Ltd, P.O. BOX 74358, Nairobi. Tel. 556411
(9.) Crescent Construction Co.Ltd, P.O. BOX 49094, Nairobi. Tel. 224780	(10.) Karsan Ramji & Sons, P.O. BOX 48838, Nairobi. Tel. 338288
(11.) Davis & Shirtliff Ltd, P.O. BOX 41762, Nairobi. Tel. 558335	(12.) Krishan Bebal, P.O. BOX 16227, Nairobi. Tel. 56964
(13.) Dhanjal Bros.Ltd, P.O. BOX 82909, Nairobi. Tel. 491652	(14.) Lamminkainen(Kenya), P.O. BOX 61102, Nairobi. Tel. 223205/330137/8
(15.) Facta Construction Co.Ltd, P.O. BOX 42337, Nairobi. Tel. 559575	(16.) Mascon Ltd, P.O. BOX 48524, Nairobi. Tel. 338154
(17.) Fairclough International Construction Ltd, P.O. BOX 60604, Nairobi. Tel. 221040/222689	(18.) Motorways Construction, P.O. BOX 72525, Nairobi. Tel. 845504/747311

Contd. Table I

(19.) Firoze Construction Ltd, P.O. BOX 46448, Nairobi. Tel. 222136	(20.) Macrocosmose E.A. Ltd, P.O. BOX 47655, Nairobi. Tel. 226263
(21.) Technoasphalt Ltd, P.O. BOX 18156, Nairobi. Tel. 559088/9	(22.) Mowlem Construction Ltd, P.O. BOX 30078, Nairobi. Tel.791241
(23.) Skanska International Civil Engineering AB, P.O. BOX 61643, Nairobi. Tel. 803109/3309	(24.) Orbit Enterprises, P.O. BOX 49604, Nairobi. Tel. 224464/338261
(25.) Sultan Construction Co. Ltd, P.O. BOX 40170, Nairobi. Tel. 225473	(26.) Oriental Construction Co. Ltd, P.O. BOX48364, Nairobi. Tel. 221684/1488
(27.) Taissi Corporation, P.O. BOX 259, Wanguru. Tel. 64	(28.) Strabag-Lima Ltd, P.O. BOX 30522, Nairobi. Tel. 740527/740630
(29.) TM-AM Construction Group, P.O. BOX 18424, Nairobi. Tel. 559088/9	(30.) Stirling Civil Engineering (K) Ltd, P.O. BOX 40770, Nairobi. Tel. 725335/725869
(31.) Z.G. Sethi & Co. Ltd, P.O. BOX 41463, Nairobi. Tel. 722181	(32.) Sogea Kenya Branch, P.O. BOX 39367, Nairobi. Tel. 221074/221423
(33.) Recchi SPA-Astaldi SPA, P.O. BOX 30237, Nairobi. Tel. 726500/1/6	

N.B.: A comprehensive list of contractors is available at the MORPW headquarters on request.

APPENDIX IV

Work Schedule and Key Personnel in the Study

CONSULTANCY INPUT TIME SCHEDULE CHART (Revised on 29.06.2000)

PROJECT PERSONNEL		WEEK 1 26/6/2000 - 30/6/2000	2 3/7/2000 - 7/7/2000	3 10/7/2000 - 14/7/2000	4 17/7/2000 - 21/7/2000	5 24/7/2000 - 28/7/2000	6 31/7/2000 - 4/8/2000	No. of ACTIVE DAYS on the Job
S. R. MANGA	CV No. 1							4 DAYS
M. A. KHANDHIA	CV No. 2							11 DAYS
P. S. THETHY	CV No. 3							5 DAYS
M. KAZUNGU	CV No. 4							12 DAYS
W. K. NGUTURI	CV No. 5							12 DAYS
D. K. NGUGI	CV No. 6							2 DAYS
C. S. WAMBURA	CV No. 7							2 DAYS

