Ministry of Works, Transport and Communications
Reli Assets Holding Company
United Republic of Tanzania

Preparatory Survey on Flood Protection Measures for Central Railway Line in the United Republic of Tanzania

Final Report
Volume 1: Main Text

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Abbreviations

AfDB	African Development Bank
ALOS	Advanced Land Observing Satellite
ARF	areal reduction factor
AWS	automatic weather stations
BCA	Bridge Condition Assessment
BDA	Belgian Development Agency
BMM	Burundi Mining Metallurgy
BRN	Big Results Now
CAG	Controller and Auditor General
CAGR	compound annual growth rate
CBS	cost-based selection
CCE	Chief Civil Engineer (of TRL)
CCTTFA	Central Corridor Transit Transport Facilitation Agency
CIR	committed information rate
CN	Curve Number
C/P	Counterpart
CRP	Compensation and Resettlement Plan
CSOs	Civil Society Organizations
CTR	complete track renewals
DBM	Dispute Board Members
DC	designated contract
DEM	Distal Elevation Model
DHWL	design high water level
DIKKMR	Dar es Salaam–Isaka–Kigali/Keza– Musongati Railway Project
DRC	Democratic Republic of Congo
EAC	East African Community
EARH	East African Railways and Harbours
EARS	East African Rift System

ECO	Environmental Control Officer
ECW	enhanced compressed wavelet
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIS	Environmental Impact Statement
ELO	Environmental Liaison Officer
EMA	external monitoring agency
EMoP	environmental monitoring plan
EMP	environmental management plan
E/N	Exchange of Note
EOI	Expression of Interest
EPC	environmental permit certifications
ESIA	Environmental and Social Impact Assessment
ESMoP	Environmental/Social Monitoring Program
ESMP	Environmental/Social Management Programme
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FL	formation level
F/S	feasibility study
GL	ground level
GDP	gross domestic product
GeoTIFF	Geographic Tagged Image File Format
GIS	Geographic Information System
GOT	Government of Tanzania
GPS	global positioning system
GS	gauging station
GSMaP_NRT	Global Rainfall Map in Near-Real-Time
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HSE	Health Safety and Environment

IA	implementing agency
IC	international consultant
ICAO	International Civil Aviation Organization
ICB	international competitive bidding
ICD	inland container depot
IR	Inception Report
ICT	information and communication technology
IDA	International Development Association
IMF	International Monetary Fund
INGO	Implementation NGO
INS	inertial navigation system
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IZ	Intermediate Zone
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
KOJ	Kurasini Oil Jetty
L/A	Loan Agreement
LCC	Life Cycle Cost
LiDAR	Light Detection and Ranging
LLZ	Low Land Zone
LRP	Livelihood Restoration Program
LTPP	Transport Sector Long-Term Perspective Plan
MAIS	Management Accounting and Information System
MEM	Ministry of Energy and Minerals
METI	Ministry of Economy, Trade and Industry of Japan
MLHHSD	Ministry of Lands, Housing and Human Settlements Development
M/M	Minutes of Meetings
MOF	Ministry of Finance
MOT	Ministry of Transport

MOW	Ministry of Water
MWTC	Ministry of Works, Transport and Communications
M/P	Master Plan
NCB	national competitive bidding
NEMC	National Environmental Management Council
NGO	Non-Governmental Organization
NT	Near Threatened
O&M	operation and maintenance
OD	origin-destination
ODA	official development assistance
OMS	Operation, Maintenance and Safety
OP	Operational Policy
OPBC	output and performance based maintenance
OSHA	Occupational Health and Safety Authority
PAHs	Project Affected Households
PAP	project-affected-person
PD	Project Director
PIT	Project Implementation Team
PMO RALG	Prime Minister's Office – Regional Administration and Local Government
PMU	Project Management Unit
PORALG	President’s Office – Regional Administration and Local Government
PPA	Project Preparation Advance
PPP	public private partnership
PQ	Pre-Qualification
PTC	positive train control
PWI	Permanent Way Inspector
QCBS	quality- and cost-based selection
RAHCO	Reli Assets Holding Company
RAP	Resettlement Action Plan
RDL	required dike level

RL	Rail Level
ROW	right of way
RRP	Railway Restructuring Project
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SIA	Social Impact Assessment
SLSC	Standardized least squares criterion
SPM	single-point mooring
SPT	Standard Penetration Test
SPWI	Subpermnent Way Inspector
SSS	single-source selection
SUMATRA	Surface and Marine Transport Regulatory Authority
TAA	Tanzania Airports Authority
TACAIDS	Tanzania Commission for AIDS
TAFSIP	Tanzania Agriculture and Food Security Investment Plan
TANROADS	Tanzania National Roads Agency
TAZAMA	Tanzania Zambia Mafuta (Pipeline)
TAZARA	Tanzania Zambia Railway Authority
TCAA	Tanzania Civil Aviation Authority
TEU	twenty-foot equivalent unit
TGFA	Tanzania Government Flight Agency
TIB	Tanzania Investment Bank
TIRP	Tanzania Intermodal and Rail Development Project
TIRTEC	Tanzania Institute of Rail Technology
TMA	Tanzania Meteorological Agency
TOR	terms of reference
TPA	Tanzania Ports Authority
TRC	Tanzania Railways Corporation
TRL	Tanzania Railways Limited
TRRL	Transport and Road Research Laboratory

TSIP	10-year Transport Sector Investment Programme
TZS	Tanzanian shilling
UH	Unit Hydrograph
UN	United Nations
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VAT	value added tax
VEO	Village Executive Officer
VHF	very high frequency
VOC	Vehicle Operating Cost
VPO	Vice President's Office
WB	World Bank
WEO	Ward Executive Officer
WMO	World Meteorological Organization
WRBWO	Wami/Ruvu Basin Water Office

Executive Summary

E0. Preface

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E1. Introduction

It is anticipated that transport demand in Tanzania will quadruple within the next two decades. To meet this rapidly increasing demand, the development of domestic and regional transport infrastructure is a pressing issue. Due to deteriorating railway infrastructure and inefficient operating standards, however, the freight traffic carried by Tanzania Railways Limited (TRL) declined substantially over the last decade. The primary reasons for the deterioration are the deferred maintenance, inadequate rolling stock, and repeated floods between Kilosa and Gulwe.

Based on the Minutes of Meetings agreed upon by the Ministry of Transport (MOT) and the Japan International Cooperation Agency (JICA), JICA commissioned the Study Team in November 2014 to conduct a feasibility study to (i) select the route proposed for flood protection measures based on a detailed hydrological and sediment analysis, and (ii) carry out the preliminary design of flood protection works and develop a project plan for consideration of Japan's Official Development Assistance (ODA) loan.

E2. Railway Sector Development/Investment Plans

E2.1 Plans of the Government of Tanzania

The Government of Tanzania (GOT) launched the Big Results Now (BRN) initiative in 2013 to enhance the performance of implementing government programs, including those in the transport sector. With respect to the railway subsector under BRN, the GOT intends to increase railway freight transportation capacity of the Central Railway Line from 0.2 million tons in 2012 to 3 million tons in 2015.

The GOT has prepared a 10-Year Transport Sector Investment Programme (TSIP) to effectively implement transport policy. TSIP runs from 2007/08 to 2016/17, and is being implemented in two phases. The second appears to have more funding mobilized and secured than the first phase; thus more of its initiatives should be actualized.

E2.2 Plans of the Other Donor Assistance

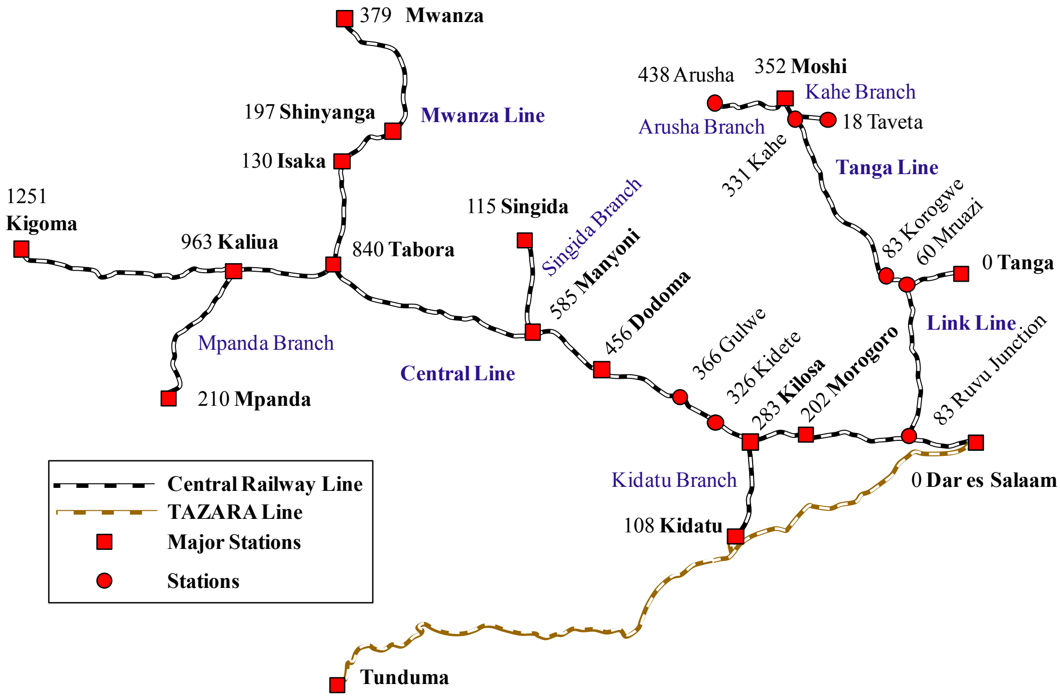
The World Bank approved of US$ 300 million in International Development Association credit in April 2014 for the Tanzania Intermodal and Rail Development Project (TIRP), and the credit became effective on 30 March 2015. The development objective of TIRP is to deliver reliable open-access infrastructure on the Dar es Salaam–Isaka section. TIRP has been designed around intermodal rail services for container transportation, and eventually intends to provide for twice weekly container train services.

The African Development Bank (AfDB) is considering implementing the Dar es Salaam–Isaka–Kigali/Keza–Musongati Railway Project through Public Private Partnership. It is employing a transaction advisor to clarify the legislation and procedures for structuring the project. The European Investment Bank (EIB) is planning to rehabilitate track on the Tabora–Isaka section, and rehabilitate/replace structures on the Dar es Salaam–Isaka section. The European Union (EU) is also exploring the possibility of providing a grant in combination with the EIB loan.

E3. Current Conditions of the Central Railway Line

E3.1 Overview of the Central Railway Line

The Central Railway Line is currently managed by RAHCO and TRL, which are both 100% owned by the Government of Tanzania. Its system includes 128 stations and 2,707 km of single-line, meter-gauge, and non-electrified track, consisting of the nine lines as shown in Figure E1.1.



Source: JICA Study Team

Figure E3.1: Rail Transport Network in Tanzania

E3.2 Institutional Structure

The Big Results Now (BRN) initiative proposes the establishment of a new institutional setup, clearly defining the roles and responsibilities of TRL, RAHCO, SUMATRA, and MOT. The planned reforms are implemented in two-phase; (i) Phase I: a transition period (for at least 2–3 years) with TRL as the only train operator on the Central Railway Line, to stabilize the system and reduce complexity, and (ii) Phase II: long-term perspective (from earliest 2016), with the option to open the network to other private operators.

E3.3 Flood Damages and Disaster Response

The Central Railway Line has been repeatedly damaged by floods (among a total of 40 floods in Kilosa–Dodoma during 2011–2014, 22 occurred in two specific locations: at Km349 and at Km365.6). Flood damages are represented by, among other things, scoring around substructure piers and/or embankments, as well as outflows of track and/or rail-bed. While recovery works have been undertaken, these works are generally just emergency response works for quick reopening of railway operations, which is due to a lack of funds for undertaking more serious preventative measures. Despite many studies and emergency response works undertaken, the railway line is still susceptible to damages resulting from floods. The implementation of flood preventative measures, which are not just temporary, is required.

E4. Traffic Demand Forecast

A freight and passenger rail traffic demand forecast was conducted through 2046, or Year 30 after the potential Project commencement. In order to estimate the potential of railway services in the country, the demand forecast is provided without considering particular constraints on the transport capacity.

E4.1 Freight Demand Forecast

The Study took a commodity-based approach to traffic demand forecasting. To determine the pace at which commodity traffic would grow, each commodity's production/consumption (depending on available datasets) rate was compared against Tanzania GDP growth rates.

This established elasticity values for each commodity to GDP growth (a Cobb-Douglass Demand Model). After assuming GDP growth rates, these commodity growth rates were used to escalate the base traffic levels.

Given the erratic nature of TRL traffic since the RITES concession, base traffic levels by commodity were generally taken as the average of 2001-2004 traffic, when TRL was at its peak operational levels. For Transit Cargo, the same methodology was followed, using neighboring countries' GDP levels.

The tonnage levels for selected years are reproduced below:

Table E4.1: TRL Tonnage Demand Forecast

Year	2023	2026	2031	2036	2041	2046
Total Tons	4,429,172	5,520,517	7,429,756	9,342,098	11,420,273	13,633,120

Source: JICA Study Team

By Year 30, it is forecasted that Domestic Cargo and Transit Cargo will be nearly equal in share (48%/52%). General Cargo (containerized cargo) will account for nearly half of all Domestic Cargo (and 25% of overall traffic).

E4.2 Passenger Demand Forecast

Overall intercity railway passenger traffic would be affected mainly by the country's population and its income levels, which can be measured by per capita GDP. Therefore, the passenger traffic demand was assumed to increase at the growth rates of GDP (population times per capital GDP) that were used for the freight demand forecast. The base year level was set as 1,000,000 passengers/year based on previous traffic as well as a passenger forecast by a relevant study[1]. Forecast levels for selected years are reproduced below:

Table E4.2: TRL Passenger Rail Demand Forecast

Year	2023	2026	2031	2036	2041	2046
Passengers	1,000,000	1,215,576	1,642,373	2,157,452	2,762,517	3,456,057

Source: JICA Study Team

[1] Governments of Tanzania, Rwanda and Burundi, *Phase II of the Dar es Salaam–Isaka–Kigali/Keza–Musongati Railway Project Study*, Final Report, March 2014.

E5. Implementation of Flood Risk Assessment and Proposal for Urgent Countermeasures

E5.1 Objective and Schedule

In order to clarify the current conditions of the crucial railway section and to subsequently formulate a plan of urgent protection measures between Kilosa and Gulwe (approximately 88 km), a flood risk assessment was conducted in December 2014. The field reconnaissance was conducted by the JICA Study Team with the staff of RAHCO and TRL from 1 to 5 December 2014. It was presumed that the proposed protection measures should be implemented before entering the rainy season in 2015 and completed at to the maximum extent considering the crucial conditions of the selected sites.

E5.2 Criteria for Selection of High Risk Areas

After creating a classification scheme for flood damages of different nature, such as riverbank erosion and clogging culverts, criteria were set up in order to select the sections requiring provision of urgent protection. The protection works mainly consist of revetment with gabion boxes/mattress. A series of spur dikes is also recommended at 337.2 km – 337.7 km.

E5.3 Proposed Urgent Protection Measures

The flood disaster risks in the target area are classified into four types of risk, referring to the patterns of flood damages: (i) riverbank erosion, (ii) flood flow overtopping railway track embankment, (iii) clogging of culvert, and (iv) flooding at the confluence of tributaries. A total of seven sites were selected with the aforementioned criteria and prioritized for implementation, as tabulated in Table E5.1:

Table E5.1: Selected Sites for Urgent Protection

Priority	Selected Site	Priority	Selected Site
1	Km 315.0 – 315.8	5	Km 366
2	Km 301.7 – 302.2	6	Km 355.0 – 356.0
3	Km 337.2 – 337.7	7	Bridge Km 293
4	Km 349.4B – 349.8B	-	Existing culverts

Note: The Kilometerage above is the existing system.
Source: JICA Study Team

E5.4 Cost Estimate

Preliminary costs of the proposed structural measures were estimated by means of prevailing unit costs of major civil works obtained from RAHCO based on the approximate bill of quantities. The total amount was TZS 2,957,032,800 (equivalent at US$ 1,689,700 or JPY 199,384,600, by the prevailing exchange rates in December 2014). The report of “Recommendation on Urgent Protection Measures for Incoming Rainy Season 2015” was submitted to MOT/RAHCO/TRL on 24 December 2014.

E5.5 Current Status of Implementation of Urgent Protection Measures

In February 2015, the JICA Study Team conducted site reconnaissance to confirm the latest status of the seven high risk sites. It is noteworthy that the riverbank at Km 337.2 – Km 337.7 encroached up to the track embankment on 6 March 2015. This section had been identified as the highest risk area in the flood risk assessment aside from two areas (Km 315.0 – Km 315.8 and Km 301.7 – Km 302.2) where restoration works were already being carried out by TRL. The damaged section was restored and the track alignment was shifted further to the land side.

Consequently, railway operation was restarted by TRL soon after the accident. A request for supplementary budget was submitted to MOF from MOT in January 2015. Due to administrative procedures of the budget in the MOF/MOT, it has not been approved yet as of March 2016.

E6. Hydrological and Hydraulic Analyses

E6.1 Data Collection and Review

Hydrological data on hourly and daily time-steps were collected and their reliability was reviewed. Further, information on climate change in the target area was summarized.

E6.2 Hydrological Characteristics

i) **Annual Rainfall**: Amounts of annual rainfall vary from year to year. The maximum of annual rainfall was 1,031 mm/year in 1967/1968, the minimum was 277 mm/year in 1952/1953. The average annual rainfall is 626 mm/year and the standard deviation is 149 mm/year.

ii) **Monthly Rainfall**: The target area receives rainfall from November to May, mostly during December to April.

iii) **Rainfall Characteristics (Depth, Area, and Duration)**: Rainfall characteristics in the target area can be summarized as high-intensity, small area, and short duration, although the availability of hourly rainfall data is limited.

iv) **Storm Area Movement**: The storm area movement in the target region was investigated by using a satellite-based dataset. The storm area might move quickly and the duration of the storm event might be several hours long.

v) **Daily Discharge**: Main streams near Kilosa have a year-long flow, whereas main streams in the upstream areas have ephemeral flow. Hydrographs of ephemeral stretches have steep rising limbs, with an almost instantaneous rise of peak flow, and steep recession limbs. These characteristics are known as “flash floods”, which happen very suddenly and continue for only a short time.

vi) **Hourly Water Level**: Availability of hourly water level records of flood is very limited in the Study Area. Only three cases of small scale flood are recorded at Kilosa G/S between January and March 2012. Duration of the three flood events was less than 24 hours. These data indicate that a flood event might not last for more than one day at this site.

E6.3 Hydrological and Hydraulic Analyses for Setting of Hydraulic Conditions for Flood Protection Measures

i) **Estimation of Probable Hydrological Variables**: Probable variables of point daily rainfall, catchment average daily rainfall, and daily average discharge were estimated by a frequency analysis. Further, probable discharges by an empirical formula were also estimated.

ii) **Hydraulic Analysis**: A hydraulic analysis was conducted to estimate flood discharge of historical flood events in the main streams between Kilosa and Gulwe. Discharge of historical flood events that caused the railway damage might be estimated about 800 m^3/s at Kilosa.

iii) **Hydrological Analysis**: A hydrological analysis was conducted to estimate flood peak discharges in return periods in the catchment areas between Kilosa and Gulwe. The flood peak discharges estimated are much higher than the historical flood discharge. The hydrological model cannot be calibrated because hydrological data required for calibration are not available in terms of temporal and spatial scales. Therefore, the accumulation of hydrological data at least in an hourly time step with a dense network of rainfall, water level and discharge gauging stations is highly recommended.

E6.4 Culverts for Landside Water

Currently there are over 200 culverts, including small bridges, between Kilosa and Gulwe. Some of them were placed for drainage, and some were placed for the crossing of residents and livestock. As a countermeasure for landside water, "Landside" culverts are located between the remaining basin and railways, the appropriate capacity and location of Waterway Culverts were designed. Using 5 m×5 m mesh DEM data and the TRRL East African Flood Model, 55 sites for culverts were estimated. For each location, the adequate design and number of Water Culverts were provided as a basic data for the discussion for the study of alternatives. As an average interval of culvert for crossing, 300 m was recommended based on the placement of existing culverts.

E7. Sediment Analysis

E7.1 Characteristics of Sediment Discharge

E7.1.1 Sediment Production from the Perspective of Geology and Topography

- **Geology and Geological Structure**: Meta-igneous, Meta-sediments, gneiss, granulite, Migmatite and granite in Precambrian, which is greater than two billion years old (>2,000 Ma), are distributed in this watershed. The geological structure of Tanzania is characterized by the Great Rift Valley. Therefore, a lot of lineaments which express faults are observed along the Rift Valley.
- **Historical Development of Landform**: According to the process of topographical change, the current stage is "the old age". Therefore, the eroded ground has formed a gentle landform. An outcrop of bedrock is observed on the mountain slope, the surface land, and the riverbed, etc. Sediment deposition with reddish or gray color is observed in the upstream areas of the Kinyasungwe, Mzase and Maswala watersheds. A large lake is presumed to have been existed in this area in the old age.

E7.1.2 Source of Sediment Production

- **The Remarkable Sediment Production Area**: The area which has the most remarkable sediment discharge is observed in the section between Kidete and Gulwe. Especially, the Maswala, the Kidibo and the Mzase Rivers are the ones in which the sediment discharge is quite significant.
- **The Source of Sediment Production**: The source of sediment production is judged to be the expanded cultivated lands in the upstream areas of the tributaries. Because the surface soil was disturbed by cultivation and overgrazing, they flow out easily during rainfall. The disturbance of surface soil is assumed to weaken the resistance to the raindrop erosion and surface flow. And the flood is presumed to accelerate the bank erosion.
- **The Sediment Productivity**: The sediment productivity of slope which is less than three degrees is low. And the material in the sediment production zone consists of the material which is less than sand.

E7.1.3 Sediment Transportation Capacity

- **Sediment Transportation Capacity of the Kinyasungwe River**: The Kinyasungwe River does not have the required volume of river water which to flow continuously and move deposition in the riverbed. Therefore, the riverbed of the Kinyasungwe River has been rising.
- **Sediment Transportation Capacity of Tributaries:** The aggradation of the Kinyasungwe River influences the aggradation of its tributaries.

E7.1.4 Calculation of Sediment Yield

- Sediment yield was calculated by using the satellite image of Rapid EYE.
- The land cover by the satellite image was classified into five color tones (Green, Yellow Green, Orange, Light Blue and White). Sediment yield was calculated based on this classification.
- Orange color zone which is observed in Mzase, Maswala and Kidibo watershed is generally used for cultivated land. And this zone has the high sediment productivity.

E7.1.5 Countermeasures for Sediment Disaster

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E7.1.6 Future Issues

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E8. Selection of the Alternatives for Flood Protection Measures

E8.1 Setting of Planning Scale for Preparation of Flood Protection Measures

- In order to examine re-routings of track alignment, the planning scale for flood protection measures was studied and set.
- Through review of the results of flood mark survey, it was clarified that maximum flood levels along the mainstream of the Kinyasungwe/Mkondoa River have reached to the embankment of the existing track in most of the sections between Kilosa and Gulwe.
- Since reliable flood discharge and water level records are quite limited, an attempt to find a discharge value which corresponded with the past highest flood marks was conducted near Kilosa. Hydraulic computation concluded that approximately 2,000 m^3/s could represent the reliable flood mark elevation, which coincides with the 30-yr return period of flood peak discharge.
- Because the Kinyasungwe/Mkondoa River basin has high potential sediment production, future sediment deposition was preliminarily assessed based on comparison river cross-sections (1999 and 2015) available between Kilosa and the Lumuma confluence. The accumulated sediment deposition was estimated at approximately 1.0 m on average along the said river section in 16 years.
- In order to determine the Design High Water Level of the structures, sediment deposition for 30 years onward was assumed by means of the rate of deposition as clarified through the comparison of river cross-sections. The average rate of 2.0 m from Kilosa to the Lumuma confluence was estimated.
- On the other hand, as for the upstream section from the Lumuma confluence to Gulwe, average sediment density and sheet erosion rates, which were derived from the suspended sediment sampling survey and satellite photo analysis, were applied and estimated at 2.5 m on average.

- Considering the sediment deposition in the period of 30 years, the Design High Water Levels along the Kinyasungwe River were examined and decided based on the discharge distribution from major tributaries joining from both sides.
- In conclusion, the required heightening of the embankment for rerouting of track alignment was decided to be 2.3 m and 2.7 m for the downstream and upstream sections, respectively, in consideration of freeboard of 1.2 m above the Design High Water Levels.

E8.2 Key Points for Preparing Flood Protection Measures

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E8.3 Preparation of Alternatives

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E8.4 Evaluation of Alternatives

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E9. Railway System

E9.1 Basic Concept

The Study Team adopts the realistic 1,000 mm-gauge. The axle load should be set at 18.5 tons. With this, freights of approximately 1,000 tons can be hauled by a locomotive having a weight of 110 tons. In case freights are heavier, or are to be hauled on sharp gradients, double-heading operation can cope with this.

A maximum speed of 80 km/h is guaranteed for train operation in meter-gauge. In short sections, however, the Study Team maintains an immediate target of train speed at the current level of approximately 50 km/h, as speedups in short sections do not cut the total travel time by much. To facilitate speedups in the future, the Study Team designs the minimum radius of curve as 400 m.

E9.2 Train Operation

A capacity to transport freights of 880,000 tons per year is guaranteed under the current operational formation of hauling 20 wagons by a single locomotive. If dormant stations were reinstated, the volume of freight transport would potential reach 1.4 million tons per year. Only in case where volume of freight transport further increases, the installation of signal stations and other measure will become inevitable.

The option to run long trains cannot be introduced before completion of the expansion work and that refuge stations for short trains are limited in number even thereafter, it may be prone to cause confusion of train operation diagrams.

In this context, it is realistic to select the policy when the demand reaches 1.4 million tons either (i) operation of long trains, or (ii) high-frequency operation of conventional train length, considering the capacity and stability of transport.

E9.3 Track

The introduction of heavy maintenance machines is inevitable in accordance with increasing destruction of track caused by frequent train operations in the future. TRL owns five tamping machines, and it began to adopt "Mobile Gang" aiming to adapt the maintenance organization for high machine performance. These efforts of TRL are highly ratable, and the Study Team expects the steady progress in accordance with the train frequency.

E9.4 Rolling stock maintenance

TRL could not implement preventive maintenance for old-type locomotives due to the shortage of spare parts. For several years, however, there will be no problems, as the frequency of train operation is not very high, with active locomotives increasing as new locomotives are being procured and rehabilitated ones are coming back to the frontlines. On this occasion, TRL shall establish the preventative maintenance system by improving budgetary procedures within TRL's organization and to the Government of Tanzania.

E9.5 Signaling system and telecommunication

TRL's signal facilities and telecommunication lines are devastatingly robbed and damaged such that block telephones and signals can no longer serve their original purpose, and there is no effective measure against such vandalism. The Study Team recommends adoption of the line clear ticket system to run trains using a portable telephone set as a realistic way.

E9.6 Stations and related facilities

Relate to the flood protection project, some sections of railway track will be relocated together with stations and related facilities. The concrete objects of the relocation will be determined considering the future usage.

E10. Preliminary Design and Cost Estimate

<This part has been removed because of confidential information.>

E11. Project Implementation and O&M Structures

E11.1 Project Implementation Structure

Following the implementation structure for the World Bank-assisted TIRP, RAHCO will be the Executing Agency for the Project, and a Project Management Team (PMT) is to be established with core personnel as listed below who are to be provided by RAHCO and the Project.

Table E11.1: Core Personnel of Project Management Team (PTM) for the Project

Position	No of Staff	Main Responsibility
Chief of PMT	1	To be responsible for overall project management and coordination with concerned agencies.
Deputy Chief of PMT	1	To be responsible for all of the technical and financial aspects of the Project and assist Chief of PMT in overall project management.
Project Engineers (Railway Civil Engineer/River Engineer)	2	To supervise technical aspects of the Project and assist Deputy Chief of PMT in technical management.
Accounting	1	To undertake accounting management of the Project and assist

Specialist		Deputy Chief of PMT in financial management.
Procurement Specialist	1	To undertake procurement management of the Project and assist Deputy Chief of PMT in procurement management.
Assistant Project Engineers (Civil Work/Hydrology)	2	To assist Project Engineers in supervising technical aspects of the Project.
Environmental and Social Specialist	1	To undertake environmental and social management of the Project and assist Deputy Chief of PMT in environmental and social management
Support Staff (Driver)	1	To undertake day-to-day operation of PMT.

E11.2 Operation and Maintenance (O&M) Structure

The table below shows the institutional setup for railway infrastructure management and railway services provision, followed by several points to be noted on railway O&M.

Table E11.2: Institutional Setup for Railway Infrastructure Management and Provision of Railway Services

Issues	Current	Transition period	Long term
Railway infrastructure			
Ownership of infrastructure assets	RAHCO	RAHCO	RAHCO
Railway infrastructure development	RAHCO	RAHCO	RAHCO
Routine infrastructure maintenance and casual renewal[1]	TRL	TRL	RAHCO[2]
Railway services			
Provide operational services for operators	TRL	TRL	RAHCO
Ownership of rolling stock	RAHCO	TRL	TRL
Provide railway freight and passenger services	TRL	TRL	TRL
Maintenance and repair of rolling stock	TRL	TRL	TRL
Procurement of new rolling stock	TRL	TRL	TRL

Notes: (1) Based on the Concession Agreement (2007), TRL is currently "responsible for the first US$ 100,000 of the cost of any restoration to such lost or damaged immovable assets and to the extent that the total cost of such restoration is less than US$ 100,000". (2) In July 2015, MOT mentioned that the transfer of this responsibility to RAHCO will be conducted by the end of 2019 when the TIRP Program is completed. However, it is still unclear who will actually conduct the maintenance work (see 3.2.6 (iii) for more details).
Source: Table 3.1 of this report

- Strengthening the capacity of RAHCO and TRL is essential for revitalizing the Central Railway Line before introducing new institutional arrangements including the implementation of the open access policy.
- In order to undertake train operation and infrastructure maintenance safely and efficiently during the construction stage of the Project, an Operation, Maintenance and Safety (OMS) Team is to be set up, consisting of representatives from RAHCO, TRL, the supervision consultant, and the contractors for the Project.
- Considering that the railway sector of Tanzania experienced a failure of a concession arrangement, a very careful step should be taken toward any re-use of PPP to provide railway services. For example, the sector should aim at achieving the level of rail freight tonnage during the peak times (2001–04) under the current institutional setup before any re-use of PPP (including the open access policy) is implemented.
- The sector should not rush toward complete vertical separation of the railway system considering that even in Europe, there is no evidence indicating that vertical separation leads to better railway performance compared to vertically-integrated systems

E12. Project Implementation Plan

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E13. Environmental and Social Considerations

E13.1 Environmental Impact Assessment (EIA)

Environmental Impacts Assessment (EIA) was studied for the following project components: track rerouting for 25 km, bank protection by installing gabion/block, river-training works at Maswara and Mzase Rivers and the construction access road along the existing railway.

As the railway construction project falls into Type A which requires EIA in accordance with the Environmental Impact Assessment and Audit Regulations, 2015, RAHCO needs to proceed with the necessary procedure with the National Environmental Management Council (NEMC) to obtain the approval by the Vice-President's Office. The procedure consists of project registration and screening by NEMC, submission of a scoping report, baseline surveys, impact assessment and preparation of Environmental Impact Statement (EIS) which is corresponding to an EIA report. The RAHCO initiated the process in 2015 and the EIS has submitted to NEMC in March 2016.

The mitigation measures and the monitoring plan proposed in the EIS were presented in this report. RAHCO shall take full responsibility on the implementation of those activities.

The local stakeholder meetings with the affected villages were held two times in accordance with the JICA Guidelines for Environmental and Social Considerations. The outline of the mitigation measures were explained and accepted by the local stakeholders.

E13.2 Compensation and Resettlement Plan (CRP)

As the rerouting and the river training works require involuntary resettlement, a Compensation and Resettlement Plan (CRP) which corresponds to the Resettlement Action Plan (RAP) was prepared in accordance with the JICA Guidelines. Considering that it is still in the feasibility study stage and the Project has not been approved officially, the CRP was prepared as the preliminary CRP with a preliminary asset valuation to be updated in the detailed design stage.

Population census was conducted on 2-9 December, 2015 together with the asset inventory. The results showed that 201 households with 952 populations would be affected by the Project. The number of the affected structures was 317; out of them, 150 were identified as houses. Although the structures need to be relocated, it was difficult to identify whether the PAP needed to move out from their land to another area because they might be able to stay within their plot just by shifting their house location. The necessity and the preference of the moving shall be decided in the detailed design stage after the project area is demarcated physically.

In spite of land-for-land compensation policy of JICA, cash compensation is deemed to be suitable for the loss of the agricultural land for this Project because of the difficulty to find alternative spare land due to the mountainous topographic conditions. Livelihood Restoration Program (LRP) needs to be provided to the PAPs to support their livelihoods which will be affected by the land acquisition.

A series of consultation meetings with the PAPs were held at six villages to be directly affected by the land acquisition in order to disclose the proposed project location, identify the affected individuals, and obtain their opinion/consensus on the compensation policies. No dissenting voice or objection against the Project or the compensation policies was identified through the meetings.

E14. Project Evaluation and Estimation of Project Effects

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E15. Conclusions and Recommendations

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1. Introduction

1.1 Background of the Study

Tanzania has achieved a steady GDP growth of around 7% per year since 2000, resulting in a rapid growth in transport demand, e.g., as seen by the increase in cargo throughput at Dar es Salaam Port, which has had an average annual growth rate of 11% during the period 2006–12. It is anticipated that the Tanzanian economy will continue to grow at a comparable rate in the medium- to long-term, and that the transport demand will quadruple within the next two decades. In order to meet this rapidly increasing demand, the development of domestic and regional transport infrastructure is a pressing issue, one that must be dealt with. Due to deteriorating railway infrastructure and inefficient operating standards, however, the freight traffic carried by Tanzania Railways Limited (TRL) declined substantially, from 1.6 million tons in 2002 (carried by the former Tanzania Railways Corporation (TRC)) to 0.15 million tons in 2013.[1] Two of the primary reasons for the deterioration are the deferred maintenance and inadequate rolling stock.[2] In addition, the floods in December 2009 between Kilosa (in the Morogoro region) and Gulwe (in the Dodoma region) damaged part of the Central Railway Line, halting train services between Dar es Salaam and Dodoma for about five months.

Under these circumstances, the World Bank, in collaboration with Reli Assets Holding Company (RAHCO), carried out a feasibility study (F/S) for the preparation of “Tanzania Intermodal and Rail Development Project (TIRP)” to rehabilitate the Dar es Salaam–Isaka section (this study was completed in March 2013). In addition, the Government of the United Republic of Tanzania (GOT) has prepared the “Big Results Now (BRN)” initiative (which is part of the larger strategy for realizing the National Development Vision 2025), the “Transport Sector Long-Term Perspective Plan (LTPP)”, the “Five Year Development Plan”, as well as the “10-Year Transport Sector Investment Programme Phase 2 (TSIP2)”,[3] all with the goal of creating a competitive and reliable transport system. In all of these plans, railway transport systems are given a high priority with the aim of implementing rapid, high-impact, fixes.

The Japan International Cooperation Agency (JICA) has recognized the importance of rehabilitating the Central Railway Line based on the results of the JICA-funded “Comprehensive Transport and Trade System Development Master Plan in Tanzania” (2011–14). The Japanese Government subsequently conducted “The Study on the Central Corridor Railway Revitalization and Energy Efficiency Project” (2013–14), which identified that the flood prone area between Kilosa and Gulwe could be the biggest bottleneck of the entire Central Railway Line, and thus recommended that flood protection measures be a candidate for Japanese assistance, which will complement the World Bank-assisted TIRP.

In light of the GOT’s programs and already-completed studies, the Ministry of Transport (MOT)[4] of the GOT and JICA discussed the implementation of a study on flood protection measures for the Central Railway Line to evaluate technical, operational, economical, financial, environmental, and social elements under the framework of a feasibility study (F/S). Based on the Minutes of Meetings (M/M) for this Preparatory Survey agreed upon by the two parties, JICA has commissioned a joint venture of PADECO, Nippon Koei, Japan International

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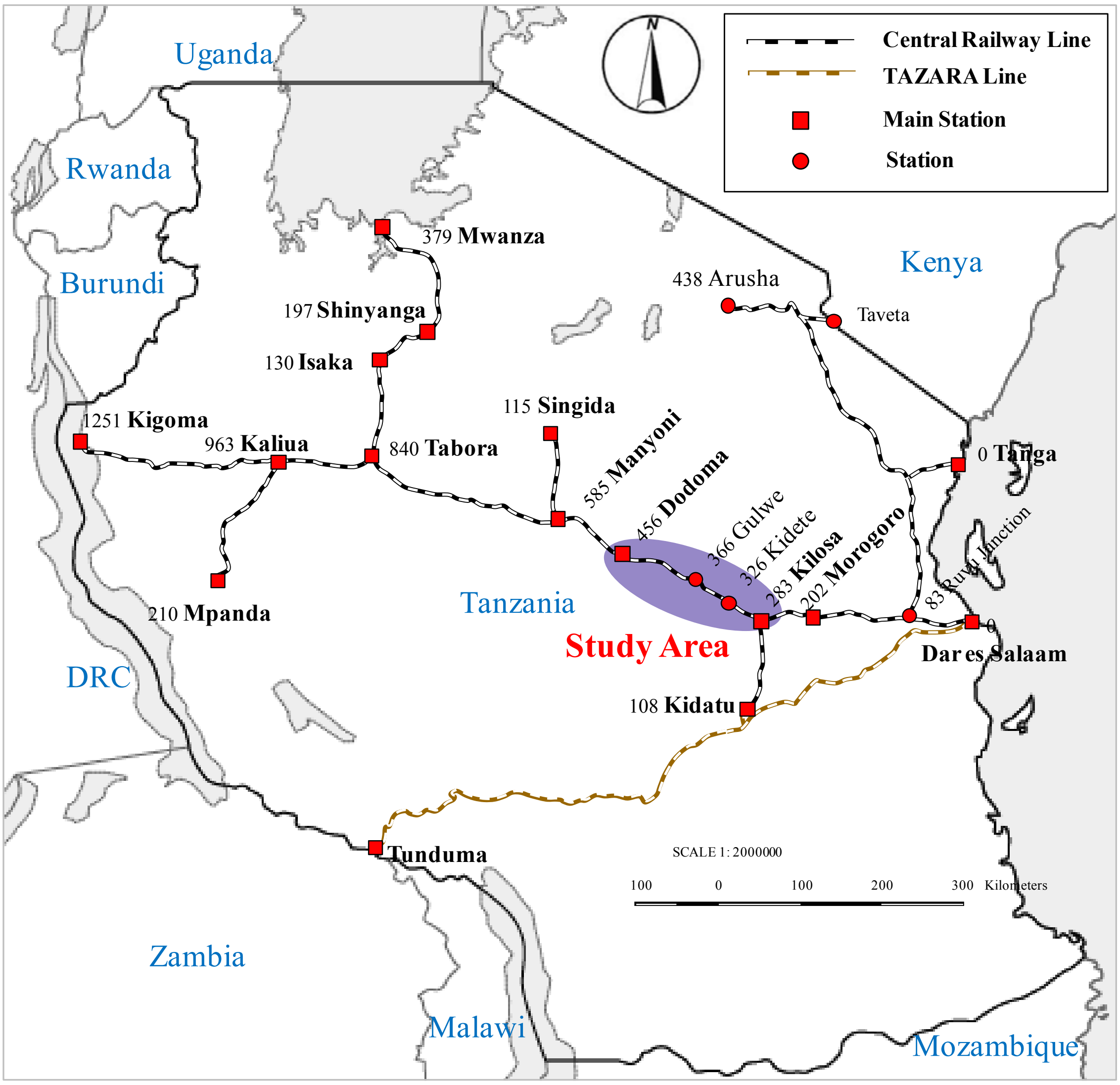
1 TRL freight traffic slightly increased to 0.19 million ton in 2014 and 0.21 million ton in 2015.

2 The deferred maintenance is planned to be addressed partly under the TIRP, while the inadequate rolling stock is being dealt with partially through finance by the Government of Tanzania and partially under the TIRP.

3 The TSIP2 aims at increasing TRL traffic to at least 750,000 tons in 2017 through the rehabilitation of the Central Railway Line.

4 In December 2015, it was announced that the MOT would be renamed as the Ministry of Works, Transport and Communications through the merge with the Ministry of Works and partly the Ministry of Communication, Science and Technology.

Consultants for Transportation, and Fukken Engineering (the "JICA Study Team") to conduct the survey.



Source: JICA Study Team

Figure 1.1: Network Map of Railways in Tanzania

1.2 Outline of the Project

The table below shows a tentative outline of the Project.

Table 1.1: Tentative Outline of the Project

Project Name:	Central Railway Line Flood Protection and Upgrading Project at Kilosa-Gulwe Section in the United Republic of Tanzania (hereinafter referred to as "the Project")
Objectives:	The Project aims at improving reliability and promoting efficient and smooth transportation in Central Railway Line, by providing long-term flood protection measures and upgrading rail infrastructure, thereby increasing cargo and passenger transportation, and stimulating the economic activity in Tanzania and the East African region.
Project Overview:	A tentative scope of the Project includes: • flood protection works (route relocation and track installation for 25.0 km, mainstream riverbank protection works for 15.1 km, and Maswala/Mzase river training works for 2.6 km); • track rehabilitation works (refurbishment of 48.8 km non-rerouting 80 ld/yd rail section, and renewal of 15.1 km 60 ld/yd rails by 80 ld/yd rails on non-rerouting section); • procurement of goods (machinery, equipment, and track materials for track installation/renewal); • development of a station on the rerouting section (Gulwe station only); and • consulting services for detailed design, bidding assistance, construction supervision, compensation and resettlement plan (CRP), and environmental impact assessment (EIA).
Project Area:	Between Kilosa (Km 283) and Gulwe (Km 366) on the Central Railway Line, and surrounding areas.
Counterpart Agencies:	• Ministry of Works, Transport and Communications (MWTC) (former MOT) • Reli Assets Holding Company (RAHCO)

Source: JICA Study Team

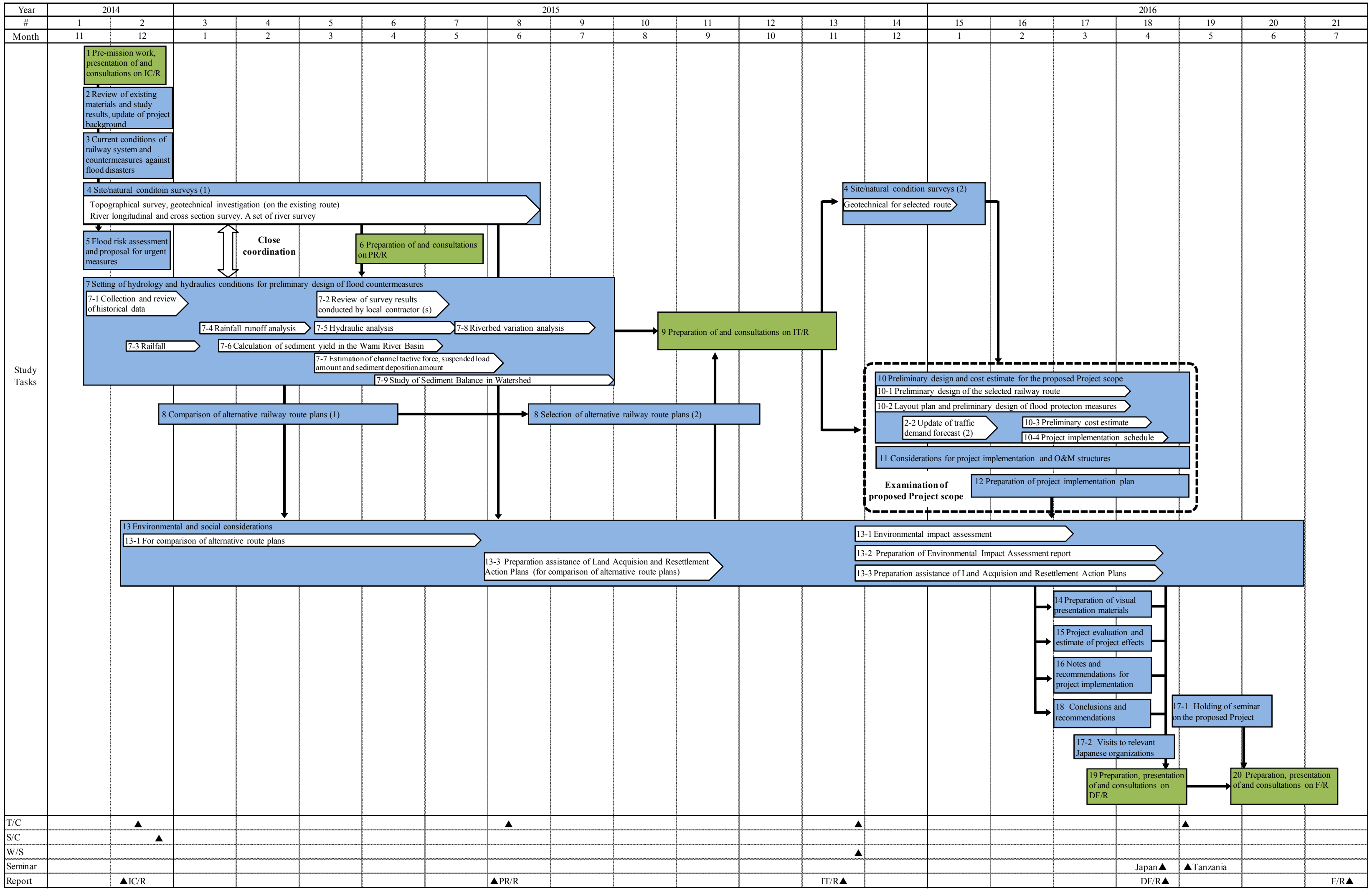
1.3 Objectives of the Study

The objectives of this Preparatory Survey are to conduct a feasibility study on the aforementioned Project, evaluating its technical, operational, economical, financial, environmental, social, and organizational elements, including the following:

- To conduct a detailed hydrological and sediment investigation and analysis for the river basin along the railway sections between Kilosa (Km 283) and Igandu (Km 402), determine hydraulic parameters for structural design of flood protection works, compare alternative railway routes, and select the route proposed for the Project; and
- To carry out the preliminary design of flood protection works for the selected railway route, and develop a project plan to be required for consideration of Japan's Official Development Assistance (ODA) loan.

1.4 Study Flows and Schedule

Figure 1.2 illustrates various tasks and periods of time in which they were carried out, and inter-relationships among them.



Source: JICA Study Team

Figure 1.2: Study Flow and Schedule

1.5 Progress of the Study

The Study was officially launched by JICA on 21 November 2014. Major progresses have included the following:

(i) On 12 December2014, the 1st technical committee meeting was held to present and discuss the Inception Report, which included study approach, methodology, composition of the JICA Study Team, organization for study implementation, and schedule.

(ii) On 22 December 2014, the 1st steering committee meeting was held to present and discuss, in addition to what has been presented at the first technical committee meeting, the recommendation on urgent protection measures for incoming rainy season in 2015 based on the results of flood risk assessment. The flood risk assessment was a joint effort of the Study Team and RAHCO/TRL to (i) clarify the current conditions of the crucial railway section between Kilosa and Gulwe, and (ii) screen the high risk areas to be protected, and (iii) formulate the plan of urgent protection measures to cope with the anticipated floods in rainy season of 2015 and onward.

(iii) On 9 June 2015, the 2nd technical committee meeting was held to present and discuss the Progress Report, which (i) defined the current conditions of the railway system and structures, and existing counter-measures against flood and sediment disasters, (ii) presented the progress of the site/natural condition surveys, and (iii) summarized the flood risk assessment and proposed urgent counter-measures. The report was prepared following the Study activities that were performed from late November 2014 to mid-April 2015.

(iv) On 27 November 2015, the 3rd technical committee meeting was held to present and discuss the Interim Report, which focused on the results of the hydrological analysis, the hydraulic parameters for structural design, and a comparison of alternative railway routes. The report included findings on the traffic demand forecast, hydrology and hydraulic analyses, sediment analysis, railway systems, selection of the alternative for flood protection measures, and environmental and social considerations, among others, all of which had been conducted from mid-April 2015 to mid-October 2015.[5]

(v) In addition, a workshop was jointly held with the 3rd technical committee meeting to present, among other things, flood risks in the Kinyasungwe/Mkondoa River basin along the Central Railway Line, recommendations for enhancing flood monitoring activities by RAHCO/TRL, and introduction of Japanese technologies for flood protection. Implemented countermeasures were also presented by TRL.

(vi) During 9-24 April 2016, four personnel from the MoWTC, RAHCO, and TRL were invited to Japan, with an aim of sharing the Japanese railway experiences, technology and knowledge in the railway sector development, management and operation. Areas of site visit included (i) flood protection structures susceptible to overflow and river bank erosion, (ii) constructed or on-going sediment control sabo works, (iii) branch block construction/manufacturing sites, (iv) weathering steel manufacturing site, and (v) capacity building facilities.

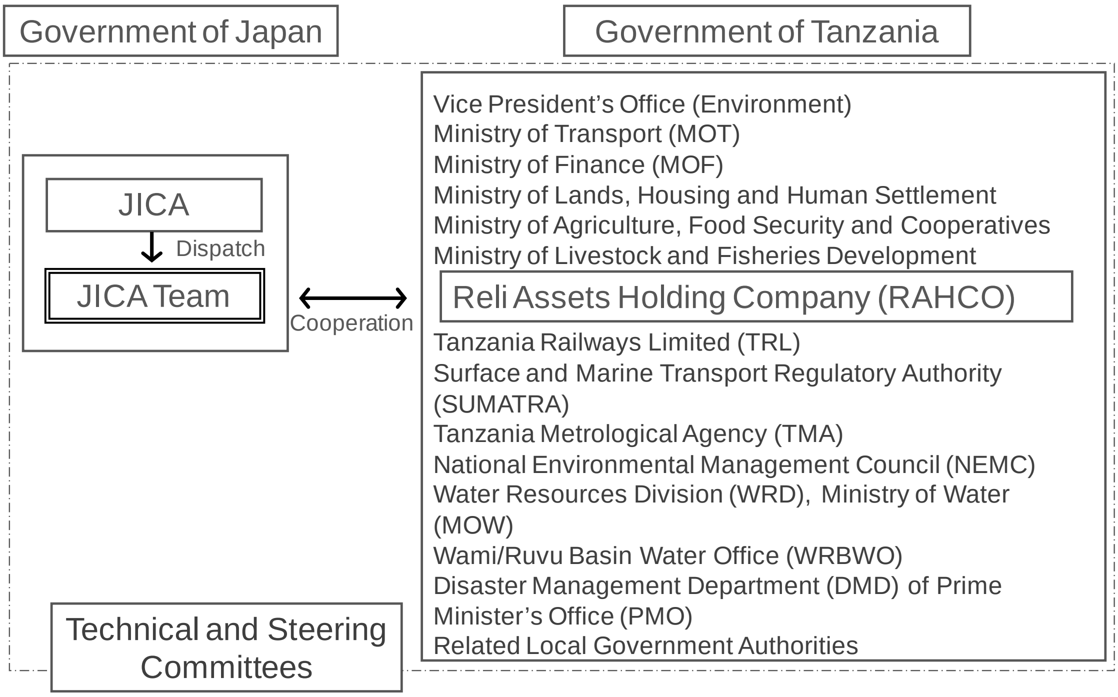
[5] Following the 3rd technical committee meeting and subsequent consultations with RAHCO, Alternative B-2 was selected for the preliminary design and development of a project plan. In this regard, RAHCO stated in its letter addressing to the MOT (CC: the Study Team) on 23 December 2015 that RAHCO has no-objection in principle to adopt Alternative B-2 which the consultant has recommended due financial limitation, subject to accommodating RAHCO's comments.

(vii) Following the flood damages in January-February 2016, a site inspection was carried out jointly by JICA, JICA Study Team, RAHCO, and TRL during 27-30 April 2016. On 3 May 2016, the 4th technical committee meeting was held to present and discuss the Draft Final Report, which compiled all of the Study results. In addition to what had been compiled in the previous reports, the Draft Final Report included (i) preliminary design and cost estimate, (ii) project implementation and O&M structures, (iii) project implementation plan, (iv) environmental and social considerations (i.e., EIA and CRP), (v) project evaluation and estimation of project effects, and (vi) recommendations and conclusions. These additional items had been prepared from mid-October 2015 to mid-March 2016.

(viii) On 5 May 2016, the seminar on flood protection measures – Japanese experiences – was held to raise awareness of long-term flood protection measures in general, considering that provision of such flood protection measures would be a first experience in Tanzania. The seminar included the presentation of flood management, general analysis/consideration made throughout the Study, Japanese experiences of flood protection measures, and lessons to be utilized in the nationwide, from the viewpoint of enlightenment.[6] The results of the 2016 April's visit program in Japan were also presented at the seminar.

1.6 Organization for Study Implementation

A Technical/Steering Committee, chaired by Permanent Secretary of the MOT, was established in order to facilitate inter-organizational coordination. Figure 1.3 presents the organization of the Study and the members of the Technical/Steering Committee.



Source: JICA Study Team

Figure 1.3: Organization for Study Implementation

[6] It was also explained that, in addition to the measures to protect the railway from flooding, basin-wide comprehensive flood control measures is needed to protect the local residents from flooding and drought, as well as natural environment.

1.7 Study Area

1.7.1 General

(1) Territory and Population

Tanzania is located in East Africa between longitude 29 and 41 degrees east and latitude 1 and 12 degrees south. The country is bordered by Kenya and Uganda to the north, Rwanda, Burundi, and the Democratic Republic of Congo (DRC) to the west, Zambia, Malawi, and Mozambique to the south, as well as the Indian Ocean to the east. Its national capital is Dodoma, while the largest city is Dar es Salaam, whose international port functions as a gateway not only to Tanzania, but also to six neighboring landlocked countries (Uganda, Rwanda, Burundi, DRC, Zambia, and Malawi).

With a total land area of 885,803 sq. km and a population of 44.93 million (as of the 2012 census), Tanzania is larger in both land area and population than all of its neighboring countries, except for the DRC. The country's population has increased fairly rapidly over the last decade, at an average rate of 2.7% per year during 2002–2012, as shown in Table 1.2 (note that data in the nine regions where the Central Railway Line, in this case the Dar es Salaam–Kigoma and the Tabora–Mwanza sections traverses, are excerpted). The population of Dar es Salaam, Tabora, and Mwanza grew at a faster rate than that of the rest of the country, indicating that the population has been concentrated in urban areas. In 2012, the population density of Dar es Salaam was 3,133 persons per sq. km, which is significantly higher than that of Mwanza, the second most densely populated region, with 293 persons per sq. km (note that the national average was 51 persons per sq. km in 2012).

Table 1.2: Area, Population, and Population Density, 2002–2012

Region	Land Area (km^2)	Population (million) 2002	2012	Growth Rate (% per year) 2002–2012	Population Density (persons/m^2) 2012
Tanzania	885,803	34.44	44.93	2.69	51
Dar es Salaam	1,393	2.49	4.36	5.78	3,133
Pwani	32,547	0.89	1.10	2.19	34
Morogoro	70,624	1.75	2.22	2.38	31
Dodoma	41,311	1.69	2.08	2.10	50
Singida	49,340	1.09	1.37	2.35	28
Tabora	76,150	1.71	2.29	2.97	30
Shinyanga	18,901	1.25	1.53	2.08	81
Mwanza	9,467	2.06	2.77	3.02	293
Kigoma	37,040	1.67	2.13	2.43	57

Source: National Bureau of Statistics, *Tanzania in Figure 2012*, June 2013.

(2) Administrative Division

Tanzania consists of 30 administrative regions, 25 of which are in the mainland and 5 of which are in Zanzibar, as of the 2012 census.[7] Each region is divided into districts, which are subdivided into divisions, and further into wards. Wards are then subdivided into streets in urban areas and villages in rural areas. Figure 1.4 shows the regional boundaries of Tanzania. As the Kilosa–Dodoma section of the Central Railway Line lies in both the Morogoro and Dodoma

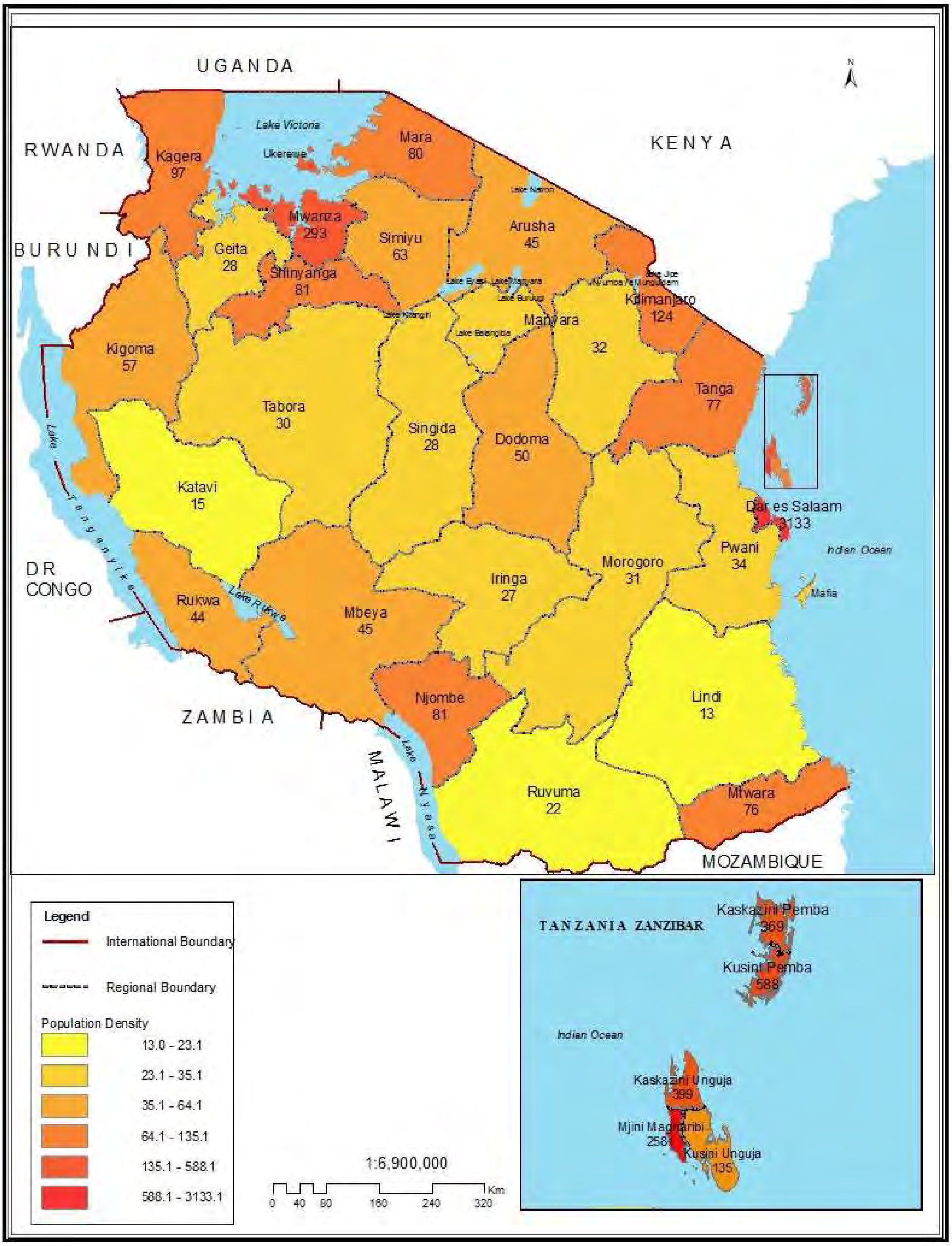
[7] The number of regions increased from 25 in the 2002 census to 30 in the 2012 census, due to administrative changes (e.g., some sub-villages were upgraded to villages, some villages were upgraded to wards, and some wards were sub-divided into more than one ward). In the process of changing boundaries, five new regions were formed in the Tanzania Mainland (i.e., Rukwa, Geita, Katavi, Simiyu, and Manyara).

regions, more detailed district boundaries are presented in Figure 1.5 (Morogoro) and Figure 1.6 (Dodoma). Additionally, these regions' population and household data, by district/council, are presented in Table 1.3.