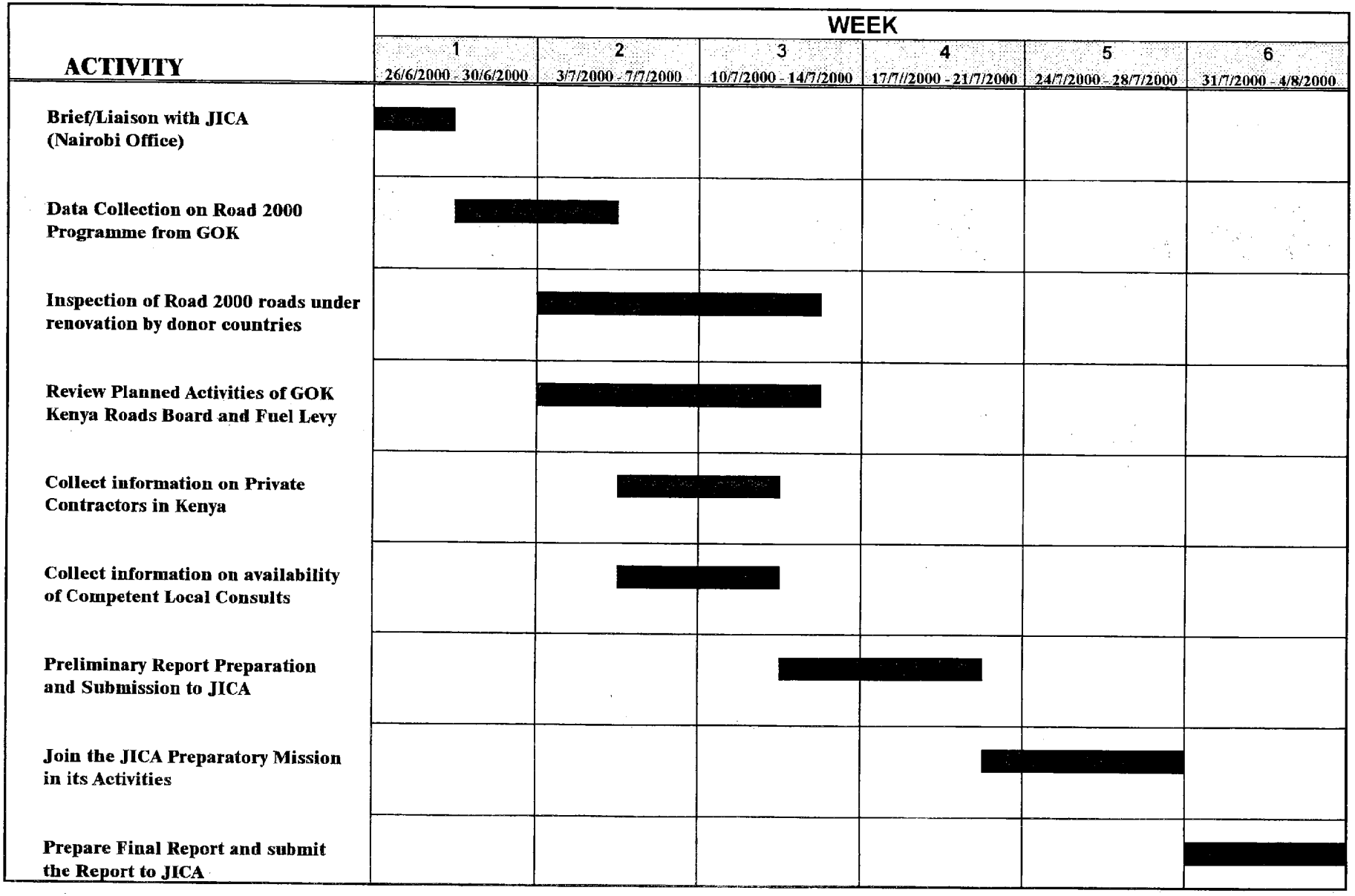
KEY:

ON THE JOB 100% OF TIME

ON THE JOB INTERMITTENTLY

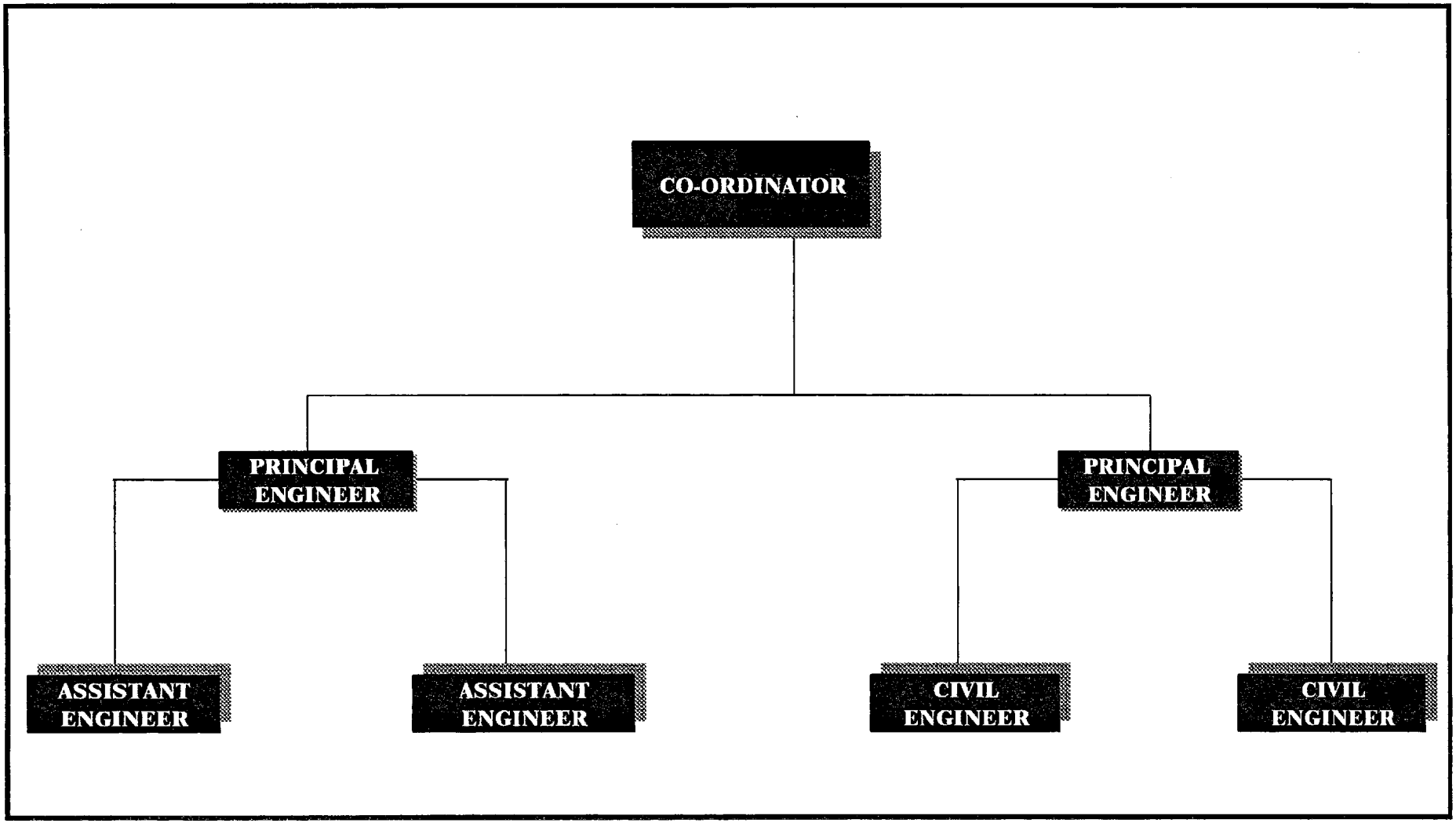
S. R. Manga and Associates,
P.O. Box 28190, Nairobi.
E-mail: srm@insightkenya.com

TIME ACTIVITY CHART



S. R. Manga and Associates,
P.O. Box 28190, Nairobi.
E-mail: *srm@insightkenya.com*

ORGANIZATIONAL CHART



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