Table 1.3: Population and Household Size by District/Council, 2012

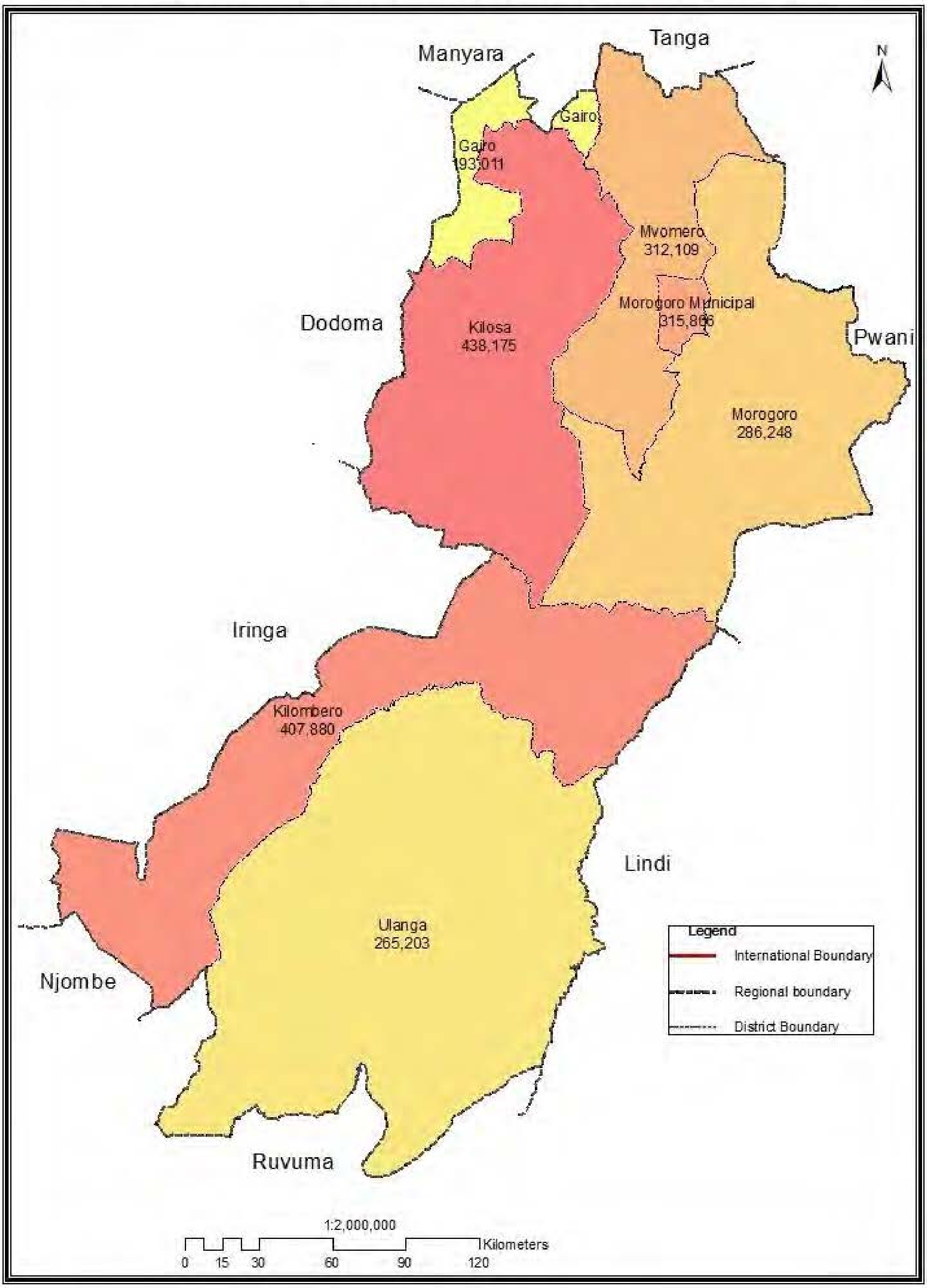
Region	District/Council	Population	Average Household Size
Morogoro	Kilosa District Council	438,175	4.2
	Morogoro District Council	286,248	4.2
	Kilombero District Council	407,880	4.3
	Ulanga District Council	265,203	4.9
	Morogoro Municipal Council	315,866	4.1
	Mvomero District Council	312,109	4.3
	Gairo District Council	193,011	5.2
	Subtotal	**2,218,492**	**4.4**
Dodoma	Kondoa District Council	269,704	4.8
	Mpwapwa District Council	305,056	4.6
	Kongwa District Council	309,973	5.0
	Chamwino District Council	330,543	4.5
	Dodoma Municipal Council	410,956	4.4
	Bahi District Council	221,645	4.5
	Chemba District Council	235,711	4.7
	Subtotal	**2,083,588**	**4.6**
	Total	**4,302,080**	-

Source: National Bureau of Statistics and Office of Chief Government Statistician, 2012 *Population and Housing Census, Population Distribution* by Administrative Areas, March 2013



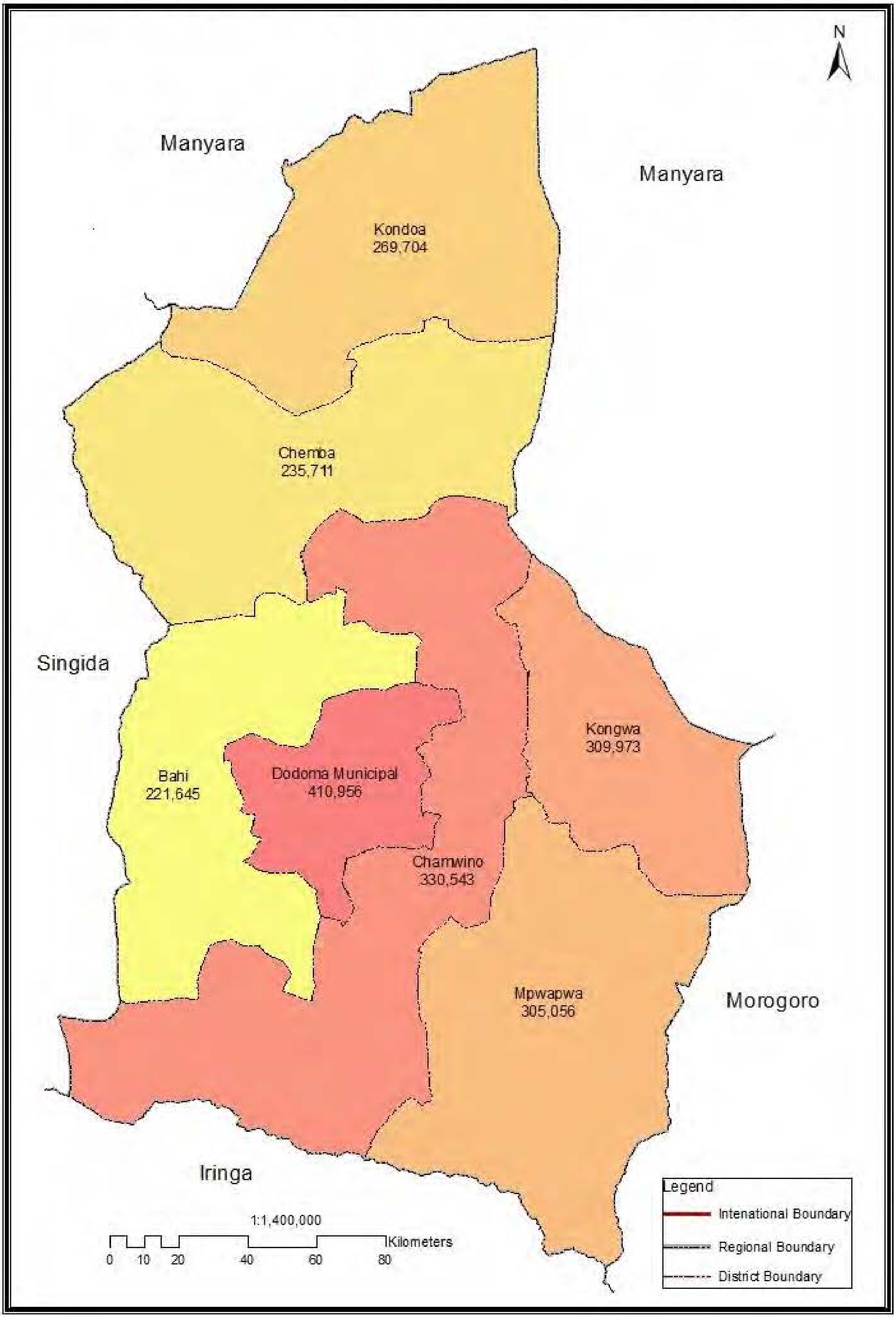
Note: The values on the map indicate 2012 population density by region.
Source: National Bureau of Statistics and Office of Chief Government Statistician, *2012 Population and Housing Census, Population Distribution by Administrative Areas*, March 2013

Figure 1.4: Administrative Regions in Tanzania, 2012



Note: The values on the map indicate 2012 population by district/council.
Source: National Bureau of Statistics and Office of Chief Government Statistician, *2012 Population and Housing Census, Population Distribution by Administrative Areas*, March 2013

Figure 1.5: Administrative Districts and a Council in Morogoro Region, 2012



Note: The values on the map indicate 2012 population by district/council.
Source: National Bureau of Statistics and Office of Chief Government Statistician, *2012 Population and Housing Census, Population Distribution by Administrative Areas*, March 2013

Figure 1.6: Administrative Districts and a Council in Dodoma Region, 2012

1.7.2 Economy

(1) Economic Overview

Tanzania has seen rapid economic growth over the last decade. In the 2000s, the economy (measured by GDP) grew at an average rate of 6.7% per year, and this pace further accelerated in the 2010s, averaging at 6.8% per year for the period 2010–2013 (Table 1.4). A key factor for this rapid economic progress was an expansion in domestic market, driven by a growth in construction, information and communication technology (ICT), and mining sectors. In fact, the percentage of gross domestic product increased by 3.1% in construction, 1.5% in mining and quarrying, and 1.2% in communication subsectors in 2001–2013 (Table 1.5).

Table 1.4: Gross Domestic Product (GDP) of Tanzania, 2000–2013

Year	2000	2001	2002	2003	2004	2005	2006	2007
GDP (at current market prices)	8,153	9,100	10,445	12,107	13,972	15,965	17,941	20,948
Real GDP Growth (% per year)	4.9	6.0	7.2	6.9	7.8	7.4	6.7	7.1

Year	2008	2009	2010	2011	2012	2013	Average 2000–09	Average 2010–13
GDP (at current market prices)	24,782	28,213	32,293	37,533	44,718	53,175	—	—
Real GDP Growth (% per year)	7.4	6.0	7.0	6.4	6.9	7.0	6.7	6.8

Note: 2013 data is provisional.
Source: National Bureau of Statistics, *National Accounts of Tanzania Mainland*, various years

Table 1.5: Share of Gross Domestic Product (GDP) by Economic Activity, 2001–2013 (%)

Economic Activity	2001	2005	2009	2013	2001/2013
Agriculture, Hunting and Forestry	**29.0**	**27.6**	**24.6**	**24.5**	**−4.5**
Crops	21.4	20.5	18.4	17.6	−3.8
Livestock	5.0	5.0	4.0	4.4	−0.6
Hunting and Forestry	2.5	2.2	2.2	2.6	0.1
Fishing	**1.7**	**1.4**	**1.4**	**1.4**	**−0.3**
Industry and construction	**18.0**	**20.8**	**22.0**	**22.2**	**4.2**
Mining and quarrying	1.8	2.9	3.3	3.3	1.5
Manufacturing	8.4	7.9	8.6	8.5	0.1
Electricity, gas	2.2	1.7	1.7	1.8	−0.4
Water supply	0.5	0.4	0.4	0.3	−0.2
Construction	5.2	7.8	7.9	8.3	3.1
Services	**45.5**	**42.5**	**43.6**	**44.3**	**−1.2**
Trade and repairs	13.0	11.0	11.8	12.1	−0.9
Hotels and restaurants	2.8	2.5	2.3	2.5	−0.3
Transport	5.4	4.4	5.0	5.8	0.4
Communications	1.2	1.7	2.1	2.4	1.2
Financial intermediation	1.5	1.7	1.7	1.8	0.3
Real estate and business services	10.3	9.5	9.0	8.4	−1.9
Public administration	7.0	8.0	8.1	7.8	0.8
Education	2.1	1.6	1.4	1.4	−0.7
Health	1.3	1.5	1.6	1.7	0.4
Other social and personal services	0.9	0.7	0.6	0.6	−0.3

Note: 2013 data is provisional.
Source: National Bureau of Statistics, *National Accounts of Tanzania Mainland 2001–2013*, December 2014

In addition, exports have increasingly contributed to the growth in the national economy. The proportion of exports to GDP rose from 17% in 2001 to 31% in 2011. Although the proportion dropped to 25% in 2013 due to lower commodity prices in the international market, the decline in the commodity values was compensated for by a rise in the re-export value, indicating the important role that Tanzania plays as a regional hub for neighboring landlocked countries.

In the coming years, the economy in Tanzania, together with its neighboring countries, is expected to grow relatively rapidly. According to the latest forecasts by the International Monetary Fund (IMF), the GDP is expected to increase at an annualized average rate of 7.0% in Tanzania, 5.1% in Burundi, 7.2% in DRC, 7.3% in Rwanda, and 6.7% in Uganda in 2015–2019 (Table 1.6).

Table 1.6: Gross Domestic Product (GDP) Growth Projections (%), 2015–2019

Year	2015	2016	2017	2018	2019	Average
Tanzania	7.0	7.1	7.0	6.9	6.9	7.0
Burundi	4.8	5.0	5.2	5.4	5.4	5.1
DRC	8.5	7.9	7.3	6.4	5.7	7.2
Rwanda	6.7	7.5	7.5	7.5	7.5	7.3
Uganda	6.3	6.5	6.7	6.9	7.0	6.7

Source: IMF, World Economic Outlook, October 2014

(2) Regional Economy

Table 1.7 presents the regional gross domestic product by region, both at market price and percentage share, for 2001–2013, indicating the increasing share in Dar es Salaam (up by 0.5%), Tabora (up by 0.5%), and Kigoma (up by 0.4%) from 2001 to 2013.

Table 1.7: Regional Gross Domestic Product (GDP) at Market Price (billion TZS) and Its Share (%), 2001–2013

	2001		2005		2009		2013	
Region	Amount (bil. TZS)	Share (%)	Amount (bil. TZS)	Share (%)	Amount (bil. TZS)	Share (%)	Amount (bil. TZS)	Share (%)
Tanzania Mainland	**9,100**	–	**15,965**	–	**28,213**	–	**53,175**	–
Dar es Salaam	1,531	16.8	2,397	15.0	4,849	17.2	9,188	17.3
Pwani	185	2.0	310	1.9	509	1.8	963	1.8
Morogoro	434	4.8	863	5.4	1,377	4.9	2,573	4.8
Dodoma	315	3.5	480	3.0	854	3.0	1,613	3.0
Singida	241	2.7	293	1.8	497	1.8	979	1.8
Tabora	314	3.4	685	4.3	1,140	4.0	2,088	3.9
Shinyanga	703	7.7	910	5.7	1,680	6.0	3,150	5.9
Mwanza	872	9.6	1,347	8.4	2,594	9.2	4,987	9.4
Kigoma	225	2.5	514	3.2	841	3.0	1,537	2.9

Note: 2013 data is provisional.
Source: National Bureau of Statistics, *National Accounts of Tanzania Mainland 2001–2013*, December 2014

1.7.3 Natural Environment

(1) Climate

Tanzania lies just south of the equator, and therefore, its climate is mostly tropical, becoming more temperate in the highlands. The coastal area is tropical and humid with average temperatures of about 27°C (81°F). Further inland, the central plateau is hot and dry with temperatures that vary by season and time of day. In the more temperate highlands, the days are warm, but the nights are cool.

The rainy seasons in the north occur from November through December and from March through May. The south has only one season of rain, from November to March. On the coast, annual rainfall averages 1,000 mm to 1,930 mm, whereas the central plateau receives only 500 mm to 760 mm. The eastern section of Lake Victoria receives 750 mm to 1,000 mm and the western side receives 2,000 mm to 2,300 mm.

The islands receive heavy rains in April and May with lighter rains in November and December. Drier weather occurs during the alternating monsoon seasons, which arrive from the northeast from December to March and from the southwest from June to October.[8]

Based on the Köppen's climate classification[9], the climate over Tanzania is divided as shown in Figure 1.7.

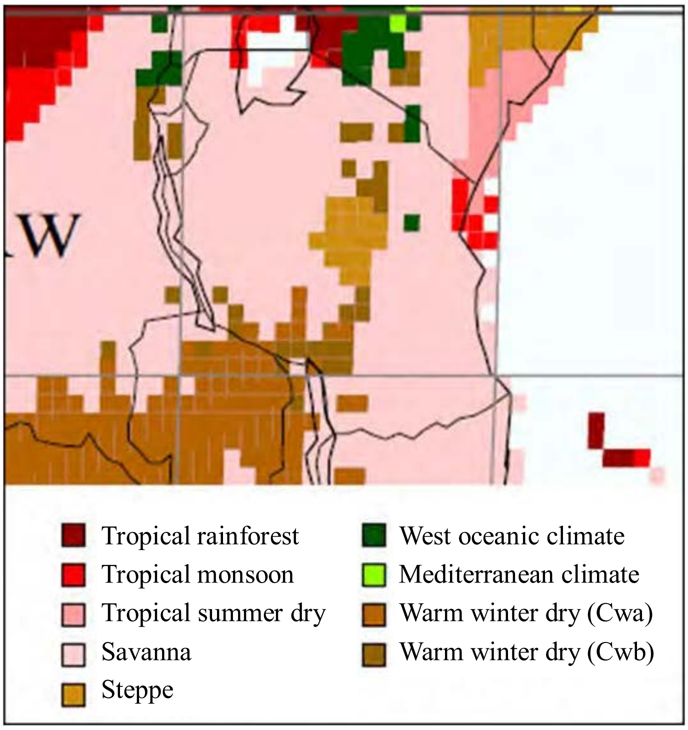


Figure 1.7: Climate Division

Further, monthly mean temperatures (highest and lowest) and mean monthly rainfall at the six major cities in the country are tabulated as follows:

8 The description above is cited from the following source: http://www.nationsencyclopedia.com/geography/Slovenia-to-Zimbabwe-Cumulative-Index/Tanzania.html#ixzz3RKWuQqKx

9 "Köppen-Geiger Klassifikation" was developed by Mr. Wladimir Peter Köppen, a German climatologist, in 1923.

Table 1.8: Monthly Temperatures and Monthly Rainfall

Dar es Salaam

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Monthly mean highest temperature (°C)	30	31	30	29	28	28	27	27	28	30	30	30	29.0
Monthly mean lowest temperature (°C)	25	24	23	23	22	20	19	19	19	21	22	24	21.8
Mean monthly rainfall (mm)	70	60	120	260	180	30	20	20	20	40	80	90	990

Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave".

Zanzibar City

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Monthly mean highest temperature (°C)	32	32	32	30	28	28	27	28	28	30	31	31	29.8
Monthly mean lowest temperature (°C)	24	24	25	25	23	23	22	22	22	22	23	24	23.3
Mean monthly rainfall (mm)	50	60	140	320	280	50	20	30	40	60	170	130	1,350

Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave".

Dodoma

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Monthly mean highest temperature (°C)	29	27	28	28	27	28	26	27	28	30	31	30	28.3
Monthly mean lowest temperature (°C)	18	18	17	17	16	13	12	13	15	17	18	18	16.0
Mean monthly rainfall (mm)	150	100	130	50	0	0	0	0	0	0	20	90	540

Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave".

Mwanza

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Monthly mean highest temperature (°C)	28	28	28	28	28	28	28	28	29	29	28	28	28.2
Monthly mean lowest temperature (°C)	18	17	18	18	17	17	16	17	17	18	18	18	17.4
Mean monthly rainfall (mm)	70	60	120	260	180	30	20	20	20	40	80	90	930

Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave".

Mbeya

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Monthly mean highest temperature (°C)	22	22	22	22	22	21	21	22	25	26	26	25	23.0
Monthly mean lowest temperature (°C)	13	13	13	12	11	8	7	8	11	12	13	13	11.2
Mean monthly rainfall (mm)	190	150	150	110	10	0	0	0	0	10	50	130	800

Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave".

Kigoma

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Monthly mean highest temperature (°C)	26	27	27	27	28	28	28	28	29	28	26	26	27.3
Monthly mean lowest temperature (°C)	19	19	19	19	19	17	17	17	20	20	20	19	18.8
Mean monthly rainfall (mm)	120	120	140	120	40	0	0	0	10	40	140	130	860

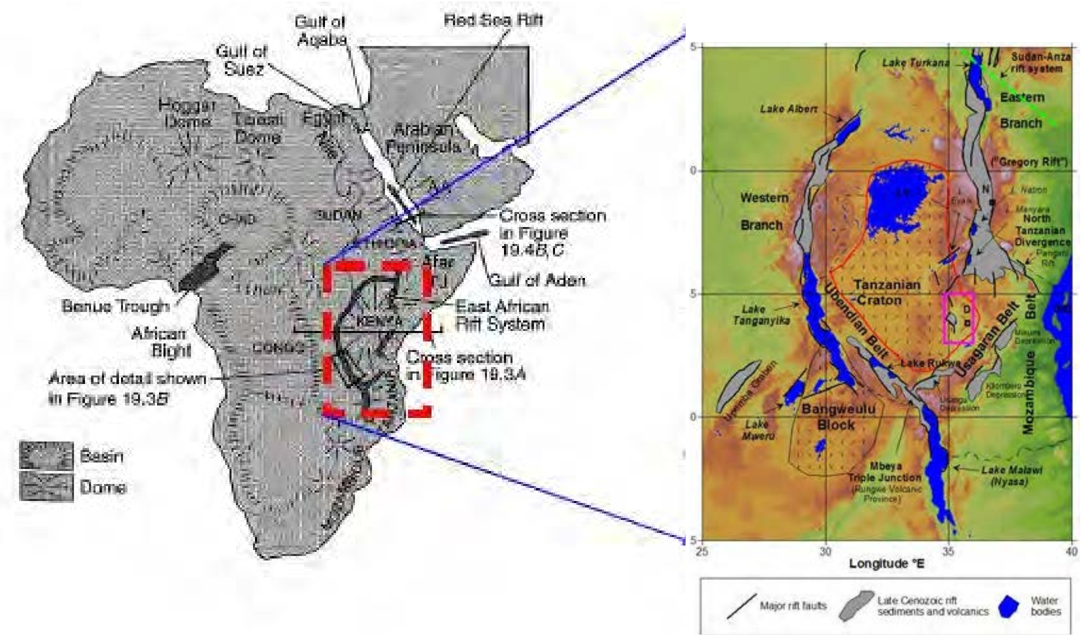
Note: As for the mean monthly rainfall, an annual total value is presented in the column of "Ave.".
Source: http://www2m.biglobe.ne.jp/%257eZenTech/world/kion/Tanzania/index.htm

(2) Geology

The geological structure of Tanzania is largely dominated by the West and East African Rift System (EARS). In Tanzania, the Western rift is marked by Lakes Nyasa and Tanganyika, while the Eastern Rift (also known as the Gregory Rift) passes through Lake Natron before joining the Western Rift south of Lake Nyasa. Subsidiary rifts are found in the Selous Basin and at Lake Rukwa, where some Karoo rocks are preserved.

The Tertiary to Recent Eastern Rift Valley reaches into Tanzania from Kenya in the north. Lake Tanganyika and Lake Nyassa (Lake Malawi) form part of the Western Rift of Tanzania. Volcanics and carbonatites are associated with both the Eastern and the Western Rift. Lacustrine sediments fill large parts of the rift valleys.

Cenozoic events resulted in the incipient dislocation of the African Plate, with rupturing occurring in the West and East African rift systems (Figure 1.8).



Source: JICA, Study on Water Resources Management and Development in Wami/Ruvu Basin in the United Republic of Tanzania, November 2013.

Figure 1.8: Regional Tectonic Setting in African Rifts

Judging by the regional geological structure in East Africa, as the target area is located in the southeast of the Kenyan Dome, the area should be an extensional field in the NW-SE direction. Generally, NE-SW trending fractures seem to be developed very well in the basins.

Its fractures were divided into two categories: clear lineaments (as faults) and unclear lineaments. These fractures were mainly developed in NE-SW direction, particularly form graven structure of Mkata plain west to Morogoro Municipality. In the coastal region, fractures were developed in the N-S direction, which shows a step-like structure dislocating the eastern block down. On the other hand, NE-SW trending faults were developed extensively in the Dodoma region, and they form graven and step-like structures. Unclear lineaments were extracted in various directions all over the area.

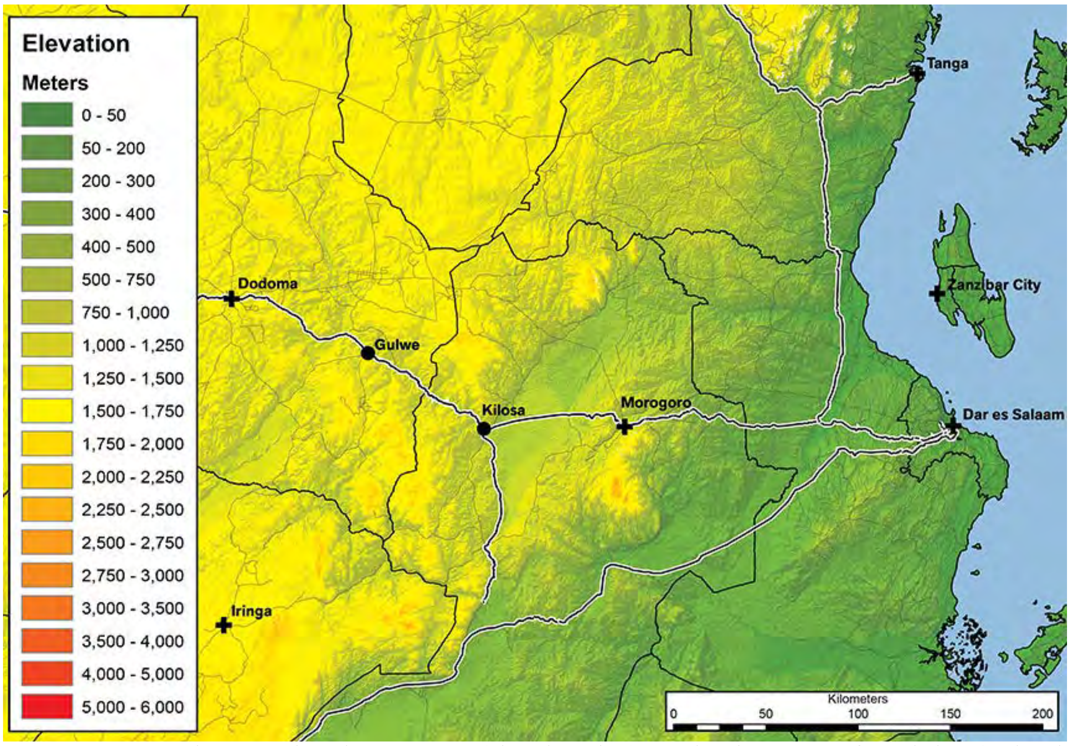
Due to their scale-like length, it was considered that these findings did not show the regional structures, but instead the local ones.

Folding structures were extracted only in the east of Morogoro Municipality. A distribution of the Proterozoic and Palaeozoic indicates a set of synclinal and anticlinal axes, whose direction was almost N-S. Their extension was cut by regional faults.

(3) Topography

The Central Railway Line runs at lower elevations from Dar es Salaam to Kilosa, where the altitude ranges from 30 m to 500 m. Then, the altitude increases from 500 m to 780 m from Kilosa to Gulwe, and further to 1,120 m to Dodoma (Figure 1.9).[10]

Variation in elevations has significant implications on the slope of the area. Higher variations in elevation may lead to higher slope values. Similarly, altitudinal variations contribute to variation in climatic conditions.



Source: JICA Study Team based on NASA (elevation data), National Bureau of Statistics (regional boundaries), and OpenStreetMap (road, rail)

Figure 1.9: Topographical Map of Study Area

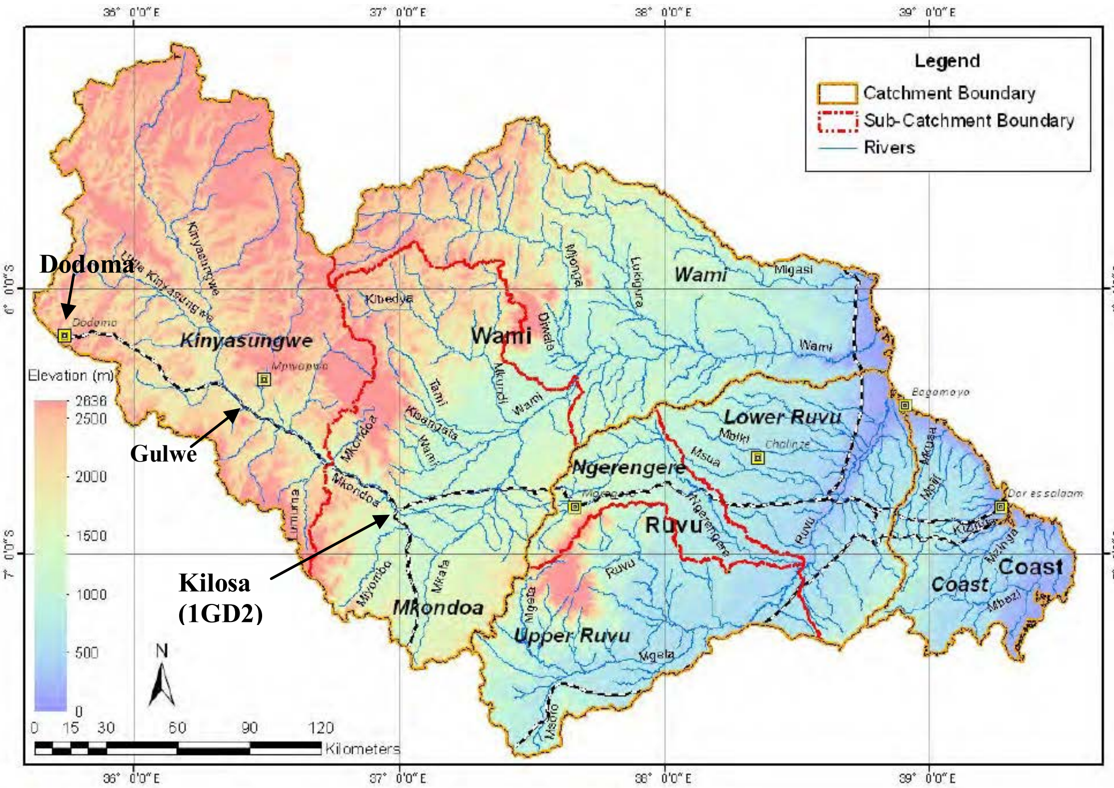
(4) Hydrological Characteristics

The study area is located in the sub-catchment areas of the Wami River basin, which are the Kinyasungwe and Mkondoa Rivers, in the center-east area of the country, as shown in Figure 1.10. Figure 1.11 shows the discharge amounts observed at the 1GD2 gauging station (Mkondoa River at Kilosa) for the 1970/1971 hydrological year. The hydrological characteristics are summarized as follows:

- Mkondoa River at 1GD2 (Kilosa) is a perennial river that has a steady flow year-round, even during the dry season. However, the discharge amounts differ greatly between the rainy season and dry season.

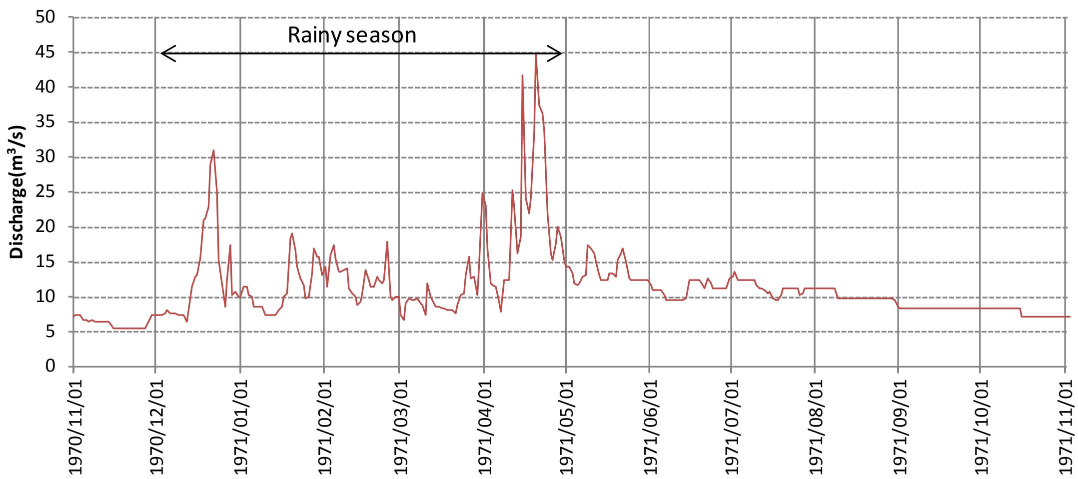
[10] See Figure 7.6 in Chapter 7 for the outline of the topography in the study area.

- On the other hand, rivers in the upstream areas of Kilosa, in particular near Gulwe and Dodoma, are ephemeral rivers that do not flow year-round, and only flow during the rainy seasons (more detailed descriptions of the rivers appear in Chapter 6).



Source: JICA, "Study on Water Resources Management and Development in the Wami/Ruvu Basin in the United Republic of Tanzania", November 2013; further modified by the JICA Study Team.

Figure 1.10: Sub-catchments in the Wami/Ruvu River Basin



Source: JICA Study Team

Figure 1.11: Discharge Observed at the 1GD2 Gauging Station (Mkondoa River at Kilosa) in the 1970/1971 Hydrological Year

1.7.4 Transport Network

Four different types of major infrastructure pass through or nearby to the study area: a rail network, a road network, an aviation network, and an oil pipeline.

(1) Rail

The rail network in Tanzania is divided into two networks: the Central Railway Line and the Tanzania Zambia Railway Authority (TAZARA) Line. The Central Railway Line is currently managed by RAHCO and TRL, which are both 100% owned by the Government of Tanzania, while the TAZARA Line is managed by TAZARA itself, which is jointly owned by the Governments of Tanzania and Zambia on a 50:50 basis.

The Central Railway Line system includes 2,707 km of single-line, meter-gauge track, consisting of the following nine lines: (i) the 1,251-km Central Line from Dar es Salaam to Kigoma (on the Lake Tanganyika), (ii) the 379-km Mwanza Line from Tabora to Mwanza (on the Lake Victoria) via Isaka, where a major inland container depot (ICD) exists, (iii) the 352-km Tanga Line from Tanga to Moshi, (iv) the 188-km Link Line from Ruvu Junction to Mruazi, (v) the 108-km Kidatu Branch from Kilosa to Kidatu, (vi) the 115-km Singida Branch from Manyoni to Singida, (vii) the 210-km Mpanda Branch from Kaliua to Mpanda, (viii) the 86-km Arusha Branch from Moshi to Arusha, and (ix) the 18-km Kahe Branch from Kahe to Taveta, at the border between Tanzania and Kenya. Among these, the Central Line and the Mwanza Line are of paramount importance; thus, the Government of Tanzania and international donors are focusing on the revitalization on these lines (see Chapter 2). On the other hand, all the five Branch Lines (the Kidatu, Singida, Mpanda, Arusha, and Kahe Branches) and part of the Tanga Line (between Korogwe and Moshi) have been closed, mainly due to low demand. Table 1.9 summarizes the current status of the Central Railway Line.

Table 1.9: Current Status of Central Railway Line

Name of Line	From	To	Distance (km)	Current Status
Central Line	Dar es Salaam	Kigoma	1,251	Operational
Mwanza Line	Tabora	Mwanza	379	Operational
Tanga Line	Tanga	Moshi	352	Operational (Tanga–Korogwe) Closed (Korogwe–Moshi)
Link Line	Ruvu Junction	Mruazi	188	Operational
Kidatu Branch	Kilosa	Kidatu	108	Closed
Singida Branch	Manyoni	Singida	115	Closed
Mpanda Branch	Kaliua	Mpanda	210	Closed
Arusha Branch	Moshi	Arusha	86	Closed
Kahe Branch	Kahe	Taveta	18	Closed
		Total	**2,707**	

Source: TRL

The TAZARA system includes 1,860 km of single-line, cape-gauge (1,067 mm) track, running from Dar es Salaam to Tunduma and further onward into Zambia (i.e., 975 km of which is in Tanzania and 875 km in Zambia). The TAZARA Line interfaces with the Central Railway Line network in Dar es Salaam Port and Kidatu; however, the latter terminal is not currently operational due to the line closure of the Kidatu Branch.

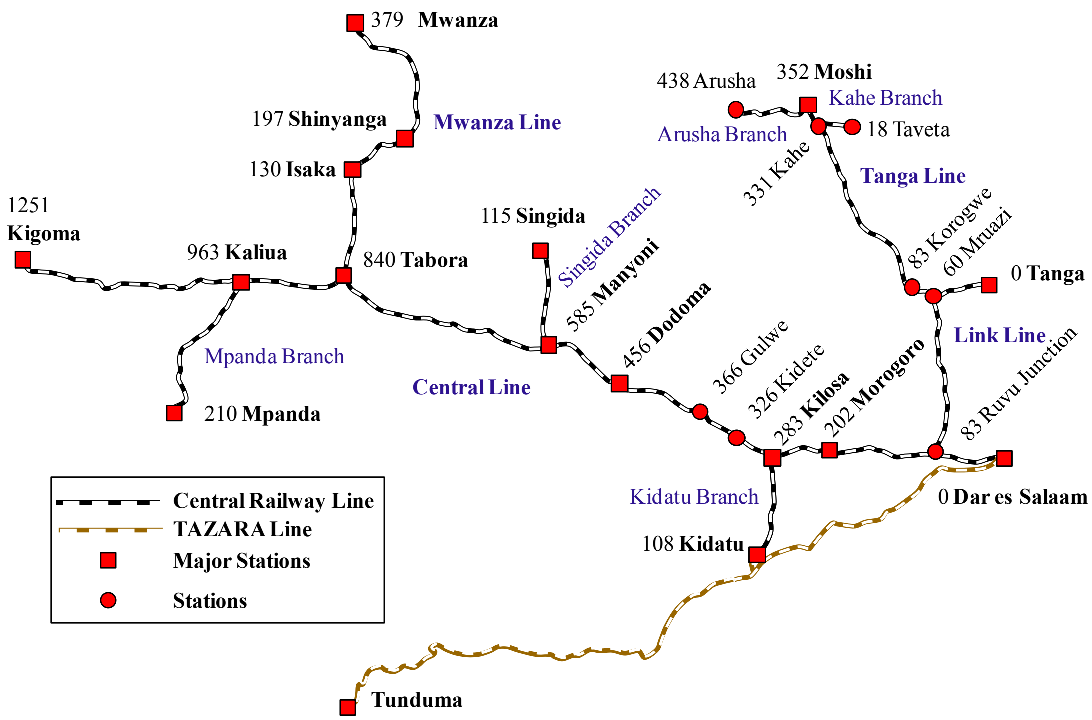
As for the rail infrastructure passing directly through the study area, this will be described in much greater detail in Chapter 9 ("Railway System"). The study area consists of the following 12 stations on the Central Railway Line: Kilosa, Munisagara, Mzaganza, Kidete, Godegode, Gulwe, Msagali, Igandu, Mnase, Kikombo, Ihumwa, and Dodoma. Table 1.10 shows the current status of these stations, including each location (by kilometer post) and the area of its station yard.

Table 1.10: Current Status of Stations in Study Area

Name of station	km post	Area of Station Yard (m^2)	Current Status
Kilosa	283	156,300	Operational
Munisagara	298	105,000	Closed
Mzaganza	311	48,900	Closed
Kidete	326	105,000	Operational
Godegode	349	144,570	Closed
Gulwe	366	101,410	Operational
Msagali	382	118,560	Closed
Igandu	402	92,250	Closed
Kikombo	426	109,270	Operational
Ihumwa	439	126,000	Closed
Dodoma	456	112,500	Operational

Source: TRL

Figure 1.12 shows the rail transport network in Tanzania:



Source: JICA Study Team

Figure 1.12: Rail Transport Network in Tanzania

(2) Road

As of 2014, the Tanzania roads network consists of 12,786 km of trunk roads (5,130 km/7,656 km paved/unpaved) and 21,105 km of regional roads (840 km/20,265 km paved/unpaved), all of this managed by the Tanzania National Roads Agency (TANROADS). An additional 52,581 km as district/urban and feeder roads are managed by local government authorities, which are managed by the Prime Minister's Office – Regional Administration and Local Government (PMO RALG).[11]

Since the late 1990s, the government has prioritized road development, and most international development aid has gone toward such projects. In 1998, a Roads Fund was established, shielding the funding for maintenance from yearly budget debates and providing stability. It was at this time that TANROADS was established, under the Ministry of Works. Even so, TANROADS is relatively underfunded; it is only able to conduct surveys and traffic counts of 1/4 segments of each road per year, due to a lack of resources; thus it takes four years to complete an inventory update of any single road.

Figure 1.13 shows the overview and status (as of 2012) of the major (trunk) roads in Tanzania:

Source: TANROADS (data), JICA Study Team (map)

Figure 1.13: Tanzania Trunk Road Network Status (2012)

[11] In December 2015, it was announced that the PMO RALG would be renamed as the President's Office, Regional Administration and Local Government (PO RALG).

As for the study area, there are no major trunk roads passing through (except for Dodoma). A regional road, B-127, passes through Kilosa, allowing trips to Iringa without having to pass through Dodoma. The road is two-lanes wide and paved. Access to Kidete, Godegode, Gulwe, and Kikombo is only by an unpaved regional road, off an unpaved truck road connecting Dodoma to Iringa. Overall, road access to the study area is poor; rail provides the best option.

(3) Air

As of 2011, Tanzania has 368 airports – the majority of them are private airfields/airstrips owned by mining companies and tour operators, and only 58 airports (on the mainland) are under the control of the Tanzania Airports Authority (TAA). The Tanzania Civil Aviation Authority (TCAA) handles both regulatory matters as well as air traffic control (navigation), although the International Civil Aviation Organization (ICAO) recommends that air traffic control be provided by a separate body from the regulatory authority.

Overall, the domestic air transport industry sees very little traffic. Incomes are generally low, and most of the population cannot afford to travel by airplane. Because of this low demand, fares remain high, further preventing people from utilizing the industry. After Dar es Salaam, the second highest international demand is at Zanzibar, but for domestic demand, it is Mwanza. Along the Central and Mwanza Lines, there are airports in Dar es Salaam, Dodoma, Tabora, and Kigoma, as well as Shinyanga and Mwanza.

In addition to the Dodoma airport there is also a small airstrip serving Morogoro which is less than 1 km away from the railway line, but aside from these two, there are no other air facilities in the study area.

(4) Oil Pipeline

The TAZAMA (Tanzania Zambia Mafuta) Pipeline is a 1,710 km oil pipeline which carries crude oil from Dar es Salaam Port to the Indeni refinery in Ndola, Zambia. It was constructed from 1965 to 1968 by the Zambian government, which has two-thirds ownership to Tanzania's one-third. There are five pumping stations along the pipeline, five in Tanzania and two in Zambia. The same motors installed at its inception are still in operation, although a 1991 World Bank-funded project included repairs and replacements of various pipe segments.

The Central Railway Line and TAZAMA pipeline cross each other in Morogoro, with the pipeline going from northeast to southwest. As the pipeline approaches the study area, it continues southwest; therefore, it is unlikely that the proposed rerouting of the Central Railway Line will cross with TAZAMA pipeline in the study area.

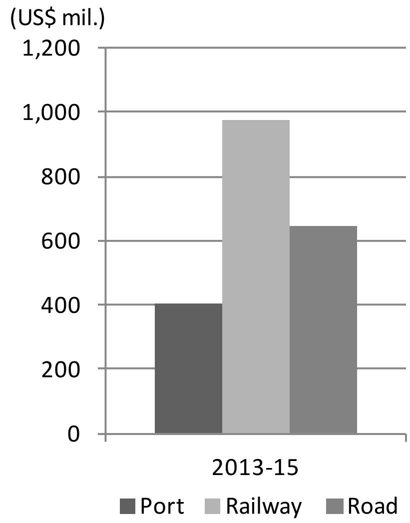
2. Railway Sector Development/Investment Plans

2.1 Plans of the Government of Tanzania

2.1.1 Big Results Now

The Government of Tanzania (GOT) launched the Big Results Now (BRN) initiative in 2013 to enhance the performance of implementing government programs, including those in the transport sector. The initiative is motivated by a similar Malaysian program known as Big Fast Results that hinges on prioritization, detailed monitoring tools, and accountability for performance. BRN aims at facilitating the realization of National Development Vision 2025, a multi-sector socio-economic development plan for Tanzania. It includes a concrete action plan with clear performance milestones and responsible entities.

The total budget required to implement all the initiatives for the entire transport sector (port, railway, and road) is TZS 3.8 trillion (US$ 2.0 billion), 48.2% of which is planned to be spent for the railway subsector (while 31.8% for the road and 20.0% for the port subsectors). It is envisaged that investments will be made by the public sector (67%), development partners (25%), as well as the private sector (8%).



Source: JICA Study Team based on BRN

Figure 2.1: Investment Requirement for BRN (US$ million), 2013–2015

With respect to the railway subsector under BRN, the GOT intends to increase railway freight transportation capacity through: (a) establishing a clear institutional setup; (b) rehabilitating railway infrastructure and intermodal handling facilities; (c) increasing the availability and reliability of rolling stock; (d) strengthening a demand-driven business model; (e) adopting a new organizational setup for RAHCO and TRL; and (f) increasing the level of maintenance.[1] With all these initiatives, BRN set an ambitious target to increase the capacity of the Central Railway Line from 0.2 million tons in 2012 to 3 million tons in 2015.

The current status of BRN was identified through consultations with MOT, RAHCO, and TRL, and is reported as shown in Table 2.1. While some improvement has been found in the availability of rolling stock and strengthening of the business model, not so much progress has been made with regards to the rehabilitation of infrastructure and intermodal handling facilities.

[1] Passenger railway services are not considered under BRN.

Table 2.1: Current Status of Big Results Now

Goal	Activity		Cost (US$ mil.)	Current Status/Remark
Institutional Setup	A1	Establish an undisputed institutional setup for railway operators, asset owners, regulators and policy makers	0	Movable assets were transferred from RAHCO to TRL in January 2015. MOT prepared two cabinet papers pertaining to the registration of TRL as a state enterprise and the proposal to revise Railway Act 2002.
Rehabilitate infrastructure and inter-modal handling facilities	B1	Upgrade/ replacement of 28 low axle load bridges and culverts under condition “E”	21.9	CANARAIL is conducting the Bridge Condition Assessment, which is planned to be completed in February 2016.
	B2	Relay light, overstretched and worn out track portions	227.8	To be conducted under TIRP. CPCS is currently preparing the bidding documents, which are planned to be completed in February 2016.
	B3	Rehabilitate 8 station buildings and 3 workshops, build 1 new station building and 15 gang camps	66	No progress. No funding is secured for these activities.
	B4	Improve telecommunication system in two phases (Dar es Salaam–Dodoma, Tabora–Kigoma/ Tabora–Mwanza)	54.4	No progress.
	B5	Improve drainage system along the Kilosa–Gulwe section	0.3	Completed. RAHCO conducted the improvement works according to its original plan (32 points were restored at TZS 28 billion).
	B6	Construction of an extension of the Ubungo line to Dar es Salaam station	0.1	No progress as this is just 100 m-long, and it is highly likely that TRL will not pay to RAHCO for using the line. Apart from this, a feasibility study for urban commuter rail from Ubungo to Kibaha, Bagamoyo (via Mwenge), Pugu, and Chamazi is about to start in December 2015 for the scheduled period of 9 months by GIBB.
	B7	Improved handling facilities at Isaka and Ilala	2.5	To be improved under TIRP. Contract on the consulting service for detailed design for improving the port interface will be made with an international consultant before the end of December 2015. These ICDs were developed by RAHCO (owner of the ICDs). 5 reach stackers were provided by the Government of Belgium through Belgian Technical Cooperation.
	B8	Find operators for ICDs in Shinyanga and Mwanza	0	No progress for Shinyanga as the ICD is idle due to the extremely low traffic volume. Contract negotiation with one of the bidders (i.e., an operator) is ongoing for Mwanza.
	B9	Improve the space situation at Isaka terminal	0.1	To be improved under TIRP.
Improve availability of rolling stock	C1	Rehabilitate 9 locomotives	12.4	Completed in November 2011, two months earlier than the original plan.
	C2	Remanufacture 14 locomotives	44.8	Remanufacturing of 16 locos from SMH of Malaysia (2 more than the original plan). Remanufacturing of 8 locos is completed. Of the remaining 8 locos, 2 were rolled out in March 2015 and some spare parts of the 6 are being cleared to Morogoro as of February 2016. Apart from the BRN initiative, 9+5 locos are planned to be remanufactured through loan by Tanzania Investment Bank (TIB) and additional 5 by Tanzania Ports Authority (TPA), although these are pending.
	C3	Procure 13 + 50 locomotives	144.2	Procured 13 locos (the last 3 has arrived at Dar es Salaam in November 2015, followed by pre-commissioning inspection). Of 50 locos, 11 was planned to be procured from

Goal	Activity		Cost (US$ mil.)	Current Status/Remark
				EMD Inc. of the U.S. through a Single-Source Tender, but the contract was floated due to the lack of fund. Supplier of 39 locos is under consideration. Noted that 3 locos to be procured under TIRP is not part of the BRN initiative.
	C4	Rehabilitate 275 freight wagons (125 and 150)	4.7	Rehabilitated 83 wagons, but no funding has been secured for the remaining wagons.
	C5	Procure 2,234 freight wagon (274 + 970 + 990)	277.0	Procured 274 wagons (174 covered wagons, 50 tank wagons, and 50 container carriers), but no funding has been secured for the remaining wagons.
	C6	Rehabilitate 13 shunting locomotives	7.4	No funding has been secured.
	C7	Procurement of 64 brake vans	10.9	Ordered 34 brake vans in January 2015 with the cost of US$ 103,000 per van. Of these, 17 have been delivered, while the remaining 17 have neither been ordered nor procured.
	C8	Procurement of 50 ballast hopper	6.4	Procured 25 ballast hoppers in September 2014 with the cost of some 100,000 per hopper, but no funding has been secured for the remaining 25 ballast hoppers.
Strengthen business model	D1	Create/adjust a demand-driven business plan for operations	0.1	Prepared a 2013–15 business plan. 5-year business plan will be prepared under TIRP.
	D2	Reestablish a financial monitoring system	1.7	Scheduled to be reestablished by a management partner to be selected under TIRP.
	D3	Reestablish a cargo tracking system	3.8	Installed at RAHCO, TRL, and SUMATRA through funds from the World Bank (different from TIRP).
	D4	Improvement of operational efficiency and adapt operations to increased traffic capacity	0.3	Working documents were revised and some stations were closed in 2014. Between Kilosa and Dodoma, Munisagara (Km 298), Mzaganza (Km 311), Godegode (Km 344), Musagali (Km 384), and Ihumwa (Km 438) are closed.
	D5	Improvement of working capital of TRL	46.6	Secured TZS 12.2 billion (US$ 6.5 million) from Tanzania Investment Bank for recurrent costs such as fuel purchases, utilities, power, etc.
Organizational setup	E1	Adapt organizational setup of RAHCO	0	New organizational structure was proposed in February 2015. However, no progress has been made due to the lack of fund for adopting the new organizational setup.
	E2	Adapt organizational setup of TRL	0	The board of directors approved the new organizational setup, consisting of six line divisions: Infrastructure, Rolling Stock, Business Development, Procurement, Finance, and Human Resources Management.
	E3	Create new recruitment strategy for TRL	3.2	TRL has resumed sending staff to the Tanzania Institute of Rail Technology (TIRTEC), also known as the Railway Training College in Morogoro and Tabora.
Maintenance	F1	Rehabilitate workshop machinery	13.9	No progress for RAHCO though it owns a bridge yard and a steel sleeper plant in Pugu where some spare parts are missing. Partial progress for TRL including the experts' examination of TRL field grinding machine in Dar es Salaam and Tabora.
	F2	Improve track maintenance procedures	33.0	No progress. Daily track maintenance is conducted by TRL, while restoration work in excess of US$ 100,000 is undertaken by RAHCO. In the future (after 2016, according to BRN and after 2020, according to the MOT), the responsibility of track maintenance will be transferred from TRL to RAHCO entirely. Maintenance of some

Goal	Activity		Cost (US$ mil.)	Current Status/Remark
				sections may contract out to a private company (as already conducted by R and A Works Company for the Mpanda and Link lines).
	F3	Improvement of trolley availability and procurement of track recording car	12.4	No progress.
	F4	Improvement of rolling stock maintenance procedures	4.5	Signed a two-year maintenance contract (with a two-year warrant period) at US$ 2 million with Malaysian SMH company in November 2014. But TRL is struggling to secure fund for that.
Total			940.9	

Note: Exchange rate of TZS 1 = US$ 0.00053 (as of 1st March 2015) is used for the cost.
Source: JICA Study Team

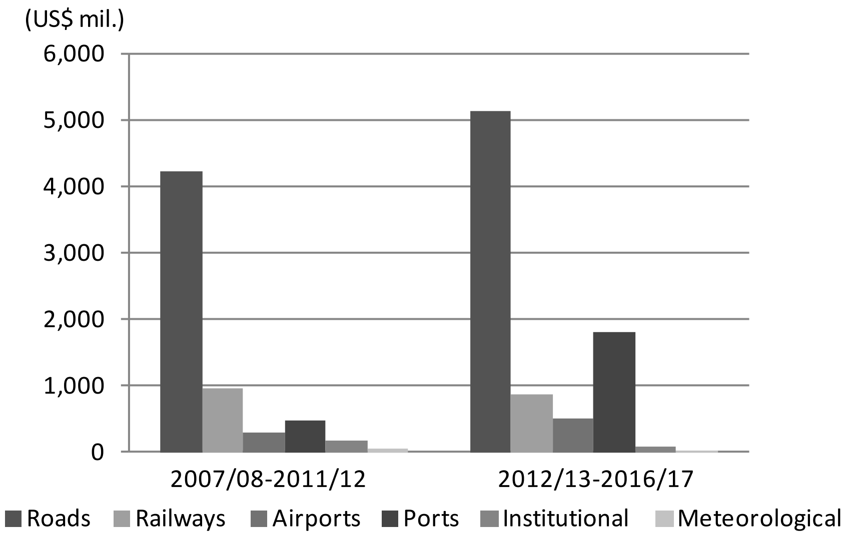
2.1.2 10-Year Transport Sector Investment Programme

The Government of Tanzania has prepared a 10-Year Transport Sector Investment Programme (TSIP) to effectively implement transport policy. TSIP runs from 2007/08 to 2016/17, and is being implemented in two phases (TSIP1: 2007/08–2011/12 and TSIP2: 2012/13–2016/17).

The first phase was ambitions but mostly unrealized because of (i) a lack of funding from the government, donors, and private entities, (ii) implementation delays due to inadequate capacity for project preparation and procurement, and (iii) institutional and structural problems, especially in managing railways.[2] In fact, while it was estimated to require investments totaling US$ 6.14 billion, only about US$ 2.55 billion (41.5%) was expended.

The second phase is projected to require even greater investments, amounting to US$ 8.4 billion, and appears to have more funding mobilized and secured; thus more of its initiatives should be actualized.

The estimated investment amount required for the railways subsector dropped from US$ 946 million under TSIP1 to US$ 856 million under TSIP2, even despite an increase in overall funding (Figure 2.2). This in turns shows that the railways share declined from 15.4% of overall funding under TSIP1 to 10.2% under TSIP2. With a view toward revitalizing the railways, which play a critical role in growing both national and regional economy, shifting investment from roads to railways is desirable.



Source: JICA Study Team based on TSIP1 and TSIP2

Figure 2.2: Investment Requirement for TSIP (US$ million), 2007/08–2016/17

For the most part, TSIP2 and BRN are comparable; however there are some variations in procurement quantities and maintenance prioritization. The current status of TSIP2, as identified through consultation with RAHCO, is summarized in Table 2.2. While most of the studies and some of the track and structures projects are either completed or ongoing, there is still a great amount of room for system improvement.

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2 World Bank, *Project Appraisal Document for Intermodal and Rail Development Project*, April 2014.

Table 2.2: Current Status of 10-Year Transport Sector Investment Programme in Phase 2

Area	Ongoing/Planned Projects	Current Status/Remark
Track and structures	Relaying 150 km with 80 lb/yard materials in the Central Line	Relaying with 80 lb rails are completed and planned as follows: 1) Itigi (Km 626) to Malongwe (Km 730): Completed by RAHCO in November 2015 2) Igalula (Km 805) to Tabora (Km 840): To be conducted under TIRP
	Rehabilitation of bridges (Dar es Salaam–Morogoro)	To be conducted under TIRP
	Track repair and improvement of drainage Kilowa–Gulwe	Completed at Km 293 and Km 303.
	Rehabilitation of branch lines (Manyoni–Singida, Kaliu–Mpanda)	No funding is secured for this activity, although it is planned to replace the current 45 lb rails with 56.12 lb rails that were removed during the track relaying work on the Kitalaka–Malongwe section.
	Upgrading Central Line track (Tabora–Kaliua, Isaka–Mwanza, and other branch lines)	Detailed engineering designs for both sections were completed in 2015 by COWI. A study for financing the entire Central Line with the length of 2,161 km including the newly proposed Kaliua–Mpanda–Karema Port line is ongoing with the progress report submitted by ROTHSCHILD in 2015.
System improvement	Upgrading of signaling and telecommunications	No progress
	Rehabilitation of stations and workshop buildings	No progress
	Procurement of various maintenance equipment	No progress
Study/design	Preparation of a Railway Master Plan (including commuter trains)	No progress. Although the importance of the Master Plan is acknowledged, asset evaluation is currently prioritized, since current assets are highly undervalued.
	Completion of a feasibility study and detailed design for construction of new rail lines: Arusha–Musoma, Mbegani to the Tanga–Arusha branch	A detailed design on the Tanga–Arusha section was completed by COWI in 2014. A feasibility study and preliminary design on the Arusha–Musoma section is planned to be completed by JGB Gauf in March 2016. These studies are both financed by GOT. Both lines are planned to be installed with standard gauge.
	Study/design of new rail lines connecting Isaka directly to Burundi and Rwanda, Arusha–Musoma, establishing an alternative route from Dar es Salaam to Uganda, and Mbamba–Mtwara, establishing a southern route from Malawi/Zambia to the coast	A feasibility study and preliminary design for Isaka–Burundi/Rwanda was completed in March 2014. Currently, AfDB is employing a transaction advisor from CPCS. A study/design for Isaka–Musongati–Uvinza has just started by JGB Gauf. A feasibility study and preliminary design for construction of Mtwara– Mbambabay Line with Spurs to Liganga and Mchuchuma is ongoing with the draft final report submitted to RAHCO on October 2015 by Korean consultants.
	Study of realignment of the Central Line from Morogoro–Dodoma	Expectation is provided to JICA.
	Appraisal of a permanent fix for the Kilosa–Gulwe flooding segment	Expectation is provided to JICA.
Others (esp. new railway construction)	Rehabilitation of Tura Quarry to supply ballast for the Central Line	Almost completed, and test run will be conducted by the end of December 2015. RAHCO was asked to close Tura Quarry from the Ministry of Energy and Minerals because of non-payment of its operating license, but the issue was settled. As ballast demand is anticipated to rise, RAHCO is planning to open quarries in Pangani and Moshi (the plan is approved by the Ministry of Energy and Minerals for Pangani)

Area	Ongoing/Planned Projects	Current Status/Remark
	Construction of ICDs in Mwanza, possibly Kigoma, Tabora, and others	Although no budget is allocated, RAHCO acquired land in Kigoma to develop an ICD in the future. There is no plan of constructing ICD in Tabora as it is not a destination for freight trains. As the necessity of having an ICD in Dodoma is obvious in light of the frequent line closures between Kilosa and Gulwe, RAHCO is looking for land in Ihumwa (next to Dodoma).
	Resettlement of populations near proposed stations and yards	No progress
	Strengthen right-of-way boundaries to prevent encroachment	Ongoing. Markers have started to be installed on the ROW boundaries. They have already been installed on the 89 km section between Kitalaka (Km 641) and Malongwe (Km 730). But no funding is secured for the other sections, although encroachment is a priority issue for RAHCO to deal with.

Source: JICA Study Team

2.2 Plans of the Other Donor Assistance

2.2.1 World Bank

(1) Outline of Tanzania Intermodal and Rail Development Project (TIRP)

The World Bank approved of US$ 300 million in International Development Association credit in April 2014 for the Tanzania Intermodal and Rail Development Project (TIRP), and the credit became effective on 30 March 2015. The development objective of TIRP is to deliver reliable open-access infrastructure on the Dar es Salaam–Isaka section. TIRP has been designed around intermodal rail services for container transportation, and eventually intends to provide for twice weekly container train services. It is considered to be fully aligned with, and is to be viewed as a subsidiary of, the BRN initiative. TIRP consists of the following four components:

Component A: Improvement of Rail Infrastructures. This includes the rehabilitation of key sections of the railway track and other infrastructure improvements to guarantee reliable service between Dar es Salam Port and Isaka Terminal. The following works would be implemented:

- **The rehabilitation of some railway track sections requiring urgent repairs on the Dar es Salaam–Isaka section:** A full rehabilitation between Dar es Salaam and Kilosa (269 km) and Malongwe and Tabora (39 km). TIRP includes provisions for replenishment of ballast along an additional 115 km of track, and the continuous welding of rails along 435 km of track. Some other upgrades (re-ballasting of stations and turn-outs, stabilizations of embankments) have also been included in the works;
- **The rehabilitation of "weak" bridges to increase the capacity:** Reconstruction or repair of 144 bridge structures to increase the axle load capacity of the Dar es Salaam–Isaka section to a minimum permissible 15 tons axle load capacity;
- **Train Control and Track Warrant Systems:** The improvement of radio communication system between Dar es Salaam and Isaka for safe train operations. A train control "very high frequency" (VHF) radio system and a new train protection and warrant system will be supported; and
- **Supervision of Track and Bridge Works:** The provision of Supervision Consultants for the track works, bridge works, and maintenance works.

Component B: Rolling Stock: This includes the procurement and leasing of locomotives and wagons (Table 2.3). The container block train rolling stock will be dedicated to the introduction of a new inter-modal service to be operated by TRL between Dar es Salaam and Isaka.

Table 2.3: Rolling Stock to be Purchased or Leased

Rolling stock	Amount (US$ mil.)	Description
Purchase of 3 new locos	9.0	• Each train set requires 2 x 2,200 hp locos and can pull 40wagons with 2 TEUs per wagon. • One as a spare and rescue operation. • Weight of a total of 90 ton (15 ton/axle) per loco.
Purchase of 44 flat-bed wagons	3.5	Wagons will be leased to TRL
Purchase or lease of 2 locos for engineering trains	5.0	This also includes the purchase of 15 ballast hoppers and one track recording machine

Source: RAHCO TIRP Operations Manuals 2015.

Component C: Development of Isaka Terminal, Ilala Terminal and Dar es Salaam Port Platform: This includes the design and civil work for construction/upgrade of rail exchanges at the three sites to allow for more efficient modal transfers to and from rail.

Component D: Institutional Strengthening, Capacity Building, and Implementation Support: This includes support for the project preparation and technical support to RAHCO, TRL, and SUMATRA to ensure that TIRP is implemented successfully and complements the BRN. Main elements of this Component are (i) preparatory design studies, (ii) enhancement of information and technology tools among TRL, RAHCO, and SUMATRA, (iii) Setting up of the Project Implementation Team (PIT), and (iv) capacity strengthening of TRL.[3]

(2) Consideration of a Japan's ODA Loan Project in Relation to TIRP

Since the project section of a Japan's Official Development Assistance (ODA) Loan is part of the TIRP section, and the timing of the implementation is different, it is important to pay consideration as shown in Table 2.4.

Table 2.4: Consideration in a Japan's ODA Loan Project in Relation to TIRP

Ref. No.	Contract or Assignment	Current status, remark	Considerations with regard to the Japan's ODA Loan project
Goods			
G9	Refurbishment of tamper car	Dependent on appointment of Rolling Stock Specialist	Availability during the construction of Japan's ODA Loan project
G10	Procurement of track recording car	Specifications under preparation as of December 2015	Availability during the construction of Japan's ODA Loan project
G12	Train control VHF radio installation for Dar es Salaam-Dodoma	Bidding document is being finalized as of December 2015	Installation on the rerouting section, especially at a new Gulwe station
Works			
W4	Rehabilitation and maintenance of track works Kilosa to Isaka (39km CTR, ballasting operations, earthwork, drainage upgrade and refurbishment of 80 lb/yd track)	To be commenced after the consideration under C20	• The boundary of the W4 Works and rerouting section by the Japan's ODA Loan project for the Kilosa–Gulwe section • The standards of the track rehabilitation (construction)
W5	Maintenance contract for Kilosa–Isaka section	To be commenced after the consideration under C21	Maintenance system and methods after the completion of the Japan's ODA Loan project
Consulting Assignments			
C2	Inspection and capacity rating of railway bridges (Bridge Condition Assessment (BCA)) 1/	The Final Report is under preparation as of February 2016.	In the case where there is no need for flood protection measures, (i) bridge renewal/rehabilitation works are not planned in the Japan's ODA Loan project and (ii) TIRP would require any measure for the bridges with insufficient loading capacity
C3	Detailed bridge engineering design and tender documentation	To be commenced after the completion of C2.	
C20	Preparation of tender documents for railway track rehabilitation works and track maintenance contracts	Completed. Designs and bidding packages for all track works will be delivered by the end of May 2016	Tender documents for the procurement of track materials should be consistent with those of TIRP

[3] According to the Quarterly Report from 1 October to 31 December 2015, the PIT consists of a Project Manager, a Procurement Specialist, a Financial Management/Accounting Specialist, an Office Technical Assistant, and a Project Engineer. A Rail Operations Specialist and a Rolling Stock Specialist have yet to be appointed.

Ref. No.	Contract or Assignment	Current status, remark	Considerations with regard to the Japan's ODA Loan project
C21	Consultancy services for the preparation of outputs and performance-based maintenance of railway track	EOI was issued in January 2016	Maintenance system and organization after the project completion

Abbreviations: CTR = Complete Track Renewal, EOI = Expression of Interest, ODA = Official Development Assistance, VHF = Very High Frequency

Notes: 1/ TIRP BCA will be done for all bridges in the Kilosa–Dodoma section (regardless of the flood protection measures for bridges and embankment under a Japan's ODA Loan project).

Source: JICA Study Team based on the PIT Quarterly Report from 1 July to 30 September 2015, the PIT Quarterly Report from 1 October to 31 December 2015, TIRP Aide-Memoire December 2015, and an interview with RAHCO

2.2.2 African Development Bank

The African Development Bank (AfDB) is considering implementing the Dar es Salaam–Isaka–Kigali/Keza–Musongati Railway Project (DIKKMR) by utilizing a Public Private Partnership (PPP) scheme. To date, feasibility studies have been undertaken in two phases (Phase I: 2007–09 and Phase II: 2012–2014). The main objectives of the Phase II study are to (i) identify the optimal technical design for the railway, choosing between meter (1,000 mm), Cape (1,067 mm), and standard (1,435 mm) gauges, and (ii) recommend an institutional and financing structuring for the project.[4] Major recommendations of the Phase II study are:

- Meter gauge will be adopted due to its lower investment requirements (it is estimated that infrastructure investments for standard gauge requires an additional US$ 770 million);
- The three governments should adopt the single infrastructure company approach;
- A vertically-separated structure should be adopted in which a state-owned enterprise will build and own the infrastructure and a private entity will operate the trains.

Following the feasibility studies, AfDB is employing a transaction advisor to clarify the legislation and procedures for structuring the project in the form of a PPP. The advisory services began in September 2014 and are ongoing as of December 2015. Its assignments include the following:[5]

- Review the available technical, financial and legal due diligence and complete the improvements of these as deemed necessary to ensure a successful completion of the transactions;
- Transaction structuring including investment options, analysis, and evaluation;
- Assist the three governments to prepare for and implement the PPP procurement process, including preparing all transaction documents, bidding documents, and marketing strategy;
- Assist the three governments in the analysis of the project and in evaluating and finalizing a workable transaction arrangement that is offered to the concessionaires;
- Providing investment risk management advisory services;
- Providing PPP agreement management support, particularly in the development phase and during the early years of the operations;
- Provide assistance with procurement and negotiations;
- Conduct capacity building during the engagement period.

[4] Governments of Tanzania, Rwanda and Burundi, *Phase II of the Dar es Salaam–Isaka–Kigali/Keza–Musongati Railway Project Study*, Final Report, March 2014.
[5] MOT, Request for Expression of Interest Consulting Services: Dar es Salaam–Isaka–Kigali/Keza–Musongati Railway.

The proposed new line on the Isaka–Kigali/Keza–Musongati section has a total length of 703 km, of which 430 km is in Tanzania, 155 km is in Burundi, and 118 km is in Rwanda. Although its implementation schedule is not clearly identified, the overall time required for the project implementation is estimated to be seven years (three years for organizing the institutional arrangements, placing the financing, and completing the design, and four years for construction). When this project is implemented, it may encourage not only the privatization of the Central Railway Line, but also a modal shift from road to rail on the Central Corridor. However, challenges remain, especially in terms of how to finance the infrastructure.

2.2.3 European Investment Bank and European Union

The European Investment Bank (EIB) is planning to rehabilitate track on the 130 km Tabora–Isaka section, as well as rehabilitate or replace structures on the 970 km Dar es Salaam–Isaka section. According to EIB's letter dated on 23 February 2015, the track rehabilitation aims to achieve a permissible load of 18 tons/axle (except structures) and an operating speed of 75 km/h on most of the Tabora–Isaka section. Also, the structural improvement intends to attain a permissible load of 25 tons/axle. EIB is considering providing a loan amounting to US$ 70 million for track rehabilitation and US$ 50–100 million for the structural upgrades.

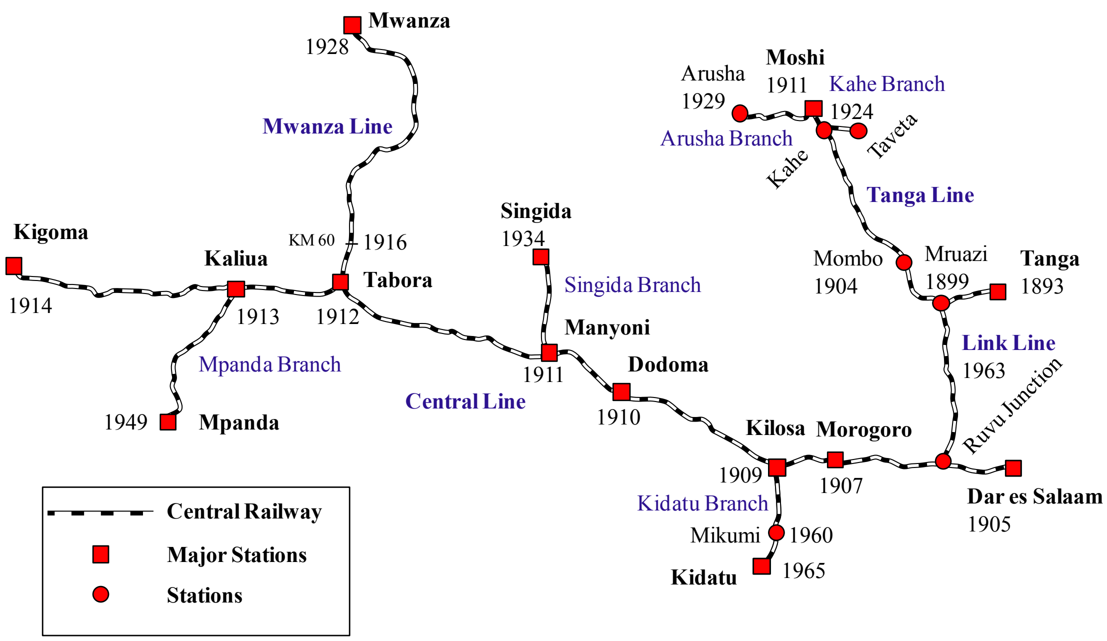
In addition, the European Union (EU) is exploring the possibility of providing a grant in combination with the EIB loan. Its assistance is not identified, but will be complementary to TIRP.

3. Current Conditions of the Central Railway Line

3.1 Overview of the Central Railway Line

The Central Railway Line plays an essential role for Tanzania, linking its east to its west, and its center to its north, while also serving transit traffic between its neighboring landlocked countries and Dar es Salaam Port, which functions as a gateway port for those countries. Its network includes 128 stations and 2,707 km of single-line, meter-gauge non-electrified track, consisting of the following nine lines: (i) the 1,251-km Central Line from Dar es Salaam to Kigoma (on the Lake Tanganyika), (ii) the 379-km Mwanza Line from Tabora to Mwanza (on the Lake Victoria) via Isaka, where a major inland container depot (ICD) exists, (iii) the 352-km Tanga Line from Tanga to Moshi, (iv) the 188-km Link Line from Ruvu Junction to Mruazi, (v) the 108-km Kidatu Branch from Kilosa to Kidatu, (vi) the 115-km Singida Branch from Manyoni to Singida, (vii) the 210-km Mpanda Branch from Kaliua to Mpanda, (viii) the 86-km Arusha Branch from Moshi to Arusha, and (ix) the 18-km Kahe Branch from Kahe to Taveta, at the border between Tanzania and Kenya.

Figure 3.1 shows the construction years of each section and/or line of the Central Railway Line. Its history dates back to 1893 when the construction of the first railway line commenced in Tanga. With the aim of exporting commercial crops harvested in the highland plantations from Tanga Port, the Tanga Line (then called the Usambara Railway) reached Mruazi in 1899, Mombo in 1904, and finally Moshi in 1911. The Central Line was the second railway line installed during the colonial era of German East Africa. Its construction began in Dar es Salaam in 1905. Following an old caravan route, the line reached Morogoro in 1907, Kilosa in 1909, Dodoma in 1910, Manyoni in 1911, Tabora in 1912, Kaliua in 1913, and finally Kigoma in 1914. The Mwanza Line reached its km 60 point (from Tabora) in 1916 (during World War I), and the remaining section (to Mwanza) was completed by Britain in 1928. Although the Kahe Branch was constructed in 1924, followed by the Arusha Branch in 1929, the Mpanda Line in 1949, the Link Line in 1963, and the Kidatu Branch in 1965, most lines of the Central Railway Line were constructed by 1930.



Source: JICA Study Team

Figure 3.1: Railway Network by Construction Year

3.2 Institutional Structure

3.2.1 Division of Roles and Responsibilities: Current and Planned

The Big Results Now (BRN) initiative launched by the Government of Tanzania (GOT) in 2013 proposes the establishment of a new institutional setup, clearly defining the roles and responsibilities of TRL, RAHCO, SUMATRA, and MOT. Table 3.1 summarizes the current and planned institutional setup of the railway sector proposed in the BRN.

Table 3.1: Current and Planned Institutional Setup of Railway Sector

Issues	Current	Transition period	Long term
Policy direction and decisions, performance monitoring and evaluation, legal matters, financing and budgeting	MOT	MOT	MOT
Railway infrastructure			
Ownership of infrastructure assets	RAHCO	RAHCO	RAHCO
Railway infrastructure development	RAHCO	RAHCO	RAHCO
Routine infrastructure maintenance and casual renewal[1]	TRL	TRL	RAHCO[2]
Railway services			
Provide operational services for operators	TRL	TRL	RAHCO
Ownership of rolling stock	RAHCO	TRL	TRL
Provide railway freight and passenger services	TRL	TRL	TRL
Maintenance and repair of rolling stock	TRL	TRL	TRL
Procurement of new rolling stock	TRL	TRL	TRL
Other related operations			
Run a railway training college	TRL	TRL	RAHCO
Run quarry operations	TRL	TRL	RAHCO
Sleeper reconditioning plant for sleeper maintenance	TRL	TRL	RAHCO
Implement railway-related regulations and standards	SUMATRA	SUMATRA	SUMATRA

Notes: (1) Based on the Concession Agreement (2007), TRL is currently "responsible for the first US$ 100,000 of the cost of any restoration to such lost or damaged immovable assets and to the extent that the total cost of such restoration is less than US$ 100,000". (2) In July 2015, MOT mentioned that the transfer of this responsibility to RAHCO will be conducted by the end of 2019 when the TIRP Program is completed. However, it is still unclear who will actually conduct the maintenance work (see 3.2.6 (iii) for more details).
Source: BRN

The main points of the planned reforms are as follows:

Two-phase approach

- Phase I: A transition period (for at least 2–3 years) with TRL as the only train operator on the Central Railway Line, to stabilize the system and reduce complexity.
- Phase II: Long-term perspective (from earliest 2016), with the option to open the network to other private operators.

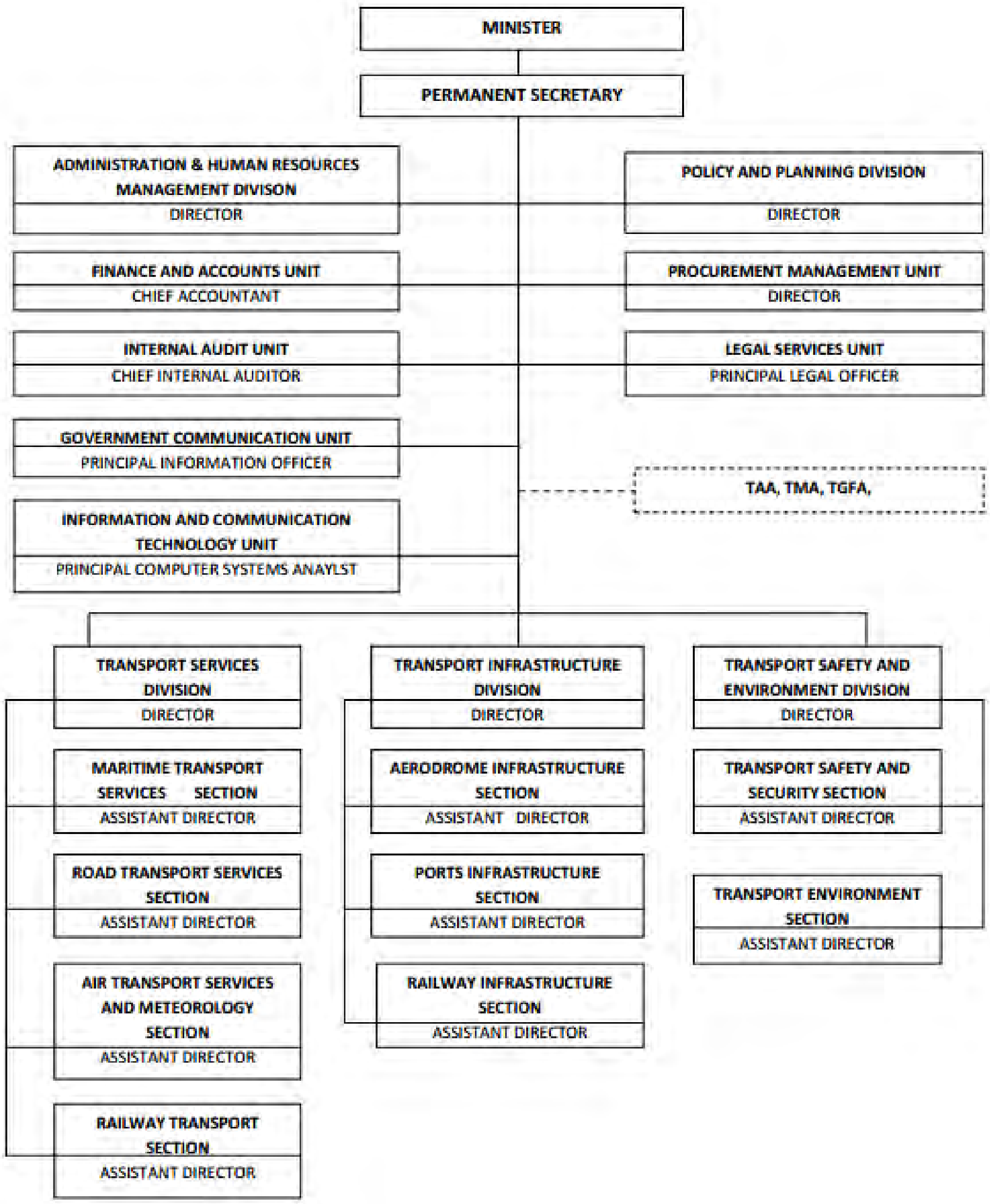
Division of responsibilities

- Phase I: Ownership of rolling stock will be transferred from RAHCO to TRL.
- Phase II: Selected roles, such as routine maintenance, operational services for operators, responsibility for the railway training college, quarry operations, and sleeper plant, will be transferred from TRL to RAHCO.

The concerned organizations (MOT, RAHCO, TRL and SUMATRA) are briefly described below.

(1) MOT

MOT was established in January 2011 as a result of the restructuring of the former Ministry of Infrastructure Development, and was organized into five divisions: (i) Policy and Planning, (ii) Transport Services, (iii) Transport Infrastructure, (iv) Transport Safety and Environment, and (v) Administration and Human Resources Management (Figure 3.2). Until December 2015, the Policy and Planning Division, Railway Transport Section of Transport Services Division, and Railway Infrastructure Section of Transport Infrastructure Division were responsible for the promotion of railway projects in Tanzania. In December 2015, MOT was reorganized as the Ministry of Works, Transport and Communications (MWTC) merging with the Ministry of Works and partly the Ministry of Communication, Science and Technology.

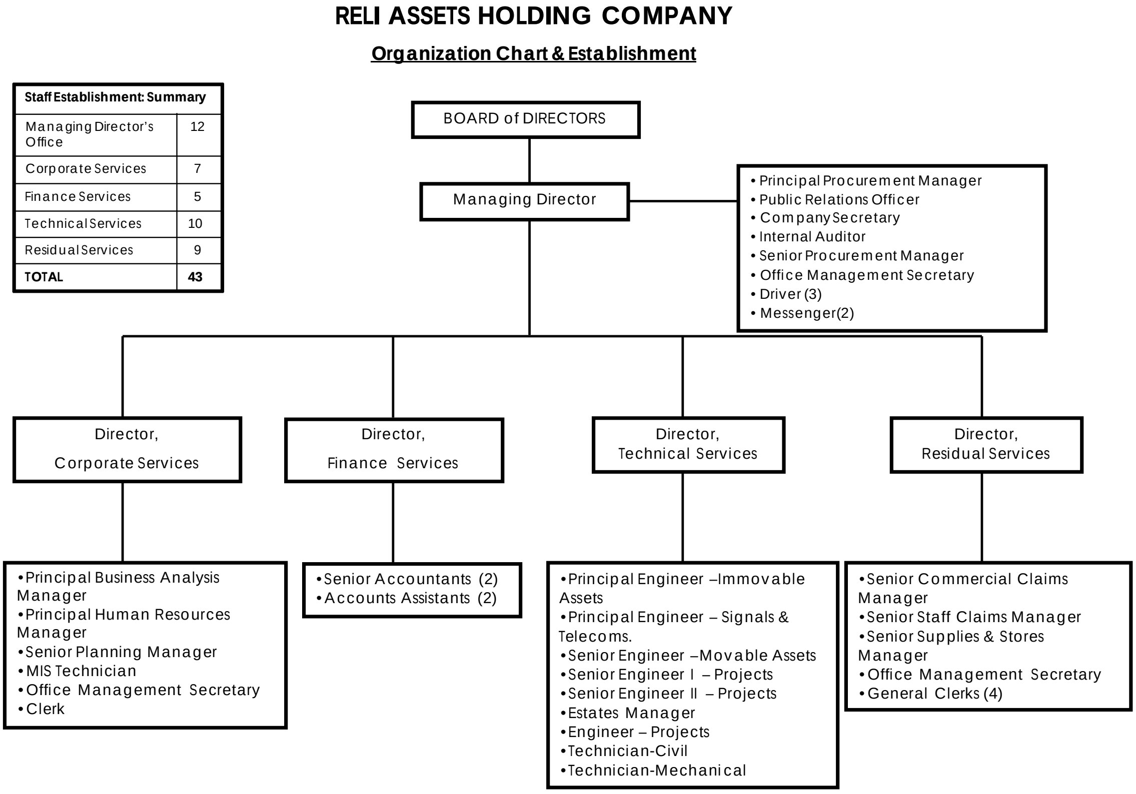


Source: MOT

Figure 3.2: Organizational Structure of MOT

(2) RAHCO

RAHCO was formed under the Railway Act No.4 of 2002 and became operational in September 2007, principally as a landlord of railway infrastructure on behalf of the government. RAHCO is governed by the Board of Directors and its day-to-day management is entrusted to the Managing Director. It has four departments: (i) Corporate Services, (ii) Finance Services, (iii) Technical Services, and (iv) Residual Services (Figure 3.3). While there are 43 established positions, the number of payroll staff at RAHCO is 46, of which 13 are in the Managing Director's Office, 13 in the Corporate Services, 6 in the Finance Services, 9 in the Technical Services, and 5 in the Residual Services, as of December 2015. There is only one office of RAHCO, which is located in Dar es Salaam.

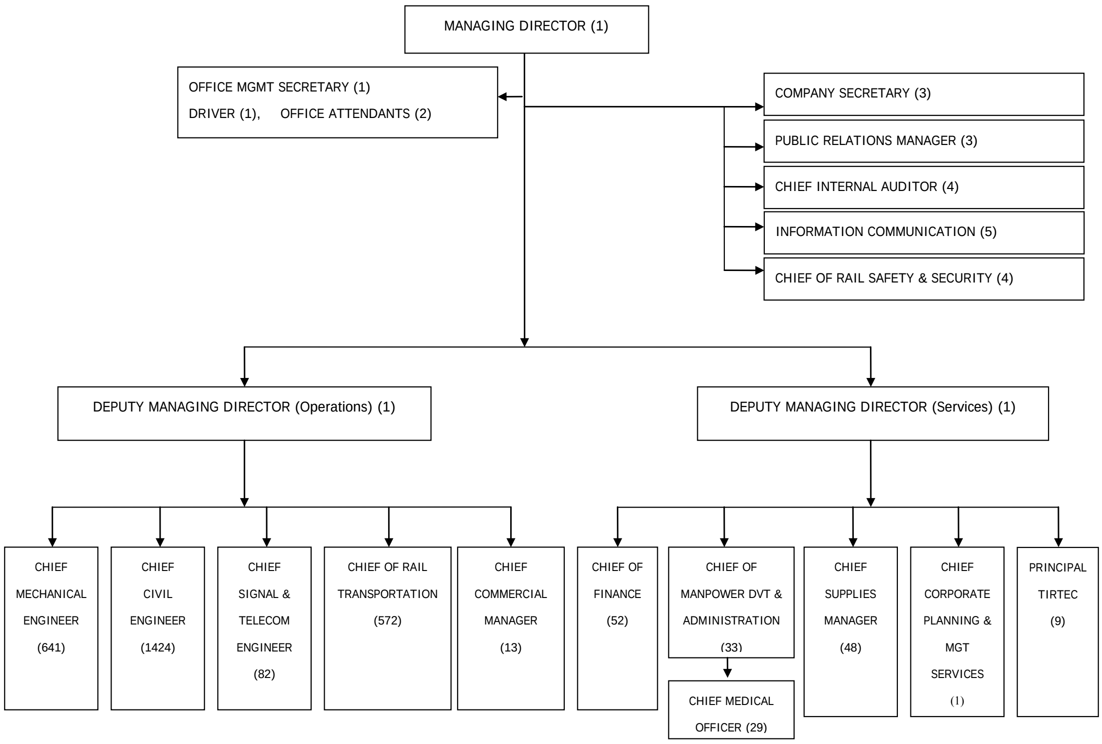


Source: RAHCO

Figure 3.3: Organizational Structure of RAHCO

(3) TRL

TRL was incorporated in September 2007 under the Company Law No. 12 of 2002, initially owned by RITES (51%), as a strategic partner, and GOT (49%), but became fully nationalized as a result of the concession termination in 2011, although its legal status has not changed (as of December 2015). TRL is organized into two divisions: (i) Operation and (ii) Services (Figure 3.4). The number of staff at TRL is 2,930, of which 1,424 are in the Civil Engineering Department, 641 in the Mechanical Engineering Department, 572 in the Rail Transportation Department, among others, as of December 2014.



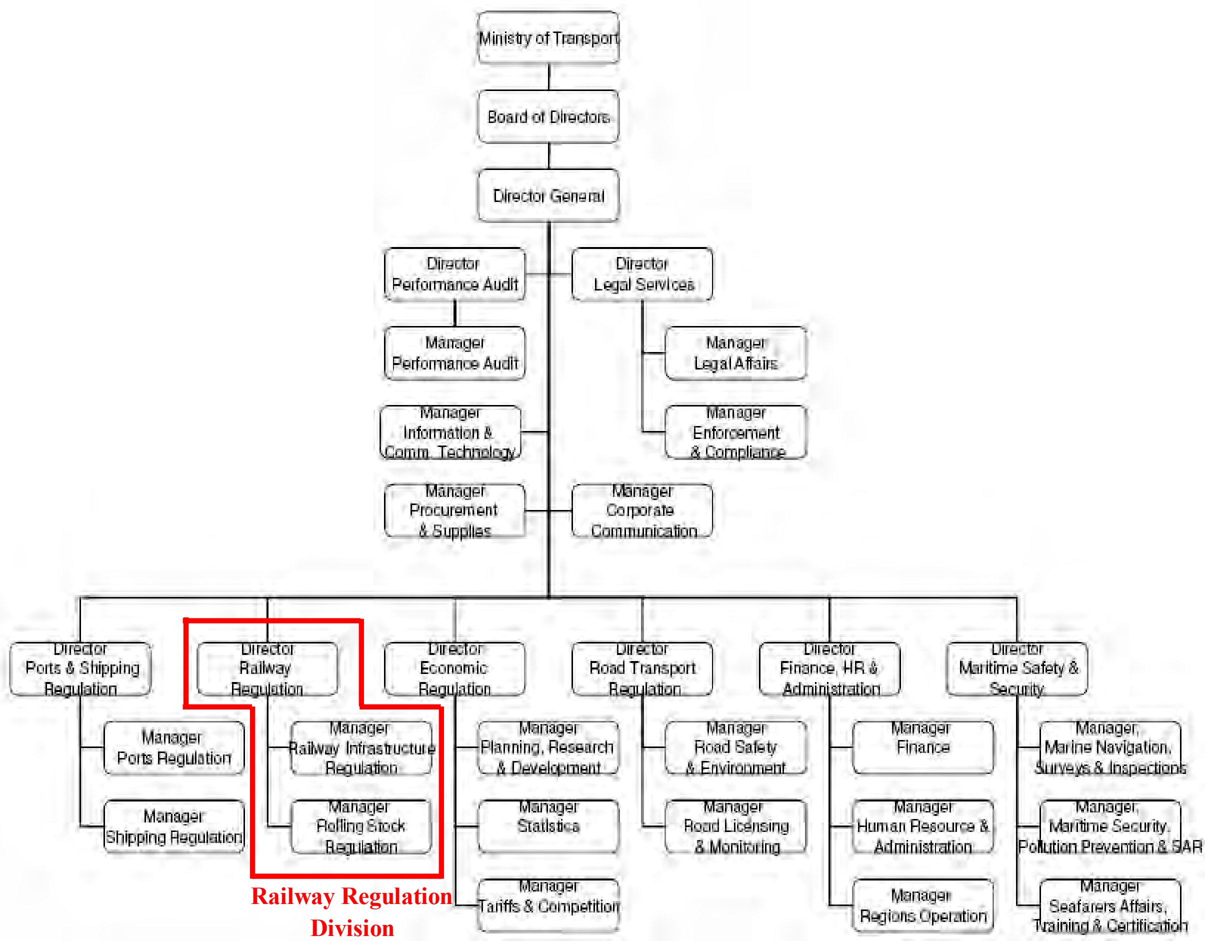
Source: TRL

Figure 3.4: Organizational Structure of TRL

(4) SUMATRA

SUMATRA was established under the SUMATRA Act 2001 and commenced operations in August 2004 as a multi-sector regulatory agency. In the railway sector, it is responsible for issuing railway operating licenses, ensuring railway safety, and approving engineering and maintenance standards. SUMATRA is governed by the Board of Directors and its daily management is entrusted to the Director General. The authority is structured into six divisions: (i) Ports and Shipping Services Division, (ii) Railway Regulation Division, (iii) Road Transport Regulation Division, (iv) Maritime Safety and Security Division, (v) Economic Regulation Division, and (vi) Finance, Human Resource and Administration Division (Figure 3.5).

Among the approximately 180 staff working for SUMATRA, only four (4) work in the Railway Regulation Division as of November 2015, although new staff recruitment has been ongoing. In addition, there are about 25 regional offices of SUMATRA with no railway staff. There is also a serious lack of funding for overseeing the railway sector. SUMATRA's operation is funded through levies and fees received from the transport subsectors under its responsibility, including a 1% levy on TRL revenues, although TRL is unable to pay this fee due to its financial difficulties. All of the levies and fees received by SUMATRA are mixed and redistributed among the divisions, thus the Railway Division in effect is cross-subsidized by other transport subsectors.



Source: SUMATRA

Figure 3.5: Organizational Structure of SUMATRA

3.2.2 Financial Situation of RAHCO and TRL

(1) RAHCO

The balance sheet and the income statement of RAHCO in recent years are shown in Table 3.2 and Table 3.3, respectively[1]. The balance sheet indicates that the volume of assets of the company has increased, although at a slow pace, over the period. This resulted from investments in property, plants and equipment, and capital work in progress, amounting to TZS 38.3 billion in 2013/14, up from TZS 27.7 billion in 2012/13 and TZS 10.6 billion in 2011/12.[2] The transfer of rolling stock assets from RAHCO to TRL started in January 2015, which is to be followed by the transfer of related assets, including rolling stock workshops and depots.

There is a pressing need for RAHCO to increase revenue. Currently, much of the revenue accrues from ‘other income’ (non-operating income), with bank interest accounting for the largest share in this income category, resulting in a heavy reliance on government grants for operation. It would also take time before RAHCO would be able to receive infrastructure access fees or concession fees from railway operators. The company plans to increase revenue by developing non-operational land into income-generating projects, including, among others, the development of ICDs to be implemented as part of the World Bank-funded TIRP.

[1] As of December 2015, the approved financial statements for 2014/15 were not available.
[2] These investment figures are based on the cash flows of RAHCO in 2011/12–2013/14.

Table 3.2: Balance Sheet of RAHCO, 2011/12–2013/14

Unit: TZS 000

	2013/14	2012/13	2011/12
ASSETS			
Current Assets			
Inventories	13,662	0	0
Trade and Other Receivables	6,258,357	8,725,939	8,970,305
Short Term Investments	25,729,082	31,063,310	40,044,828
Cash and Cash Equivalents	7,625,269	553,228	
Total Current Assets	39,626,370	40,342,477	49,015,133
Non-Current Assets			
Property, Plant and Equipment	100,781,501	76,214,330	79,672,796
Capital Work in Progress	114,574,498	104,430,711	76,826,722
Total Non-Current Assets	215,355,999	180,645,041	156,499,518
Total Assets	**254,982,369**	**220,987,518**	**205,514,651**
LIABILITIES			
Current Liabilities			
Trade and Other Payables	12,011,381	10,593,086	14,287,146
Total Current Liabilities	12,011,381	10,593,086	14,287,146
Non-Current Liabilities			
Deferred Capital Grants	125,242,088	90,238,490	71,228,703
Long Term Loan - IDA Loan	36,210,723	36,210,723	36,210,723
Total Non-Current Liabilities	161,452,811	126,449,213	107,439,426
Total Liabilities	**173,464,192**	**137,042,299**	**121,726,572**
EQUITY			
Share Capital	546,000	546,000	546,000
Former TRC Assets	110,974,924	110,974,924	112,584,423
Accumulated Surpluses/(Losses)	(30,002,747)	(27,575,705)	(29,342,343)
Total Equity	**81,518,177**	**83,945,219**	**83,788,080**
Total Liabilities and Equity	**254,982,369**	**220,987,518**	**205,514,652**

Source: Tanzania National Audit Office

Table 3.3: Income Statement of RAHCO, 2011/12–2013/14

Unit: TZS 000

	2013/14	2012/13	2011/12
Revenue			
Revenue[1]	754,336	745,148	816,085
Other Income[2]	3,447,282	6,825,153	2,303,926
Grants from Government	2,614,270	2,906,642	5,837,162
Total Revenues	**6,815,888**	**10,476,943**	**8,957,173**
Operating Expenses			
Personnel Costs	2,040,704	2,048,333	2,015,980
Infrastructure Monitoring and Protection	2,603,682	5,212,301	1,638,925
Residual Services[3]	1,065,226	2,116,087	1,541,838
Provision for Obsolete and Damaged Items	0	0	4,254,669
Provision for Impairment of Receivables	0	124,516	5,123,272
Impairment of Property, Plant and Equipment	0	0	7,262,670
Net Depreciation Expenses	3,588,900	3,581,294	2,759,972
Total Operating Expenses	**9,298,511**	**13,082,531**	**24,597,326**
Operating Surplus/(Loss)	**(2,482,623)**	**(2,605,588)**	**(15,640,153)**
Finance Gain	60,568	117,557	133,240
Surplus/(Loss) before Tax	(2,422,055)	(2,488,031)	(15,506,913)
Taxation	0	0	0
Surplus/(Loss) for the Year	(2,422,055)	(2,488,031)	(15,506,913)
Other Comprehensive Income	0	0	0
Total Comprehensive Income	**(2,422,055)**	**(2,488,031)**	**(15,506,913)**

Notes: (i) 'Revenue' consists of concession fees and rental income, but all accrued from rental income in 2011/12-2013/14. (ii) 'Other Income' consists of 12 components represented by bank interest (75.6%), sale of spare parts (21.3%), and compensation (4.8%) in 2011/12-2013/14. (iii) 'Residual Services' consists of 21 components represented by EARC/TRC pension costs (59.8%), commercial claims (17.1%), and EARC/TRC lump-sum verification costs (6.1%) in 2011/12-2013/14.

Source: Tanzania National Audit Office

Table 3.4 shows budget allocations by MOT to RAHCO in recent years. While there seems to be some inconsistency between these figures and relevant figures in the financial statements, the disbursed amounts relative to the request by RAHCO clearly suggest that the company suffers from a severe lack of funding for its investing and operating activities. However, the approved amount for 2014/15 was significantly higher than in previous years due to the increasing importance of the railway sector relative to road.

Table 3.4: Budget Allocation for RAHCO, 2010/11–2015/16

	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Budget requested by RAHCO (bil TZS)	183	184	141.5	174	164.2	309.1
Budget approved by MOT (bil TZS)	24	42.7	30.9	51.1	116.7	31.7
Budget disbursed by MOT (bil TZS)	15.6	30.1	26.2	29.0*	10.76**	N/A

Notes: (i) The fiscal year in Tanzania ends on 30 June. (ii) * 29.0 is the budget disbursed up to May 2014. (iii) **10.76 is the budget disbursed up to December 2014.
Source: RAHCO

(2) TRL

TRL's financial statements for 2008, 2009 and 2010 are shown in Table 3.5 and Table 3.6. During the long transition from a private company to a state enterprise, several issues remained unresolved, causing a long delay in the preparation of TRL's financial reports for 2011, 2012 and 2013; for example, there were arguments whether the company should be audited by a private audit firm or by the government's Controller and Auditor General (CAG) of the National Audit Office. In 2015, it was decided that the CAG should conduct the audit, and an appointed auditor worked on the financial reports for 2011, 2012 and 2013, although they were not ready as of December 2015.

Table 3.5: Balance Sheet of TRL, 2008–2010

Unit: TZS 000

	2010	2009	2008
ASSETS			
Current Assets			
Inventories	3,532,235	4,441,882	3,223,435
Trade and Other Receivables	4,405,236	3,478,184	5,289,967
Due from Related Party	378,301	373,580	372,469
Margin Money	314,020	486,494	3,244,326
Bank and Cash Balances	1,023,043	10,198,065	9,783,770
Total Current Assets	9,652,835	18,978,206	21,913,967
Non-Current Assets			
Property, Plant and Equipment	7,827,337	8,424,712	5,217,079
Start-up Costs	1,259,590	1,972,629	2,685,669
Deferred Tax Asset	0	0	15,096,293
Total Non-Current Assets	9,086,927	10,397,341	22,999,041
Total Assets	**18,739,762**	**29,375,547**	**44,913,008**
LIABILITIES			
Current Liabilities			
Bank Balance Overdrawn	0	306,670	0
Due to Related Party	77,570,036	55,338,445	23,868,678
Trade and Other Payables	10,775,623	10,132,910	8,472,873
Total Current Liabilities	88,345,659	65,778,026	32,341,551
Non-Current Liabilities			
GOT Top-up Money	12,189,370	12,189,370	5,617,795
Long Term Loan	10,119,879	19,714,764	18,737,647
Total Non-Current Liabilities	22,309,249	31,904,134	24,355,442
Total Liabilities	**110,654,908**	**97,682,160**	**56,696,993**
EQUITY			
Share Capital	20,000,000	20,000,000	20,000,000
Accumulated Surpluses/(Losses)	(111,915,146)	(88,306,613)	(31,783,985)
Total Equity	**(91,915,146)**	**(68,306,613)**	**(11,783,985)**
Total Liabilities and Equity	**18,739,762**	**29,375,547**	**44,913,008**

Source: TRL Reports and Financial Statements

Table 3.6: Income Statement of TRL, 2008–2010

Unit: TZS 000

	2010	2009	2008
Income			
Freight	19,783,800	35,204,527	37,259,490
Passenger	3,317,817	7,911,386	8,096,960
Wagon lease	80,463	1,317,061	0
Operating Income	23,182,080	44,432,974	45,356,450
Others	6,131,226	238,827	410,968
Total Income	**29,313,306**	**44,671,801**	**45,767,418**
Expenses			
Operating Expenses	52,180,954	68,745,256	69,791,530
General Expenses	1,995,257	3,583,412	4,253,378
Administrative Expenses	9,100,296	11,787,695	9,957,359
Financial Expenses	56,150	1,338,425	1,282,328
Foreign Exchange Loss	7,606,122	637,798	390,672
Total Expenses	**70,938,779**	**86,092,585**	**85,675,265**
Loss before Government Grant and Tax	**(41,625,473)**	**(41,420,784)**	**(39,907,847)**
Government Grant	18,024,300	0	0
Loss after Government Grant before Tax	(23,601,173)	(41,420,784)	(39,907,847)
Withholding Tax on Interest Income	7,360	5,551	14,834
Corporate Tax	0	0	0
Deferred Tax	0	15,096,293	(13,009,014)
Net Income/(Loss)	**(2,422,055)**	**(2,488,031)**	**(15,506,913)**

Source: TRL Reports and Financial Statements

3.2.3 Lessons from Past Railway Sector Restructuring

One important lesson learned from the past railway sector restructuring in Tanzania, which was pointed out by the World Bank[3], is that institutional restructuring alone cannot be embraced as the solution for improving the performance of an ill-performing sector, and that a strengthening of the capacity of the Tanzanian railway industry and related institutions on a broader level needs to accompany or be implemented before introducing new arrangements. The Study Team fully agrees with this point. The World Bank-funded TIRP includes a component (Component D) to strengthen the capacity of the concerned organizations and clarify their roles and responsibilities (see the following section for details), which is expected to support the institutional arrangement proposed in the BRN (see section 3.2.1 for details).

3.2.4 Initiatives for Institutional Reform and Strengthening

In order to move forward with the proposal in the BRN, the Government of Tanzania has started various undertakings toward railway institutional reform and strengthening. Table 3.7 summarizes the current status of relevant initiatives, many of which are implemented as part of the TIRP.

Table 3.7: Initiatives for Railway Institutional Reform and Strengthening

Concerned Entity	Initiative	Status/Remarks
MOT	Implementation of the railway institutional reform, e.g., amendments to the Railway Act	In February 2015, MOT proposed to the cabinet: (i) the formal registration of TRL as a government institution, and (ii) amending of the Railway Act No. 4, 2002 to legalize the new institutional setup. As of December 2015, these had not been approved yet.
RAHCO	Review of the organizational structure	In February 2015, a report titled "RAHCO Organization Structure 2014" was prepared, which proposes a new organizational structure. The report was under review by RAHCO as of December 2015.
	Preparation of a 2nd corporate strategic plan 2014/15–2019/20	As of December 2015, a local consulting firm had submitted the draft final report, which would be reviewed by RAHCO.
	Designing the right maintenance organization and sustainable maintenance program (under TIRP)	Procurement of a consultant was in process as of December 2015.
TRL	Preliminary audit/due diligence (under TIRP)	In December 2014, it was decided that these two initiatives will be combined into one, and a revised TOR dated December 2014 was prepared. Procurement of a consultant was in process as of December 2015.
	Preparation of 5-year business plan (5yBP) (under TIRP)	
	Strengthening of management with management contract (under TIRP)	Delivery of audit and 5yBP is a preliminary step to prepare for competitive bidding of this 3-year contract to employ TRL's "Transformation Partner". TOR is to be prepared for selection of this management partner with no actions yet as of December 2015

[3] Source: The World Bank, Project Appraisal Document for the Tanzania Intermodal and Rail Development Project, April 2014, p. 17.

Concerned Entity	Initiative	Status/Remarks
RAHCO, TRL, SUMATRA	Establishment of a Management Accounting Information System (MAIS) (under TIRP)	Initial set of specifications of the system is to be prepared by the World Bank TIRP team with no actions yet as of December 2015. The system may be introduced with assistance by the above-mentioned management partner.
	Training to be provided for staff of the three entities (under TIRP)	No specific plan yet as of December2015
SUMATRA	Implementation of effective regulation for an open access policy (under TIRP)	As of December 2015, PIT was preparing a TOR for experts to assist SUMATRA in drafting the regulation.

Source: MOT, World Bank, RAHCO, TRL, and SUMATRA

As suggested by the lesson mentioned previously, strengthening RAHCO and TRL is essential for revitalizing the Central Railway Line and for realizing the successful implementation of the open access policy. Some of the major initiatives for RAHCO and TRL are described below.

(1) RAHCO

RAHCO started a review of its organizational structure to prepare for private sector participation in the provision of railway services and establish the functions of railway maintenance, train control, and scheduling. In February 2015, RAHCO issued a report titled "Organization Structure 2014", which proposed an organizational structure consisting of seven directorates: (i) Procurement and Supplies, (ii) Civil Works Engineering, (iii) Land and Real Estates, (iv) Telecommunications and Signals, (v) Business Support, (vi) Finance Services, and (vii) Permanent Way Engineering. As of December 2015, the report was under review by RAHCO.

RAHCO has also been preparing a 2nd corporate strategic plan 2014/15–2019/20 with its own funds, following its first plan covering the period 2009/10–2013/14. A local consulting firm was employed and worked according to the Terms of Reference (TOR) summarized in Table 3.8, with a draft final report submitted to RAHCO as of December 2015.

Table 3.8: Summary of TOR for Preparation of RAHCO Corporate Strategic Plan 2014/15–2019/20

Task Item	Summary Tasks
(1) Review of existing corporate plan	Review and appraise performance of the existing corporate plan and draw lessons
(2) Analysis of external environment	Analyze and review external environment through review of a number of policy documents, developments, programs, and initiatives related to the transport sector and in particular the railway sub-sector
(3) Analysis of the company	Undertake an in-depth analysis of RAHCO's company profile, including establishment, functions and mandates, organizational structure, staffing and implementation capacity, and size of assets
(4) Proposing of vision, etc.	Through a consultative approach and the analysis done above, review and propose the vision, mission statement, core values, corporate objectives, strategies, monitoring, and reporting framework, and performance indicators
(5) Development of the plan	Drawing from the above tasks, develop the 2nd (or revised) corporate strategic plan 2014/15–2019/20
(6) Preparation of operation plan	Prepare a revised operation plan 2014/15–2019/20 which shall include detailed and scheduled targets, inputs, budget, and proposed financing
(7) Other	Review and prepare clear and unambiguous definition of terms

Source: RAHCO

(2) TRL

Table 3.9 and Table 3.10 summarize the TOR for the audit and due diligence of TRL and the preparation of the TRL business plan, respectively. In December 2014, it was decided that these two services would be combined into one, and these tables are based on the combined TOR dated December 2014. Procurement of a consultant to work on these tasks was in process as of December 2015.

The audit and due diligence would include, among other outputs, an assessment of the capability of the existing organization and the review of policies and processes regarding the company's human resources. These tasks are important to formulate a plan for organizational development, which is included in the TRL business plan preparation. The business plan would also include, among other outputs, the assessment of the existing maintenance activities, implications of a new relationship between TRL and RAHCO in infrastructure maintenance, and opportunities in the maintenance business. The division of responsibilities for maintenance activities to be set out in the business plan should be in line with the current plan to transfer the role of infrastructure maintenance from TRL to RAHCO. Setting up an efficient and effective maintenance arrangement will be essential for keeping the rehabilitated infrastructure intact in the medium to long term.

Table 3.9: Summary of TOR for Audit and Due Diligence of TRL

Task Item	Summary Tasks
(1) Diligence on financial aspects	Assess the quality of: • Net assets and funding items, examining key line items in the balance sheet • Financial information including reporting systems and strength of finance function • Cash flows including primary uses/sources of funds in the past • Earnings including non-recurring revenues/expenses, key drivers of earnings
(2) Diligence on commercial and operational aspects	Assess the following: • Commercial processes including contracting with customers, vendors/service providers, and any other partners • Pricing for key cargos and key routes, and competitiveness against road transport • Various operating and technical parameters, and availability of standard documented policies and processes for key functions
(3) Diligence on organizational aspects	• Assess suitability, sufficiency, and capability of the existing organization (structure, staff numbers, and skills and experience) • Review policies and processes for human resources (recruitment, training, strategic planning, marketing and sales, maintenance, logistics planning, etc.)
(4) Diligence on customer aspects	• Assess the quality and sustainability of revenues from key customers (repeat business of key customers, customer stability/concentration, bargaining power/ overall relationship with key customers, cost/benefit for customer acquisition, etc.)
(5) Diligence on service definition	• Assess the suitability of the existing service offerings versus customer requirements and overall market context
(6) Diligence on support services	• Assess the sufficiency of support services (e.g., accounting, human resources, technology, procurement, utilities, and infrastructure) and the management information systems

Source: TOR dated December 2014

Table 3.10: Summary of TOR for Preparation of TRL Business Plan

Task Item	Summary Tasks
(1) Cargo and passenger traffic assessment	• Estimate current and future traffic volumes by market segment • Specifically assess growth in traffic led by service availability • Examine expected demand-supply position for logistics services • Examine the logistics sector in Tanzania and services provided by key stakeholders besides TRL • Assess potential/latent demand and propensity for payment
(2) Customer and competition assessment for freight and passenger operations	• Present the business models and operations of key container logistics operators • Understand key players' business drivers, revenues, and margins • Assess drivers of competitiveness of road-based freight movement and potential for change in the railway sector • Carry out a "total logistics cost" assessment on selected cargos and compare the cost of road vs. rail transport
(3) Infrastructure maintenance	• Assess the existing maintenance activities within TRL and the technical, commercial, and financial relationship between TRL and RAHCO • Clarify the implications of a new relationship based on clear contractual arrangements and new performance-based maintenance programs to be developed by RAHCO • Identify opportunity for TRL to become a player in the rail maintenance sector and the required drivers to optimize this business
(4) Business model options development	• Develop a shortlist of three (3) options regarding competitive rail services, with the maintenance activities to be integrated • For each option, prepare estimated investment requirements, achievable returns, and capabilities required to address the identified opportunities • Facilitate discussions on the options to finalize consensus, and agree with TRL management on the preferred option
(5) Detailed business and financial plan development	The selected business model option will develop into a detailed business plan and financial projections, including: • Revenue, cost and investment projections for rail operation • Operational and financial requirements for track maintenance activity and in-house rolling stock maintenance • Prepare detailed financial projections for initial 3 years of operation, including funding requirements, options for funding mechanisms, and possible sources of funds • Develop a high-level go-to-market approach and operations plan • Suggest an optimal organizational structure with independent business units along with staff numbers, job responsibilities and specific skill sets • Suggest organizational enhancement required for achieving the targets • Develop a high-level outline for tracking, monitoring and evaluation of TRL's performance against the business plan

Source: TOR dated December 2014

The organizational change of TRL has been started, and as of February 2015, MOT has proposed to the cabinet formal registration of TRL as a government institution. It is expected that TRL will continue to be a government-owned operator even after the open access policy is implemented. The importance to strengthen TRL for competing against other potential operators is widely shared by the agencies concerned.

Within TRL, a new organizational structure has been examined, and the Board of Directors approved the introduction of independent six business units (Infrastructure, Rolling Stock, Business Development, Procurement, Finance, and Human Resources Management), each to be headed by a General Manager who will be positioned directly under the Managing Director. With this structure, the organizational layers will be reduced from the current system, bringing closer the top management and the operational levels. At the same time, larger discretionary powers and responsibilities will be given to General Managers, thereby enabling more responsive decision making and operations than before.

3.2.5 Implementation Structure for TIRP

Table 3.11 shows the roles of key stakeholders for the implementation of TIRP. RAHCO is the overall implementing agency (IA) of the project. In order to support, monitor and coordinate the implementation, RAHCO has established a Project Implementation Team (PIT), which is placed within the organizational structure of RAHCO.

Table 3.11: Roles of Key Stakeholders for TIRP Implementation

Key Stakeholders	Roles under TIRP
MOT	• Develop transport policy and undertake overall sector oversight • Establish and administer the TIRP Steering Committee
RAHCO	• Railway asset owner and asset manager • Overall Implementing Agency (IA) of TIRP • Establish a Project Implementation Team (PIT) within RAHCO
TRL	• Government-owned train operator, and track maintenance contractor
SUMATRA	• Railways open-access licensing and regulatory authority
TPA	• As port owner and operator, to be coordinated with for realigning the railway infrastructure within the port
TIRP Steering Committee	• Monitor the development of TIRP • Members include MOT, RAHCO, TRL, SUMATRA, TPA, and CCTTFA.
CCTTFA	• One of the key stakeholders as the Central Corridor transit trade stakeholders' agency, formed and ratified by Tanzania, Burundi, DRC, Rwanda, and Uganda

Abbreviation: CCTTFA = Central Corridor Transit Transport Facilitation Agency
Source: World Bank

The PIT is to consist of: a Project Manager, a Procurement Specialist, a Financial Management/Accounting Specialist, a Rail Operations Specialist, a Rolling Stock Specialist, and Support Staff. These PIT members are recruited individually, with the recruitment process ongoing as of December 2015.

3.2.6 Potential Issues Related to the Project

<This part has been removed because of confidential information.>

3.3 Route and Structures

3.3.1 Route

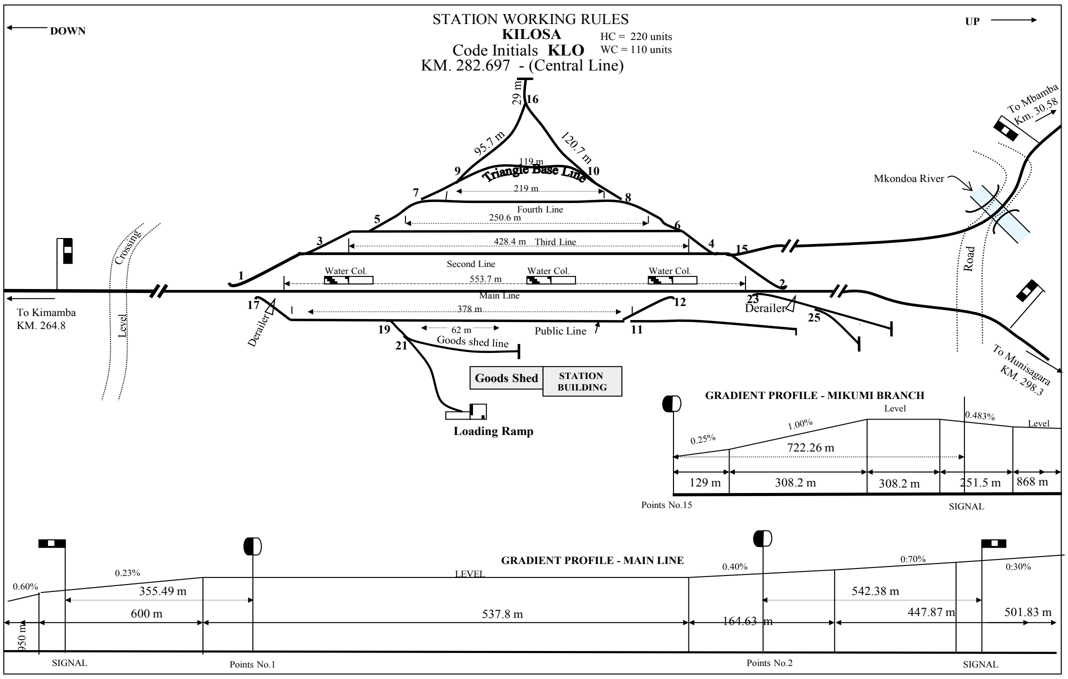
The 174 km-long Kilosa–Dodoma section of the Central Line is single-tracked with 11 stations, with each equipped with a sub-mainline track. The effective length in Table 3.12 indicates the maximum track length in each station yard, with the figure of 374.7 m in the Dodoma station yard is the shortest among those in the station yards along the Kilosa–Dodoma section.

Table 3.12: Particulars of the Stations between Kilosa and Dodoma

Station name		km post (km)	Distance b/w stations (km)	Number of turnout	Effective length (m)
Abb.	**Station name**				
KLO	Kilosa	283	15	19	553.7
MGA	Munisagara	298	13	3	425.0
MZZ	Mzaganza	311	15	4	490.0
KID	Kidete	326	23	6	454.3
GGD	Godegode	349	17	5	418.0
GLW	Gulwe	366	16	6	447.0
MSG	Msagali	382	20	6	493.9
IGD	Igandu	402	24	3	431.0
KBO	Kikombo	426	13	4	431.7
HUA	Ihumwa	439	17	5	487.8
DOM	Dodoma	456	-	38	374.7

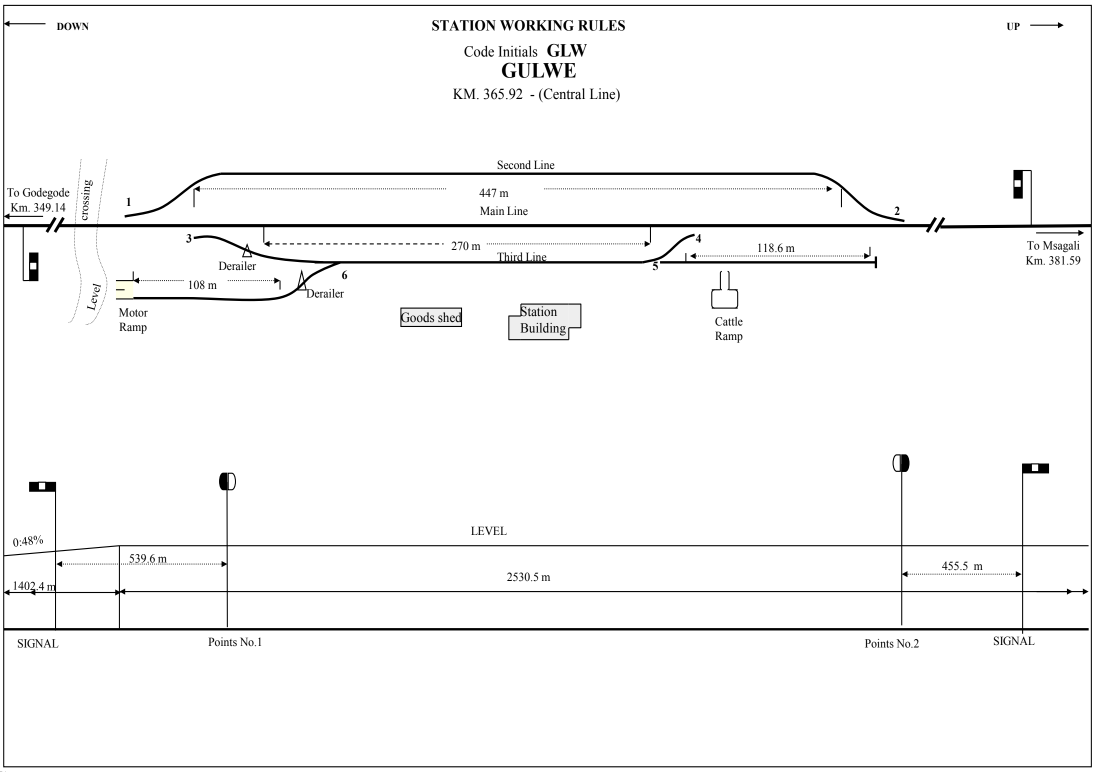
Source: TRL

Figure 3.6, Figure 3.7, and Figure 3.8 represent the track layouts in major station yards along the Kilosa–Dodoma section.



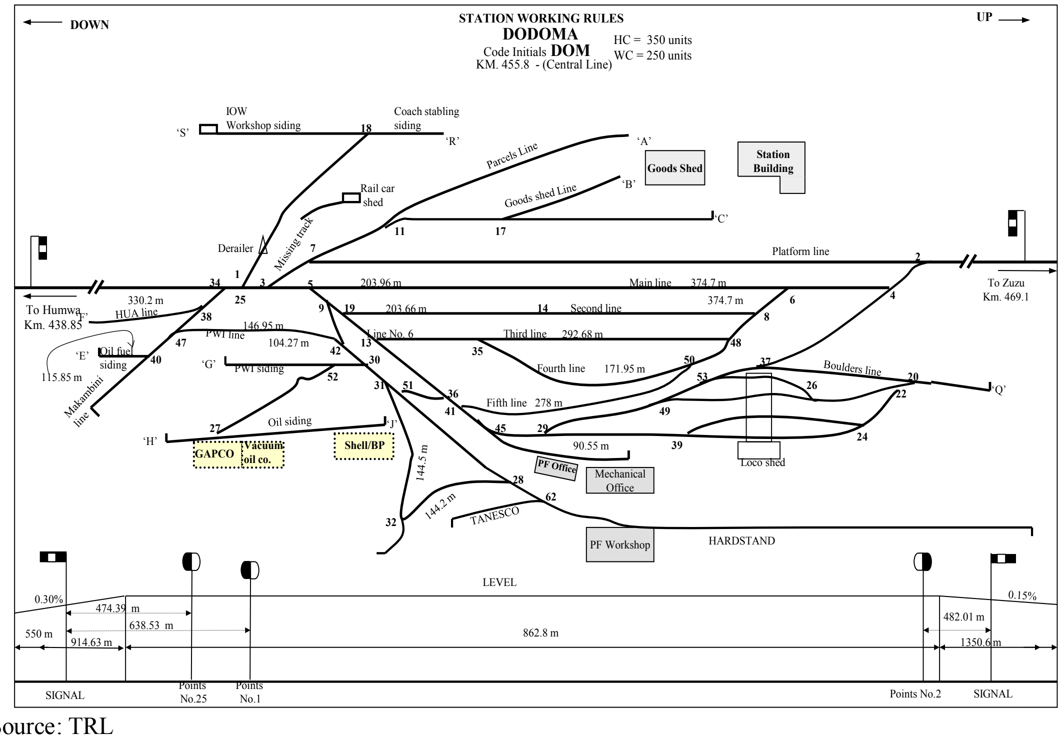
Source: TRL

Figure 3.6: Track Layout, Kilosa Station



Source: TRL

Figure 3.7: Track Layout, Gulwe Station



Source: TRL

Figure 3.8: Track Layout, Dodoma Station

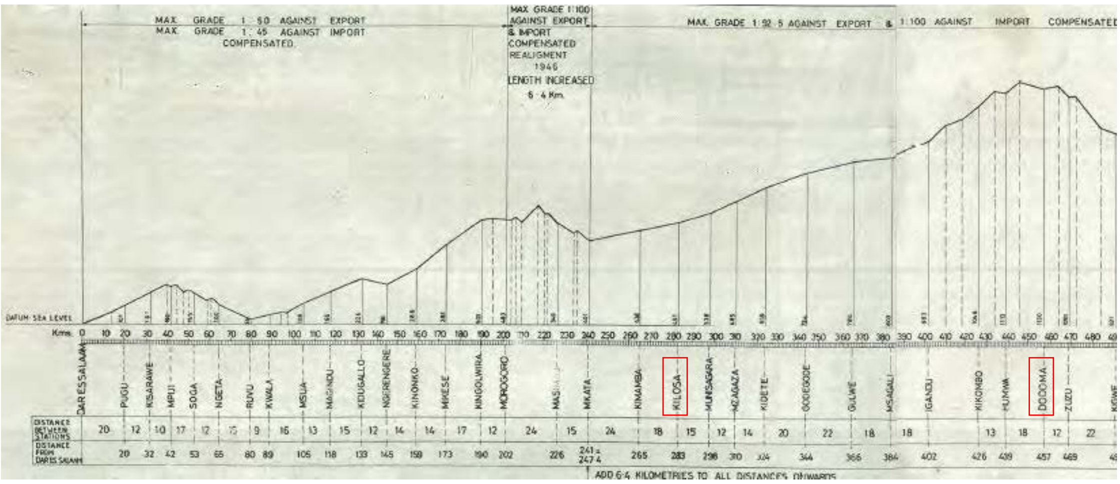
Table 3.13 summarizes the ratio of the lengths of curved sections in the Kilosa–Dodoma section, together with the corresponding figure of the straight portion. The ratio of curved sections is very small according to a relevant ledger, in that curves having a radius of 400 m or less account for only approximately 10% of the total.

Table 3.13: Ratio of Curved Sections between Kilosa and Dodoma

Radius (m)	Length of straight/carve portion (m)	Ratio (%)
R ≦300	1,842	1.1
300<R ≦400	16,478	9.5
400<R ≦600	16,008	9.2
600<R ≦800	6,255	3.6
800<R	24,938	14.4
Straight portion	107,582	62.1

Source: JICA Study Team based on TRL data

Between Kilosa and Dodoma, moderate gradients (less than 5%) are encountered (Figure 3.9). The ruling gradient in the Central Railway Line is 1% except between Makutopora Station (Km 546) and Manyoni Station (Km 585) where the maximum gradient reaches 2.2%. A banking locomotive is stationed at Makutopora for assisting train operation between Makutopora and Aghondi (the station after Manyoni).



Source: TRL

Figure 3.9: Vertical Track Alignment

3.3.2 Structures

(1) Confirmation of Existing Data (from the World Bank Survey)

The Bridge Register was first published in 1996 by TRC, containing overall information of bridges and culverts. In the register, information including bridge and culvert location, year of construction, bridge type, bridge length, embankment height, design axle load, catchment area, opening section diameter, and bridge category (grade) for the entire Central Railway Line is provided. Bridge grades are determined by visual checking as a simple determination measure and classifications range from an “A” grade, which indicates good operating conditions, to an “E” grade, which indicates a necessity for replacement before being used for operations. The register was last updated in 2007. Going forward, the “Inspection and Capacity Rating of Railway Bridges” ongoing under TIRP should be followed closely.

The entire Central Railway Line has 2,192 bridges and culverts, 1,340 of which are located on the Central Line, 227 on the Mwanza Line, and 625 on the other lines. 92% of these bridges and culverts have a design axle load of 15 tons or less. Focusing on the Central Line only, 65% have a design axle load of 10 tons (built during the German colonial era) and 25% have a design axle load of 11-18 tons (built during the British colonial era). The remaining 10% have a design axle load of 25 tons (built from 1990 onwards in bridge renovation projects financed by the German development cooperation through KfW). As for the span of structures on the Central Line, 70.6% are 2-5m, 18.6% are 5-15m, and 6.3% are over 15m.

(2) Railway Structures in Proximity to the Wami River and Tributaries

From Kilosa to 14 km past Gulwe (a 97 km stretch), the railway is laid parallel to the Wami River. Most of the tracks are placed on low ground on embankments several tens of meters away from the river area. Moreover, the railway crosses tributaries of the Wami River, and bridges are placed at locations of relatively wide river width. Bridge types include steel truss (Figure 3.10), steel deck girder (Figure 3.11) and steel through girder (Figure 3.12). There is no concrete girder with a long span. These girders are all simple girders and none are continuous girders.

At locations of small scale water flow, culverts are used for passing water under the railway. Culvert types are box type (Figure 3.13), circular type (Figure 3.14), and arched type (Figure 3.15). Culvert building material includes concrete, concrete blocks, and corrugated pipes.

Source: JICA Study Team

Figure 3.10: Truss Bridge (Km 325)

Source: JICA Study Team

Figure 3.11: Steel Girder Bridge (Km 292)

Source: JICA Study Team

Figure 3.12: Steel through Bridge (Km 293)

Source: JICA Study Team

Figure 3.13: Box Culvert (Km 359)

Source: JICA Study Team

Figure 3.14: Circular Culvert (Km 349)

Source: JICA Study Team

Figure 3.15: Arched Culvert (Km 410)

(3) Adverse Effects of Anticipated Running Water on Railway Structures

Based on the site survey done in December 2014, the Study Team found that the following concerns exist for the railway structures due to anticipated running water and/or flooding.

Culvert Clogging

Culverts frequently become clogged with sand carried by running water (Figure 3.13 above). When a culvert becomes clogged, running water crossing under the track stops, causing overflows and/or backwater flows. When running water hits an embankment slope, the embankment will be eroded, causing a higher possibility of embankment destruction, to be mentioned below. Moreover, backwater around a culvert causes water penetration into the embankment, reducing its strength.

Embankment Destruction

If an embankment supporting a track is destroyed, railway operations will be stopped for a long period. In the site survey, the Study Team found several places where the risk of embankment destruction is high due to erosion from running water. In many places, running water hits embankment slopes beside culverts and bridges (Source: JICA Study Team
Figure 3.16). Embankment destruction may possibly occur at those places in the future.

Source: JICA Study Team

Figure 3.16: Embankment Erosion by Running Water (Km 410)

Bridge Destruction

If a bridge supporting a track is destroyed, railway operations will be stopped for a long period. In the site survey, the Study Team found several places where bridges are exposed to high risk of destruction due to running water. Source: JICA Study Team

Figure 3.17 shows a small clearance between the river water level and the soffit of the bridge girder, and this presents a possibility of the bridge being washed away when water levels rise. It is necessary to confirm the height of under the girder, and high water marks will be verified in the course of future investigations.

Source: JICA Study Team

Figure 3.17: Danger Point of the Bridge Destruction (Km 293)

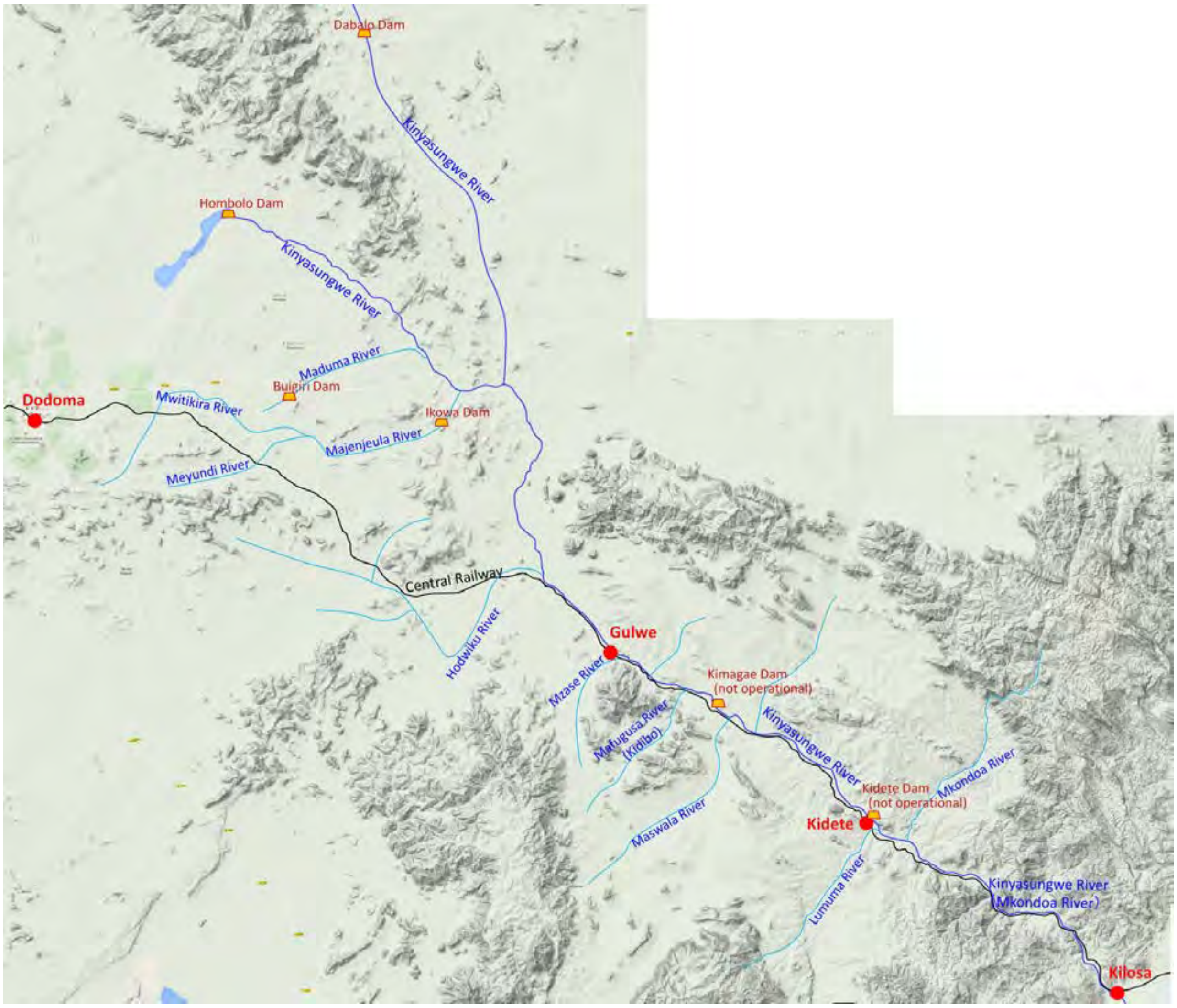
3.4 Flood Damages and Disaster Response

3.4.1 The Kilosa–Dodoma Section

Because the railway between Kilosa and Dodoma was constructed along the Kinyasungwe/Mkondoa River, the railway has been damaged by a number of floods in the past, such as the floods in 1962, 1968, 1992, 1997/1998, 2009/2010, 2011, 2014, etc.

The topographical features of the Kilosa–Dodoma section are shown in Figure 3.18.

Kilosa (Km 283)–Kidete (Km 326):	Route in parallel close to the Kinyasungwe River, in the valley
Kidete (Km 326)–Gulwe (Km366):	Route in parallel close to the Kinyasungwe River in the region of gentle slope (three large-scale tributaries crossing the railway)
Gulwe (Km 366)–Msagali (Km 382):	Route in parallel close to the Kinyasungwe River in the region of gentle slope
Msagali (Km 382)–Dodoma (Km 456):	Route in the region of gentle slope (three tributaries crossing the railway)



Source: JICA Study Team

Figure 3.18: The Kilosa–Gulwe Section with Mainstream and Tributaries

3.4.2 Hydrological and Hydraulic Impact to the Damage of Railway Infrastructure

Historical records of daily rainfall collected from the Wami/Ruvu Basin Water Office (WRBWO) and Tanzania Meteorological Agency (and other agencies) were preliminarily assessed to examine the relationship of rainfall intensity/amount to flood damage of railway infrastructure.

Those rainfall events almost directly coincided with the instances of large-scale damage to the existing railway facilities in the target areas. After the damages occurred, investigations were conducted and a series of countermeasures were recommended and implemented. However, although those countermeasures were conducted mostly as recommended, those countermeasures can be categorized as “urgent restoration works”, and were not long-term/ sustainable solutions. This was due to both time constraints and funding constraints. Although countermeasure works were continuously conducted, perennial, large-scale flood damages to the railways have not been eliminated.

It is important to note whether or not the hydrological and/or hydraulic impacts were properly or substantially examined after major flooding events. Therefore, the JICA Study was focused on updated data-oriented studies, coupled with modern remote sensing technology, to verify the hydrological phenomena and flood characteristics in the Wami River basin and its tributaries.

Additionally, in the past, there had not been comprehensive sediment-related analyses, such as analyses of the yield rate of the terrain, the material composition, transportation, deposition and lateral erosion mechanisms, etc. Therefore, the JICA Study Team conducted field reconnaissance in the upstream areas to confirm present land use and land cover conditions, because those factors in particular affect the sediment yield and volume of sediment discharge to the downstream reaches, toward Msagali–Gulwe.

The results of hydrological studies are presented in Chapter 6 and those of sediment transport and deposition are presented in Chapter 7.

3.4.3 Current Status of Kidete Dam (Construction Works Suspended)

(1) Location of Kidete Dam (Existing)

The Kidete Dam is located at S 63° 8’ 16” and E 36° 42’ 12”, around 500 m upstream of Kidete (village), along the Kinyasinguwe River. Some principal information about the dam is presented below:

- Dam type: Homogeneous fill type dam (without core)
- Objective: Irrigation, water supply and flood control (added later, as a design change)
- Principal dimensions (approximate, to be confirmed): height: 25 m; crest length: 200 m; length along the base: 150 m

(2) Background of Construction

Before construction of the existing Kidete Dam, the Gombo Dam was constructed just downstream side of the existing one in 1940. However, in November 1997, flood flow overtopped the dam crest and embankment material was washed away downstream. Due to this dam failure, the river stretches between Kidete and Kilosa have been heavily damaged. According to an MOT engineer, it took more than eight months to complete the restoration works of the railway facilities.

After this, the construction of the new dam (the existing Kidete Dam) started in November 2010, by the local government of Kilosa District, financed by the central Government of Tanzania (through the MOW). Design and construction were conducted by ENV Consultant, Ltd., and HAINAN International Limited, respectively.

However, construction works were initially suspended during the rainy season in October 2013, and now construction has stopped completely due to budget constraints. In the course of the construction of embankment, the construction materials were washed away by floods several times because of insufficient dewatering measures at the site (there was no coffer dam, for example).

(3) Current Conditions

In accordance with the engineer in charge of the Kilosa District Office, a meeting was held in Morogoro in January 2015 to discuss the resumption of construction works of the Kidete Dam by MOW. However, key issues, such as the source of project finance, and an organizational set-up for implementation, etc., were not yet decided.

(4) Effects on the Central Railway

The condition of the Mkondoa River upstream and downstream of the Kidete Dam differs greatly, if the dam were to exist. If it did, there would be a back sand effect in certain river stretches upstream of the dam. On the contrary, due to the trapping of sediment material at the reservoir, a degradation trend would govern the river regime downstream of the dam. This phenomenon will affect the hydraulic conditions to be set for flood protection measures.

3.4.4 Records of Flood Disasters

(1) Flood Damage in 1997/1998

During December 1997 and January 1998, unseasonably heavy rains caused extensive damages to the Central Railway Line, especially the Kilosa–Kidete section, which suffered major washaways at 16 locations, as shown in Table 3.14.

Table 3.14: 16 Locations Damaged by Floods between Kilosa and Kidete, 1997/98

No.	Kilometerage (km)	No.	Kilometerage (km)	No.	Kilometerage (km)
1	283.3 – 283.6 (300 m)	7	293.4 – 293.9	13	306.9 – 307.2
2	288.3 – 283.7 (400 m)	8	297.3 – 297.4	14	308.9 – 308.97
3	289.8 – 289.9 (100 m)	9	301.8 – 302.2	15	314.2 – 315.0
4	290.2 – 290.7 (500 m)	10	302.5 – 303.1	16	bridge area around Kilosa
5	292.3 – 292.7 (400 m)	11	303.8 – 304.2		
6	293.0 – 293.2	12	305.3 – 305.34		

Source:Tanzania Railway Restructuring Project IDA CR 2267 T.A., Emergency Assistance for Flood Damage "Assessment of Flood damages on Railway Line between Kilosa and Kidete", March 1998. (Appendix B)

According to the "Report on Preliminary Investigations on the Impact of Mkondoa river Floods in Kilosa District", September 2002, President's Office for Regional Administration and Local Government (PORALG), the Kidete Dam was washed away between the 10th and 15th of January 1998. The flood wave after the failure of Kidete Dam caused a scouring of the riverbed, lowering the riverbed levels between 4 and 5 meters below the previous riverbed. This substantial deepening of the Kinyasungwe River resulted in erosion in the downstream areas, including at the Lumuma Bridge, which is located 50 m from the Kinyasungwe River, near Kidete Station.

Downstream of this, at the Lumuma Bridge, existing protection measures were scoured, gabions were washed away, and the sheet piles protecting the bridge abutments were heavily damaged. Immediately after the damages, TRC installed temporary measures to protect the bridge abutments using boulders, but in early 2001, permanent protective measures were taken, in the form of construction of stepped gabion walls in the riverbanks, as well as gabion mattresses in the riverbed to stop further erosion. The work was completed in August 2001.

The report also includes the drainage system of the Kinyasungwe–Mkondoa River, as described below:

- There were six regulatory reservoirs: Dabalo, Hombolo, Ikowa, Buigiri, Kimagae and Kidete (Table 3.15).
- The main aim of the reservoirs were to supply water to the population, provide or livestock watering and dripping, and occasionally for fishing. There was also the intangible benefit of river regulation by the existence of the reservoirs.

Table 3.15: Outline of Six Reservoirs

No.	Name	Background of dam/reservoir	Map (Google map)
1	Dabalo	Location: (Google Map) Latitude 5^0 80' Longitude 36^0 11' Elevation 1,032 m Dam construction: 1961 Catchment area : n/a Current status : Operational in 2002	
2	Hombolo	Location: (Google Map) Latitude 5^0 95' Longitude 35^0 96' Elevation 1,053 m Dam construction: 1957 Catchment area : 1,684 km^2 Current status : Sedimentation on-going	
3	Ikowa	Location: (Google Map) Latitude 6^0 19' Longitude 36^0 22' Elevation 916 m Dam construction: 1957 Catchment area : 466 km^2 Current status : Operational in 2002	
4	Buigiri	Location: (Google Map) Latitude 6^0 15' Longitude 36^0 03' Elevation 1,005 m Dam construction: 1960 Catchment area : 10.36 km^2 Current status : Operational in 2002	
5	Kimagae	Location: (Google Map) Latitude 6^0 50' Longitude 36^0 52' Elevation 751 m Dam construction: 1960 Catchment area : n/a Surface area : 2.25 km^2 Current status : Collapsed in 1955/1956	
6	Kidete	Location: (Google Map) Latitude 6^0 63' Longitude 36^0 70' Elevation 667 m Dam construction: 1960 Catchment area : not more than 15,000 km^2 Surface area : 0.52 km^2 Current status : Washed away in Jan.1998	

(2) Flood Damage in December 2009–January 2010

In the Morogoro Region, flooding occurred from 26 December 2009 (especially in Kilosa District), due to heavy rainfall on 25 December 2009 in the Dodoma Region (in the Mpwapwa and Kongwa Districts). The 24-hour rainfall at Dodoma was recorded at 107 mm, which is the highest amount since 1948 (67 years ago). This is compared to the normal annual rainfall in the Dodoma Region of 600 mm. This distinct rainfall resulted overtopping along the Mkondoa River and caused serious flooding in many wards downstream of Kilosa. The damage was widespread, and included the destruction of residential houses, infrastructure, public services and farms, etc.

In terms of damage to railway facilities, a total of 2.1 km of railway line between Kilosa and Gulwe were devastated, due to embankment damages, as listed in Table 3.16.

Table 3.16: Affected Railway Section by Flood January 2009–January 2010

Railway Section	Length (m)	Embankment Damage
Kilosa – Munisagara	100	100 m of 3 m height embankment washed away
Munisagara – Mzaganza	1,200	120 m of 3 m height embankment washed away
Mzaganza – Kidete	300	300 m of 9 m height embankment washed away
Kidete – Godegode	300	300 m of 7.5 m height embankment washed away
Godegode – Gulwe	200	200 m of 3 m height embankment washed away
Total	2,100	

Source: "Report on Assessment of Disaster Caused by Flood in Kilosa District and to Restore Previously Situation and to Avoid it to Happen Again", 15 March 2010, Prime Minister's Office with Assistance of Ardhu University

Major repairs were needed to restore the rail to its normal condition. The Ministry of Infrastructure, in collaboration with the Army of the People of Tanzania, rehabilitated the affected area. However, during the course of rehabilitation works, there was a shortage of resources and lack of locally-available tools. Therefore, the rehabilitation resulted mostly in the emergency restoration of the damaged section.

(3) Flood Records in the Kilosa–Dodoma Section, 2011–2014

A record of floods in the Kilosa–Dodoma section of railway from 2011 to 2014 appears in Appendix A, and a summary of records is indicated in Table 3.17.

Table 3.17: Records of Floods in the Kilosa–Dodoma Section, 2011–2014

	Number of Floods			Duration of Closing the Line (hour: min.)		
Year	Kilosa–Gulwe	Gulwe–Dodoma	Total	Kilosa–Gulwe	Gulwe–Dodoma	Total
2014	16	4	20	222:33	22:55	245:28
2013	7	3	10	66:40	13:35	80:15
2012	2	1	3	207:00	3:00	210:00
2011	6	1	7	252:00	1:00	253:00
Total	31	9	40	748:13	40:30	788:43
(%)	77.5	22.5	100.0	94.9	5.1	100.0

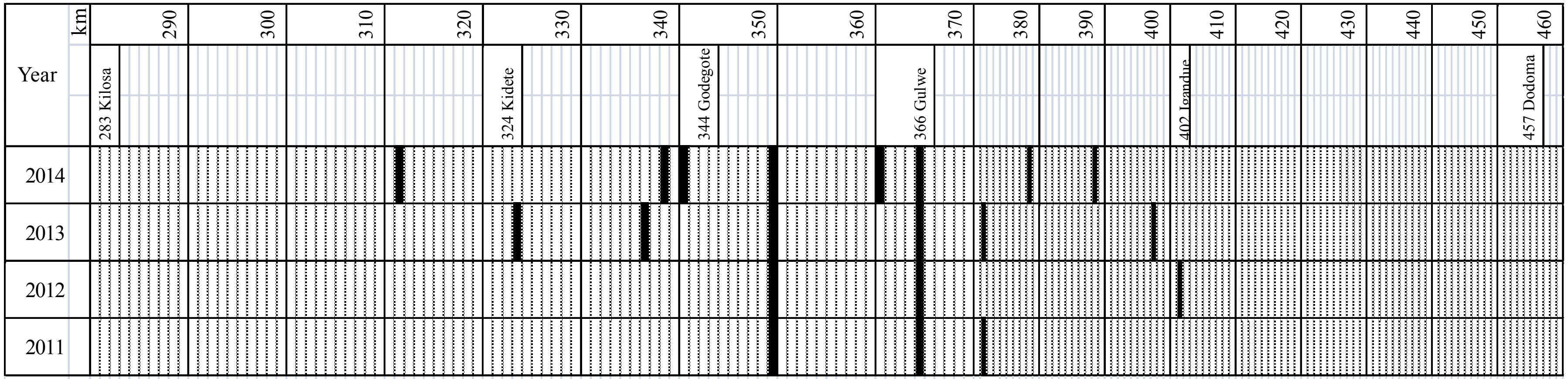
Source: TRL.

The table clearly shows that the extent of flood damages in the Kilosa–Gulwe section is more significant than that of the Gulwe–Dodoma section. The total number of floods for 2011–2014 in the Kilosa–Gulwe and Gulwe–Dodoma are 31 (77.5%) and 9 (22.5%), respectively. In terms of duration line closure, the Kilosa–Gulwe flood damages correspond to 748 hours and 13 minutes (94.9%) in total delays, while those in the Gulwe–Dodoma section account for a mere 40 hours and 30 minutes (5.1%).

Table 3.18 shows the distribution and number of flood disasters in the Kilosa–Dodoma section for 2011–2014. Among a total of 40 floods in 2011–2014, flood disasters occurred many times in two specific locations: at Km 349 (Maswara River section, 12 flood disasters) and at Km 365.6 (Mzase River section, 10 flood disasters). The former accounts for 30.0% and the latter 25.0% of the total number of flood occurrences. These two sections receive floods every year.

Beside those two locations, other locations that have received multiple flood disasters are Km 324/5–6, Km 360/1–3, Km 372/4–6.5, Km 378/4–5, Km 388/6, and Km 397/5–7 (flood disasters took place twice in 2011–2014 in these locations).

Table 3.18: Distribution and Number of Flood Disasters in the Kilosa–Dodoma Section, 2011–2014



Year															Total
2014	1			1	1	1	6	2	4		2	2			20
2013		2	1				3		1	1			2		10
2012							1		1					1	3
2011							2		4	1					7
Total	1	2	1	1	1	1	12	2	10	2	2	2	2	1	40

Source: TRL

3.4.5 Studies and Protection/Restoration Works in the Past

(1) Past Flood Studies and Protection/Restoration Works

Every time the railway was damaged, a great deal of repair works and protection works were conducted, such as the re-routing the track, replacement of bridges, expansion of cross drainages, excavation and re-alignment of the river channels, gabion works, etc. These were part of several flood restoration works programs, carried out with the participation of international consulting firms. There were three major studies and corresponding protection/restoration works conducted in the past. These are shown in Table 3.19, and detailed descriptions are included in Appendix B.

Table 3.19: Three Flood Studies and Protection/Restoration Works

Task Name	Sponsor/Consultants	Outline of the activities
Flood prevention Works on TRC Central Line Contract Nr 3806 Additional Works April 1997 (Hereinafter, this report is called "the Mott Mac Report")	<u>Sponsor:</u> The Commission of the European Communities <u>Consultants:</u> Mott MacDonald in association with Inter-Consult Ltd.	As part of a strategy to improve cross-drainages of the Central Line, the European Union (EU) funded improvement works between Kilosa and Gulwe. This Additional Works focused on Km 288, Km 315, Km 349, Km 355 and Km 365. The works included topographic/soils survey, design and cost estimate. (Construction Measures) • Excavation and re-alignment of the river channel under the track • Gabion works/ geotechtile works • Track raising at Maswala • Additional cross drainages (culverts) • Sheet piling at Kidibo • Further river training at Mzase • Catchment Management Planning & implementation at Mzase
Tanzania Railway Restructuring Project IDA CR 2267 T.A.: Emergency Assistance for Flood Damage "Assessment of Flood Damages on Railway Line between Kilosa and Kidete" March 1998 (Hereinafter, this report is called "the Gauff Report")	<u>Sponsor:</u> World Bank (IDA) (US$3 million) <u>Consultants:</u> Gauff Ingenieure Consulting Engineers and DE-Consult	During Dec. 1997 and Jan. 1998, unseasonably heavy rains occurred. This caused a lot of damage to the Central Railway, especially the section between Kilosa and Kidete. This Project inspected the damages and proposed the actions, including conceptual design and bill of quantities, focusing on the 15 sections below: 1) Km 283.6 (300 m) 2) Km 288.4 (300 m) 3) Km 289.9 (100 m) 4) Km 290.3 (400 m) 5) Km 292.3 (350 m) 6) Km 293.1 (60 m) 7) Km 293.4 (500 km) 8) Km 297.3 (80 m) 9) Km 301.8 (300 m) 10) Km 302.5 (500 m) 11) Km 303.8 (400 m) 12) Km 305.3 (30 m) 13) Km 306.9 (200m) 14) Km 308.9 (60 m) 15) Km 314.2 (450 m) (Construction Measures) • Re-construction of embankment • Re-routing of the track • Temporary drainage structures • Protection measures, such as gabions, rip rap, etc.

Task Name	Sponsor/Consultants	Outline of the activities
Railway Restructuring Project (RRP) IDA CR 2267 T. A: Design and Supervision of Permanent Structures and River Training Works on Kilosa–Kidete Section (Contract No. 029811) December 1999 (Hereinafter, this report is called "the WSP Report")	Sponsor: World Bank (IDA) Consultants: WSP international (UK) in association with Ambicon Engineering	• Review of the reports below: • The 1998 Gauff/DE-Consult Report (1) • The following 1998 COWI Report (2) • Inspections of the existing 144 structures • Hydrology and hydraulic study • Scour protection • Detailed design • Cost estimate • Environmental Management Plan (construction measures) • River training works • Cross drainage pipe culverts • Additional culverts

Source: JICA Study Team

Mott Mac Report, 1997

This work was conducted before the railway received great flood damages in December 1997 and January 1998. The report proposed railway protection measures for the five locations where flood damages were a concern. Therefore, the contents of the proposed measures were urgent protection measures for limited sections of track, not an inclusive package of the necessary sustainable/long-term flood protection measures.

A noteworthy element of the report is that at the time the floods from the tributaries had been identified, due to deforestation and vegetation decrease from an increase in agricultural land development and pastoral uses, that the water velocity and quantity had been increasing at that time.

Gauff Report, 1998

The Gauff Report was launched with funds from the World Bank, shortly after great flood damages occurred in December 1997 and January1998.

This report inspected and proposed the protection measures for the 15 sections between Kilosa and Kidete, which were damaged by the floods in December 1997 and January 1998. To date, some of the proposed measures have been implemented, such as the relocation and construction of a new bridge at Km 303.4.

WSP Report, 1999

This work consisted of reviewing the Gauff Report, conducting a hydrology and hydraulic study, conducting inspections of 144 structures, and detailed designing of the protection measures between Kilosa and Kidete. However, the protection measures were also urgent protection measures, not sustainable/long-term flood protection measures, because of budget constraints. The report mentioned that: "[w]hile it is considered very unlikely that 100% access to the Kilosa to Kidete line can be achieved in terms of flood risk, at least at acceptable economic cost, it is considered that various measures can be undertaken to reduce both the risk of closure and the cost of damage."

Regarding the aforementioned flood protection works, the following points are of note:

- The consultants in charge of flood protection measures understood that "railway route relocation must be required for full-fledged flood measures.

- However, urgent protection measures, not including all of the necessary sustainable flood protection measures, were not carried out due to budget constraints.

Hydrological Characteristics of Flood Damages Indicated by Past Reports

The Mott Mac report proposed major protection works at five locations, namely at Km 288 (Mkadage Bridge), Km 315.6 (gully erosion), Km 349 (4b & 4c Maswala cross drainage), Km 355 (Kidibo River crossing), and Km 365 (Mzase crossing).

The Gauff Report and WSP Report both focused on the December 1997/January 1998 flood event. Among the flood damage experience past three decades, this event might be most serious one in terms of the stretches between Kidete and Kilosa. It should be noted that the damage would have been amplified by flood waves created by the failure of the Kidete Dam (Clause 3.6.2). Therefore, the relationship between external forces of hydrological parameters and flood damages to the railway shall be carefully examined.

Finally, the previously mentioned "Report on Assessment of Disaster Caused by Flood in Kilosa District and to Restore Previously Situation and to Avoid it to Happen Again" investigated the 2009/2010 flood. (This report was written originally in Swahili.) It notes that Kilosa town was hit heavily by the swollen Mkondoa River between December 2009 and January 2010.

(2) Temporary Urgent Protection Works in December 2014

During the first site investigation by the JICA Study Team in December 2014, the Team observed the temporary urgent protection works conducted by TRL at the sections railway between Km 302 and Km 315. It was very impressive that the construction works by the TRL employees, who live along the railway and work as the track maintenance gang, were well-organized and performed quickly under a limited budget. The details of these works are shown in Appendix C, and the following are works observed in Km 302.6–302.8 and Km 315.

Km 302.6–Km302.8

The track of this section was washed away on 30 March 2014.

In December 2014, to prepare for the protection against the coming rainy season, the temporary urgent protection work was conducted. The work included land filling and gabion works along the riverbank.

16 December 2014 (Toward Kidete)

Km 315

The erosion of the riverbank was very close to the track.

In early December 2014, to prepare for the protection against the coming rainy season, the track was re-routed toward the mountain side (max. 18 m diversion).

On 18 December 2014, the trial run was conducted successfully.

1 December 2014 (Toward Kidete)

(3) Temporally Remedy Works in the Past

The major temporary remedial works between Kilosa and Dodoma conducted by TRC and RAHCO/TRL are as follows (detailed in Appendix C).

- Re-routing of track
- Excavation and re-alignment of the stream channels crossing the track
- Excavation of the river channel and forming of embankments
- Gabion works along riverbanks, riverbed, and ballast
- Construction of a new bridge with longer span
- Repair of bridge abutments
- Replenishment of ballast
- Improvement of cross drainage
- Re-routing the Mafugusa River and the Mzase river
- Sheet piling with anchor bolts to protect the riverbanks at Kidibo
- Track raising by ballast (25 cm)
- Replacement of collapsed culverts
- Excavation of drainage trenches

3.4.6 Present Situation

(1) Outline of the Current Status of the Kilosa-Dodoma Section

The Study Team conducted an investigation of the current status of the section between Kilosa and Dodoma in the first site survey in December 2014. The outline of the current status of each section is shown in Appendix D. The investigation identified three different patterns of flood-induced damages to the railway between Kilosa and Dodoma.

Pattern 1: Flood damages from the main stream (Kinyasungwe River)
Pattern 2: Flood damages from the tributaries and/or slopes of mountains along the railway, due to inadequate cross drainage
Pattern 3: Submergence of the track by the floodwaters from the main stream and/or tributaries/ slopes of mountains, due to inadequate drainage along the railway

The explanation of damage patterns and photo as an example are shown in Table 3.20.

Table 3.20: Damage Patterns and Examples

Pattern 1: Flood damages from the main stream (Kinyasungwe River)

Pattern 1-1: Washaway and/or scouring of bridges foundations. An example at Km 293

Pattern 1-2: Erosion of the track embankment. An example at Km 299.5

An example at Km 337.4, 6 March 2015

Pattern 1-3: Washaway of the track and/or water/mud flowing over the track

An example at Km 302 (toward Kilosa)
The track was washed away by the flood.

An example at Km 331 (toward Gulwe)
The ballast was damaged by the flood.

Pattern 2: Flood damages from the tributaries and/or slopes of mountains along the railway, due to inadequate cross drainage

Pattern 2-1: Damage of the surface of the track by the floodwaters overtopping the track

An example at Km 337.1 (toward Gulwe)
Overtopping flood damaged the track.

An example at Km 365 (Mzase River)
The track on the bridge was washed away.

Km 349 (4B - 7C) Maswala Section
Overtopping flood damaged the track.

Pattern 2-2: Damage of the track embankment
An example at Km 378.5

Pattern 3: Submergence of the track by the floodwaters from the main stream and/or tributaries/slopes of mountains, due to inadequate drainage along the railway

An Example of at Km 363 (toward Gulwe)
・Image of submergence of the track

Table 3.21 shows the outline of the section between Kilosa and Dodoma observed during the first Site Survey (see details in Appendix D).

Table 3.21: Outline of the Kilosa–Dodoma Section, 1st Site Survey, Dec. 2014

Location (km)	Pattern of Damage	Flood Protection Works in the past	Possible Flood Protection Measures	Priority for Flood Protection
283 – Kilosa – 293.6	2-1 2-2	• Re-routing • Excavation and re-alignment of the stream channels crossing the track • Gabion works	• Sustainable excavation of the stream channels crossing the track	Low
293.6	1-1 1-2	• A new bridge with a longer span was constructed in 2014, as the old bridge was washed away in 2010. • Gabion works	• Expansion of the bridge • Additional gabion works to protect riverbank • Sustainable excavation of the riverbed	Medium
293.6 – 303.4	1-2 1-3	Restoration of the track washed away	• Re-routing toward mountain side • Track raising by embankment • Protection from the erosion of the riverbank	Medium – High
303.4 – 311.8	1-1, 1-2, 1-3, 2-1, 2-2	• Restoration of the track washed away Note: A new bridge at Km 303.8 was constructed at the mountain side in 2014	• Protection from the erosion of the riverbank, etc.	Low – Medium
311.8 – 317.7	1-2 1-3	• Restoration of the track washed away Note: The track around Km 315 was shifted toward the mountain side (Max. 18 m) in December 2014	• Re-routing toward mountain side • Track raising by embankment • Protection from the erosion of the riverbank • River training works	Medium – High
317.7 - 328.0	1-3, 2-1, 2-2	• Removal of boulders washed away by floods at Km 324/5-6	• Protection from the erosion of the riverbank • Improvement of cross drainage	Low
328.0	1-2	Note: The erosion of the riverbank is close to the track	• Protection from the erosion of the riverbank	Medium
328.0 – 337.1	1-2 1-3	• Restoration of the track washed away • Repair of the ballast damaged by flood overtopping • Improvement of cross drainage	• Protection from the erosion of the riverbank, etc. • Improvement of cross drainage • Track raising	Low

Location (km)	Pattern of Damage	Flood Protection Works in the past	Possible Flood Protection Measures	Priority for Flood Protection
337.1	2-1 2-2	• Repair of the ballast, many times a year • Improvement of cross drainage	• Improvement of cross drainage • Track raising	Medium
337.1 – 337.8	1-2	• The riverbank was washed away on 6 March 2015. • The re-routing & protection of riverbank is on-going.	• Protection of the erosion of the riverbank, etc. • Re-routing the track	High
337.8 – 340.8	2-1 2-2 1-3	• Repair of the ballast, many times a year	• Improvement of cross drainage • Track raising • Protection of the erosion of the riverbank	Low – Medium
340.8 – 349.8c	1-3, 2-1, 2-2	• Restoration of the track washed away • Improvement of cross drainage	• Improvement of cross drainage • Track raising • Protection of the erosion of the riverbank	Low – High
349.8c – 350.0	1-3 2-1	• Excavation of the stream channels crossing the track • Gabion works • Improvement of cross drainage • Repair of the ballast	• Re-routing the track toward mountain side • Protection of the erosion of riverbank • Improvement of cross drainage • Sustainable excavation of the stream channel crossing the track	Low – High
350.0 – 355.1	2-1		• Improvement of cross drainage	Low
355.1 Mafugusa River. Kidibo Bridge	2-1 2-2	• Re-routing the Mafugusa River • Excavation of the river channel and forming embankment • Sheet piling with anchor bolts to protect the riverbanks • Gabion works	• Re-routing the track • Track raising • Protection of the erosion of riverbank • Improvement of cross drainage • Sustainable excavation of the stream channel crossing the track	Medium
355.1 – 360.8	1-2 2-1	• Re-routing the Mafugusa River • Gobion works • Restoration of the track washed away at Km 360.1, etc.	• Re-routing the track • Track raising • Protection of the erosion of the tributary bank, etc. • Improvement of cross drainage • Sustainable excavation of the stream channel crossing the track	Medium

Location (km)	Pattern of Damage	Flood Protection Works in the past	Possible Flood Protection Measures	Priority for Flood Protection
360.8 – 364.2	3	• Track raising by ballast (25 cm) to avoid submergence of the track	• Improvement of cross drainage • Improvement of drainage to avoid submergence of the track	Medium
364.2 – 365.7	2-1	• Excavation of the river channel	• Improvement of cross drainage	Low
365.7 Mzase River	2-1	• The ballast was solidified with cement, as the track on the Mzase Bridge was washed away on 30 March 2014 • Gabion works	• Re-routing the track toward mountain side • Tack raising	High
366.0 Gulwe Station	2-1	(Sometimes, if the space under the bridge is full of mud, Gulwe Station is flooded) • Restoration of the track washed away	• Relocation of the station toward mountain side	Low – Medium
366 – 367	1-2 2-1	A new road was constructed over Kinyasungwe River at Km 366.4 in 2014	• Protection of the track against the flood. Note: due to the new road bridge having very inadequate drainage, the track will likely be flooded in the future	Medium
367 – 380.0	1-2	• Improvement of cross drainage • Repair of the track embankment	• Improvement of cross drainage • Track raising	Low
380.0 – 385.0	2-1 2-2	• Improvement of cross drainage	• Improvement of cross drainage	Low
385.0 Hodwiku River	2-1 2-2	• Improvement of cross drainage	• Gabion works, etc. to protect the bridge against erosion	Low
385.0 – 403.0	2-1 2-2	• Protection works of the ballast • Improvement of cross drainage, incl. replacement of collapsed culverts • Gabion works • Excavation of drainage trench • Repair of the ballast • Repair of bridge abutment • Restoration of the track washed away, etc.	• Improvement of cross drainage	Low

Location (km)	Pattern of Damage	Flood Protection Works in the past	Possible Flood Protection Measures	Priority for Flood Protection
403.0 – 415.0 Hodwiku River Igandu	2-1 2-2	• Excavation and of the stream channels crossing the track • Gabion works • Improvement of cross drainage • Repair of the ballast	• Re-routing the track toward mountain side • Tack raising	Low – Medium
415.0 – 426.0	2-2	• Improvement of cross drainage • Gabion works	• Improvement of cross drainage	Low
426.0	2-1 2-2	Meyundi River	• Gabion works, etc. to protect the bridge against erosion	Low
426.0 – 440.0	2-1		• Improvement of drainage along the track	Low
440.0 Ihumwa	2-1 2-2	Mwitikira River	• Improvement of drainage along the track	Low
440.0 – 455.0	2-1		• Improvement of drainage along the track	Low
455.8	2-1	Dodoma	• Improvement of drainage along the track	Low

Note: The priorities (low, medium, and high) for flood protection was set based on (i) the photos taken in the field surveys (for the difference in height between the water level and the rail level), and (ii) the high-resolution color aerial photos taken in March/April 2015, and (iii) the topographical maps with 2.0 m contours (outputs from the aerial survey).
Source: JICA Study Team

From Table 3.21 and Appendix D, Table 3.22 is produced, and showing that:

- The sections in which damage is a concern classified by Medium/High Concern are all located between Kilosa and Gulwe, except at Km 403 (Igandu) where the damages of pattern 2-1 and 2-2 are of Medium concern.
- The total length of the sections of Medium/High concern is approximately 55 km.

Table 3.22: Damages by Pattern and Location and Length of Section with Priority

Classified Damages	Sections, in which damage is classified as Medium/High (kilometerage)	Appro. total length of sections, in which damage is classified by Low/Medium/High
Pattern 1: Flood damages from the main stream (Kinyasungwe River)		
Pattern 1-1: Washaway and/or scouring bridges foundations	Km 293 (Bridge), Km 304 (Bridge)	Low : 0 Medium: 0.2 km High : 0
Pattern 1-2: Erosion of the track embankments	Km 299–Km 303, Km 304–Km 307, Km 311–Km 318, Km 328 –Km338, Km 355–Km 361, Km 366–Km 367	Low : 22 km Medium: 12 km High : 9 km
Pattern 1-3: Washaway of the track and/or water/mud flowing over the track	Km 293–Km 304, Km 307– Km 315, Km 339–Km 350	Low : 14 km Medium: 17 km High : 8 km
Pattern 2: Flood damages from the tributaries and/or slopes of mountains along the railway, due to inadequate cross drainage		
Pattern 2-1: Damage of the surface of the track by the floodwaters overtopping the track, due to inadequate cross drainage	Km 303–Km 307, Km 337, Km 340, Km 349–361, Km 365–Km 366, Km 403–Km 426	Low : 82 km Medium: 20 km High : 1 km
Pattern 2-2: Damage of the track embankment due to inadequate cross drainage	Km 303–Km 307, Km 337–Km 340, Km 349–Km 350, Km 355.5, Km 403–Km 415	Low : 51 km Medium: 11 km High : 1 km
Pattern 3: Submergence of the track by the floodwaters from the main stream and/or tributaries/ slopes of mountains, due to inadequate drainage along the railway	Km 360–Km 364	Low : 0 Medium: 3 km High : 0

Note: The locations of High concerns of each pattern are underlined.
Source: JICA Study Team

Table 3.23 shows the classified damage patterns to the railway, possible measures, and protection priority.

Table 3.23: Classified Damage Patterns to the Railway, Possible Measures, and Protection Priority

Classified Damage Pattern	Events and Time for Restoration		Protection Priority	Possible Sustainable Measures	Temporary Urgent Protection Measures proposed in Dec. 2014
Pattern 1: Flood damages from the **main stream** (Kinyasungwe River)	**Pattern 1-1**: Wash-away and/or scouring bridge foundations	This pattern is likely to require **long time** for the railway restoration.	High	• Re-routing/raising the bridge • Expansion of the bridge • Additional Gabion works • Sustainable excavation of the riverbed	
	Pattern 1-2: Erosion of the track embankments	This pattern is likely to require **one week or more** for the railway restoration.	High	• Re-routing • Raising the track • Protection of riverbank against erosion	• Km 337: Spur dikes, and Protection of riverbank by gabion
	Pattern 1-3: Wash-away the track and/or water/mud flowing over the track	This pattern is likely to require not so long time (**less than one day**) for the railway restoration.	Medium–High	• Re-routing • Raising the track • Building embankments along the river • River Training	• Km 293: Heightening of dike by gabion • Km 302: Protection of the riverbank by gabion
Pattern 2: Flood damages from the **tributaries** and/or slopes of mountains along the railway, due to inadequate cross drainage	**Pattern 2-1**: Damage of the surface of the track by the floodwaters overtopping the track, due to inadequate cross drainage	This pattern is likely to require not so long time (**less than two day**) for the railway restoration.	Low–Medium, except Mzase (High)	• Re-routing • Raising the track • Improving cross drainage • Implementation of Catchment Management Plans	• Km 349, Km 355, Km 366: Channel excavation and riverbank protection
	Pattern 2-2: Damage of the track embankment due to inadequate cross drainage	This pattern is likely to require not so long time (**less than one day**) for the railway restoration.	Low	• Re-routing • Raising the track • Improving cross drainage • Implementation of Catchment Management Plans	
Pattern 3: **Submergence** of the track	**Pattern 3**: **Submergence** of the track by the floodwaters from the main stream and/or tributaries/ slopes of mountains, due to inadequate drainage along the railway	This pattern is likely to require **3 - 4 days** for the railway restoration.	Medium	• Re-routing • Raising the track • Improving drainage along the track	

Source: JICA Study Team

3.4.7 Flood Disaster Response Practice

(1) Regulations, Procedures/Order

RAHCO/TRL have no formal procedures or regulations specifically for the handling of flood disasters. However, generic rules and regulations have to be followed when dealing with flood disaster prevention and response. Examples of such rules are:

(a) "General Rules" and "General Appendix to the General Rules" give instructions on how to report accidents, how to respond to accident reports and how to operate trains under abnormal conditions. Floods which can cause disruption of train movements are handled as accidents.

(b) "East African Railways Engineering Manual, 1963" provides standards for safety of railway track. It prescribes track inspection frequencies and procedures. It provides technical standards and a methodology for carrying out remedial works.

(c) Financial regulations and various finance circulars of TRL and RAHCO guide management of the respective organizations on budgeting, expenditure control, levels of authority, etc.

(d) Since both TRL and RAHCO are government owned institutions, they must abide by the "Public Procurement Act" when procuring preventive or remedial works.

It should be noted, however, that the implementation of some of the rules prescribed in the "Engineering Manual" have become somewhat relaxed due to inadequate manpower (in numbers and skills), poor cash availability, and the general outdatedness of the rules.

Routine inspection and maintenance of the track and bridges is described in Section 3.6.7 (5).

(2) Allocation of Roles

The roles of TRL, RAHCO, SUMATRA and MOT can be summarized as follows:

(a) TRL: They are the first responder in the case of flood occurrences. They take measures to restore traffic movement in the shortest possible time. They report the occurrence to the other organizations. If TRL assesses that the remedial works will cost more than US$ 100,000 they ask RAHCO to undertake the remedial works.

(b) RAHCO: They are responsible for all remedial works in excess of US$ 100,000. Since RAHCO does not have field workers, they may contract this work to TRL or to private contractors. The decision whether to use TRL or outside contractors depends on the analysis of the workload, availability of skilled labor, and urgency of the project.

(c) SUMATRA: As the safety regulator, SUMATRA carries out safety audits from time to time to check whether safety rules are being complied with. Further, regulations require that a new railway or a railway line which has undergone considerable reconstruction must be inspected and approved by SUMATRA before it is opened for public use.

(d) MOT: The Ministry makes final approval of the annual budgets of TRL and RAHCO, as they are public institutions. They also finance disaster recovery and prevention activities, because currently TRL and RAHCO are not able to generate enough funds to finance their activities. In the case of serious disasters, MOT may play the role of managing public expectations.

(3) Disaster Response

A flood situation may be detected by any of the following people:

- A Keyman in the course of his daily walking inspection along the railway track
- A Keyman undertaking special inspection of the track after a heavy rainfall
- Train crew approaching the flooded point
- Any other railway employee on duty or off duty near the track
- Any other person passing by the track

The situation will be reported to the nearest stationmaster by the fastest available means. The stationmaster will immediately report by control telephone to the Controller who will then give orders to close the section to all traffic.

The PWI, having received a report from the Keyman or the Stationmaster or from any other person, will go to site, take necessary measures to secure the site, make a detailed inspection, and report the situation to the District Civil Engineer.

Based on the PWI report and his own inspection, the District Civil Engineer will advise the Chief Civil Engineer on measures required to be taken. He will initiate immediate action if it is within his available resources.

The Chief Civil Engineer (CCE) will make a report to management to request for resources required to open the line to traffic. In serious situations the CCE will rush to site and take over command of restoration work.

TRL Management's intervention will aim at opening the line to traffic. For that matter, their level of responsibility for track repairs is limited to US$ 100,000. Actions costing more than that amount, i.e., long term remedial measures and protective measures will be advised to RAHCO. RAHCO will want to make their own inspection to satisfy themselves as to the nature and cost of required measures. However, TRL will not sit idle while they wait for RAHCO to do permanent remediation works, they will do whatever they can to facilitate flow of traffic in the meantime.

Financial and procurement regulations have to be complied with, even in emergency situations. For example, the TRL Managing Director can only approve direct purchases not exceeding TZS 20,000,000. Above that amount, tender procedures apply.

Financing of emergency works is not normally included in the annual budget. The Managing Director will somehow have to mobilize funds for such extraordinary expenses. Further, as the two organizations are currently not generating adequate revenue, the CEOs have to resort to asking the Government to provide funds for emergency works. Naturally, this results in unpredictable delays. Government response time can be very short if the nature of the emergency is such that it has the potential to cause adverse political impact.

(4) Case Study of Disaster Response

The following is an example of a recent occurrence of a flood disaster, to illustrate the process of emergency response. It pertains to Km 337/4, between Godegode and Gulwe

On 2 December 2014 the JICA Study Team, which made an inspection of the line from Kilosa to Gulwe, identified Km 337/2 to 337/7 as one of most critical railway sections to be protected against progressive bank erosion. Their report indicated:

- Serious bank erosion observed in this section;
- Height of riverbank is 4.5 m and the shortest distance from riverbank to railway track is 18 m;
- There is high possibility to be damaged during the coming rain season

They recommended urgent countermeasures in this section to prevent a possible disaster. Their report was submitted to RAHCO, which requested emergency funds for implementing the recommended measures.

On the night of 6 March 2015, as predicted, the river burst its bank, sweeping away the embankment to the toe of the sleepers. All traffic through this section was suspended. Restoration work was completed in 16 March 2015.

In order to undertake emergency restoration work, TRL decided that they need to shift the track 40 m away from the present alignment. The TRL Managing Director used his authority to procure the following items within his limit of TZS 20 million:

- Hiring of one bulldozer, one excavator, one roller, and one dump truck for four days;
- Employment of casual laborers to do river training.

While waiting for requested funds from Government, funds were diverted from other operations in order to deal with the emergency.

TRL has estimated that after the line is restored there will be need for protection works involving the placement of gabions, boulders and sandbags. The envisaged protection measures are estimated to cost TZS 370 million. This has, therefore, been reported to RAHCO, as it is greater than US$ 100,000. RAHCO is to make its own assessment before making a final decision.

(5) Inspection of Infrastructure

The Civil Engineering Department of TRL is responsible for routine inspections and maintenance of track. The department is organized into the following hierarchy:

Sectional Gang - The lowest work group. Each gang maintains 8 km of the running line. It has one Ganger (supervisor of the gang), one Keyman, and six Gangmen (semiskilled workers)

Subpermnent Way Inspector (SPWI) - Supervises 4 section gangs

Permanent Way Inspector (PWI) - Supervises 12 section gangs (3 SPWI's). Has technician certificate.

District Civil Engineer - Supervises several PWI's. A university graduate with additional training in track technology.

Each level is responsible for a specific type of routine inspection of the railway infrastructure, as summarized in Table 3.24.

Table 3.24: Schedule of Inspection of Infrastructures

Structure	Category of Employee	Type of Inspection	Frequency of Inspection
Track	Keyman	On foot inspection of the track structures, i.e., rails, fastenings, sleepers and formation	Daily (seven days a week)
	Ganger	Acceptance inspection of completed daily works and condition appraisal of the Gang's section	Once a week for condition appraisal of the section. This is done every Thursday. He takes over the work of the Keyman's duties on this day.
	Subpermanent Way Inspector	Push trolley and static inspection of the track parameters	Once a week
	Permanent Way Inspector	Push trolley and static inspection of track parameters	Once every two weeks
	District Permanent Way Inspector	Trolley Inspection of the whole district	Once per month
	District Civil Engineer	• Locomotive and rear vehicle ride • Detailed inspection of the track, formation and bridges by foot and by using push trolleys	Once a month Once every three months
Bridges	Chief Civil Engineer	Detailed inspection of track, formation and bridges on foot and on motor trolleys	Twice a year
	Sub-Permanent Way inspector	Inspection of the track on bridges and the substructure	Once every two-three months
	Permanent Way Inspector	Detailed inspection of the superstructure and substructure	Obligatory
	District Civil Engineer	Detailed inspection of the superstructure and substructure including flood protection works	Obligatory once in a year

Note: A SUMATRA consultant observed in 2011 that "currently the Civil Engineering Department does not have manpower for bridge inspection. Bridges are severely deteriorated due to lack of maintenance."
Source: JICA Study Team

Deficiencies and risks found during the inspection are either corrected or reported to higher levels depending on the complexity of the defect and the type of resources needed.

The District Civil Engineer will report to the CCE his observations and proposed remedial measures. The Chief Civil Engineer will prepare short- and long-term action plans after analysis of the inspection results and determination of the required quantities of materials, skills, number of people, machinery and funds. For projects which require more than US$ 100,000 the CCE will forward his proposals to RAHCO.

During the company's annual budgeting time, the CCE will present his plan and budget to Management, who will then consider it together with other departmental proposals. The consolidated budget will be presented to the Board for approval. Because the company is owned 100% by Government, the budget proposal will be presented to MOT for inclusion in the national budget.

Likewise, RAHCO's Director of Technical Services will analyze TRL's proposal for high-level protective measures, enhanced by RAHCO's own inspections if necessary, and prepare long- and short-term plans for Management's approval. RAHCO Management proposals, approved by its Board, will be presented to MOT for scrutiny and approval.

Due to scarcity of finance and conflicting priorities, departmental budget proposals from CCE (in the case of TRL) and from the Director of Technical Services (in the case of RAHCO) are often scaled down at the levels of Management, the Board and the MOT. Often it is a case of negotiation and prioritization.

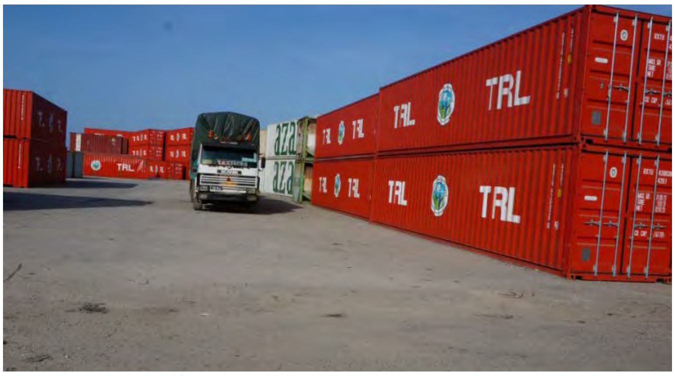
3.5 Intermodal Facilities

3.5.1 Inland Container Depots

Because of the trend toward containerization of both imported and exported goods, RAHCO has opened four inland container depots (ICDs) with rail sidings for cargo: Ilala (Dar es Salaam) ICD, Isaka ICD, Shinyanga ICD, and Mwanza South ICD.

(1) Ilala ICD (Km 2)

Ilala ICD was recently modernized as part of a larger project, funded by the Belgian Technical Cooperation (BTC), and organ of the Belgian Development Agency (BDA). The project also included the opening of two new ICDs at Shinyanga and Mwanza South (described later), and ran from 2007-2011 with a budget of €2.5 mil. Ilala ICD is located within Dar es Salaam; it is the location where tracks from Dar es Salaam Central Station and the Dar es Salaam Port merge to continue on as the “Central Railway Line”. Its size is approximately 1 ha, and it was the recipient of one of the five container reach stackers donated by the BTC to RAHCO. Two sheds, each with rail sidings, exist next to the container handling area. Figure 3.19 shows the scene of Ilala ICD in March 2015:



Source: JICA Study Team

Figure 3.19: Ilala Inland Container Depot, 2015

(2) Isaka ICD (130 km)

Isaka ICD is currently the most important ICD connected to the Central Railway Line. It was constructed in the mid-1990s, also with assistance from the Belgian government, to handle the increasing traffic from Rwanda and Burundi. It functioned well, with a good amount of traffic, until the concession started. At present, it is basically vacant, due to the decline in TRL services. However, there are vast plans for its future expansion, in anticipation of the completion of other projects and the revival of TRL services. This is driven by the World Bank TIRP, the aim of which is to run block trains from Dar es Salaam to Isaka. There is also potential for a rail link to Kigali (via the Rusumo border crossing), as described in Section 1.4.4 (Transport Network). Isaka ICD is equipped with two container stackers, as well as lighter equipment for plant repairs. Figure 3.20, from a METI Study Team site visit, shows the scene of Isaka ICD in October 2013:

Source: METI

Figure 3.20: Isaka Inland Container Depot, 2013

(3) Shinyanga ICD (Km 197 on Mwanza Line)

Shinyanga ICD has completed construction, but has basically no activity due to the low capacity of TRL. The original rationale for construction for this ICD was to containerize cotton/cotton cake for export, as Shinyanga is a major cotton production area. However, as later described in Chapter 4 (Traffic Demand Forecast), TRL has completely lost this business, and Shinyanga sits idle. The Government of Tanzania is working with Chinese investors to drastically grow industries in this area; many of them are cotton-related but not all of them, so there is potential for future use of the ICD.

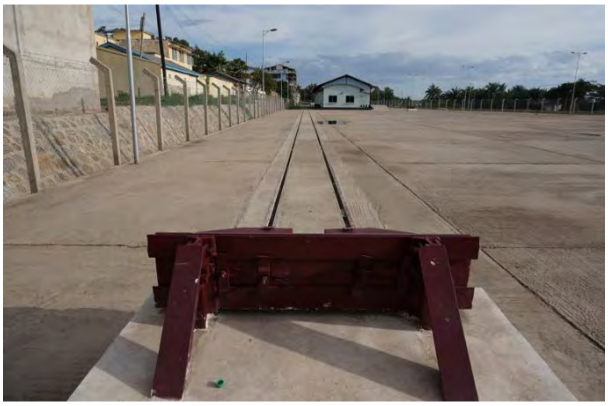
RAHCO is still in the process of inviting tenders for leasing this ICD. Two of the five container reach stackers donated by the BTC to RAHCO were intended to go to this ICD, but they are still in Dar es Salaam, and there is an open invitation for bidders for their leasing. At present, there is a low probability that they will actually end up at Shinyanga in the near future, since there is no demand there for their use. (More private ICDs are opening in Dar es Salaam, and it is more likely that they will end up there.) Figure 3.21, from a METI Study Team site visit, demonstrates the lack of activity at Shinyanga ICD in October 2013:

Source: METI

Figure 3.21: Shinyanga Inland Container Depot, 2013

(4) Mwanza South ICD (Km 378 on Mwanza Line)

Mwanza South ICD has also completed construction, but similar to Shinyanga, is basically not utilized due to a lack of TRL traffic. The original rationale for construction was to handle containers for local cargo and cargo bound for Uganda. There is an open invitation for bidders to lease the ICD. The remaining two container stackers donated by the BTC to RAHCO were intended to be used at Mwanza South ICD, however, they included in the same tender as those intended for Shinyanga ICD, and it is similarly unlikely that they will make it to this ICD. Figure 3.22, from a METI Study Team site visit, shows the scene of Mwanza South ICD in October 2013:



Source: METI

Figure 3.22: Mwanza South ICD, 2013

3.5.2 Ports

For the purposes of the Central Railway Line, there are three marine ports of significance: Dar es Salaam Port, Kigoma Port, and Mwanza South Port.

(1) Dar es Salaam Port (Km 0)

Dar es Salaam Port has rail access from both the Central Railway Line (from the northern end) and TAZARA Line (from the southern end), with two tracks serving the warehouse area and one track serving the container stack behind berths 3-8. Overall, Dar es Salaam port is very close to reaching its maximum operating capacity, and there are already a variety of issues at the port, partially caused by bad spatial allocations, and partially caused by operational problems. There are plans to upgrade the rail platform to be undertaken with World Bank assistance.

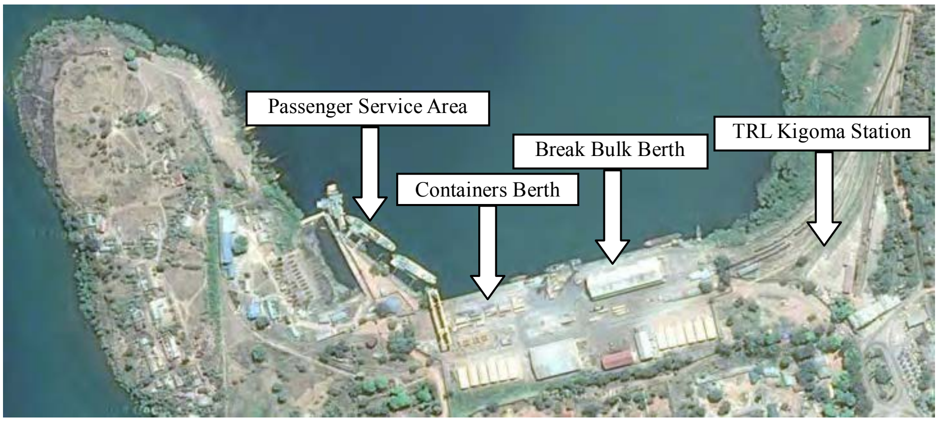
A much larger project, the Dar es Salaam Maritime Gateway Project, was originally released for an expression of interest, but was subsequently cancelled by the Bank. The project would have modernized berths 1-7, constructed a new ro-ro terminal, and installed other new systems (conveyors, unloading systems, etc.) with external (World Bank/International Bank for Reconstruction and Development) funding, and constructed berths 13-14 with internal (TPA) funding. Figure 3.23 shows the current layout of Dar es Salaam Port:

Source: Tanzania Ports Master Plan (TPA/Royal Haskoning)

Figure 3.23: Dar es Salaam Port Area

(2) Kigoma Port (Km 1,251)

Kigoma Port, on Lake Tanganyika, is at the western end of the Central Railway Line. It is strategically located, and serves as a storage location for World Food Programme for distribution to the Democratic Republic of Congo and Burundi. However, the track between Tabora and Kigoma is some of the oldest and most dilapidated on the Central Railway Line, with steep slopes and sharp curves in the last 60 km approaching it. As such, it is presently barely utilized for TRL purposes. The Tanzania Ports Master Plan calls for an expansion of the port area by 700 m to the northeast, toward the oil jetty (located at Kibirizi, approximately 1.5 km north of the port). Figure 3.24 shows the basic area of Kigoma Port:

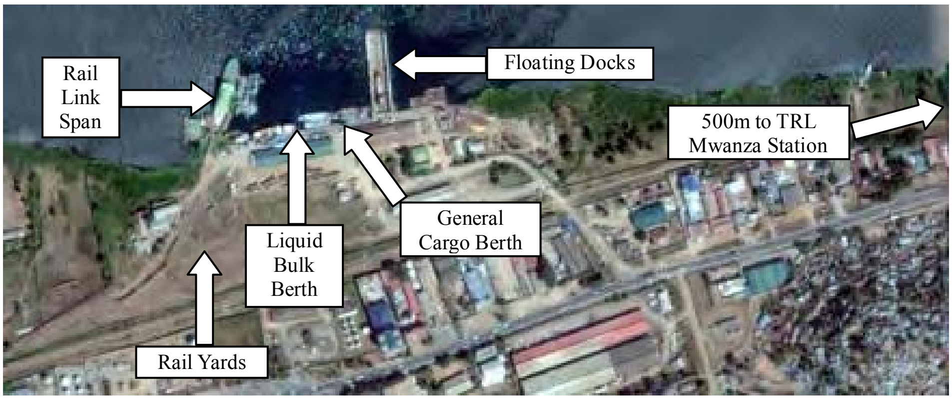


Source: Google Earth (CNES /Astrium, DigitalGlobe), JICA Study Team

Figure 3.24: Kigoma Port Area

(3) Mwanza South Port (Km 379 on Mwanza Line)

Mwanza Port, on Lake Victoria, is at the end of the Mwanza Line which passes through both Isaka ICD and Shinyanga ICD. It has a rail link to Mwanza station (about 1 km north of the port), a rail yard, general cargo berths, a liquid bulk berth, warehouses, floating docks, and a marshalling yard. The tracks connecting the link span to the main tracks are in need of repairs, but the actual link span is in good working order. There is more TRL traffic at this port compared to Kigoma, mostly getting cargo to Isaka or Tabora where it is then transshipped to trucking. The Tanzania Ports Master Plan calls for internal reorganization of uses within the port, which could require the rail yards to move slightly. Figure 3.25 shows the basic area of Mwanza South Port:



Source: Google Earth (CNES /Astrium, DigitalGlobe), JICA Study Team

Figure 3.25: Mwanza South Port Area

4. Traffic Demand Forecast

In this chapter, a freight and passenger rail traffic demand forecast is presented through 2046, or Year 30 after the potential Project commencement. In order to estimate the potential of railway services in the country, the demand forecast is provided without considering particular constraints on the transport capacity. It should however be noted that an estimate of the rail traffic that would result after the Project requires an assessment of the transport capacity to be achieved by the Project. The estimated rail traffic based on the assessment of the transport capacity is provided in Chapter 14.

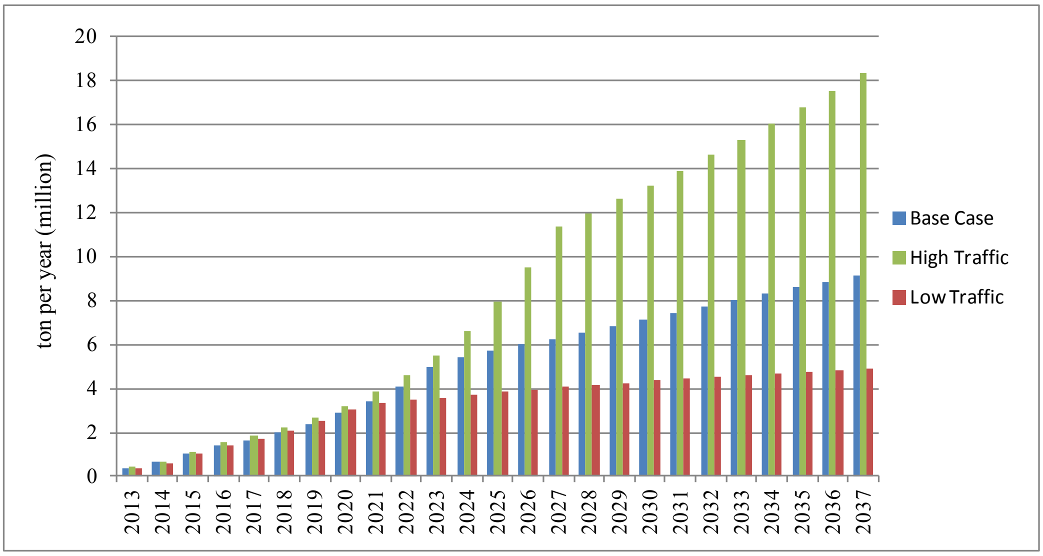
4.1 Review of Traffic Demand Forecasts in Related Studies

4.1.1 Review of RAHCO/CPCS "Tanzania Railways Upgrading and Performance Improving Study"

The RAHCO/CPCS study that was conducted for the preparation of TIRP provided three scenarios for freight traffic growth for the Central Railway: a base case, a low case, and a high case. The analyses were based on country GDP estimates, commodity projections, as well as estimates for specific mining projects in Tanzania and neighboring countries expected to open in the near future, providing a commodity-based forecast.

The three cases (base, low, high) were adjusted not just by growth rates, but also by the inclusion/exclusion of certain potential sources (i.e., excluding a mining project in the low case).

Figure 4.1 below shows the significant differences between the three cases:



Source: RAHCO/CPCS "Tanzania Railways Upgrading and Performance Improving Study", 2013

Figure 4.1: RAHCO/CPCS 2013 Projected Demand for the Central Railway (million tons)

Commodity-based forecasts were provided in the study, which are reproduced below in Table 4.1 for the year 2030:

Table 4.1: RAHCO/CPCS 2013 Study Commodity-Based Forecasts for the Year 2030

Commodity	Forecast (1,000 tons)	Share (%)
Coffee	50	0.70
Cement	1,542	21.60
Fertilizer	159	2.20
Fuel	802	11.20
General cargo	1,336	18.70
Gypsum	6	0.10
Maize	251	3.50
METL	379	5.30
Nickel	0	0.00
Salt	40	0.60
Sugar	119	1.70
Timber	28	0.40
Tobacco	27	0.40
WFP	279	3.90
Wheat/grains	481	6.70
Containers – 20 ft (Burundi)	156	2.20
Containers – 20 ft (DRC)	156	2.20
Containers – 20 ft (Rwanda)	166	2.30
Containers – 20 ft (Tanzania)	858	12.00
Containers – 40 ft (Burundi)	28	0.40
Containers – 40 ft (DRC)	55	0.80
Containers – 40 ft (Rwanda)	66	0.90
Containers – 40 ft (Tanzania)	158	2.20
Total	7,142	100.00

Source: RAHCO/CPCS "Tanzania Railways Upgrading and Performance Improving Study", 2013

4.1.2 Review of METI "Study on the Central Corridor Railway Revitalization and Energy Efficiency Project in the United Republic of Tanzania"

The METI study's main focus was on identifying railway improvement projects along the Central Corridor that could be potential candidates for financial assistance from Japan. The demand analysis conducted in the METI study sought to validate the RAHCO/CPCS forecasts.

Using World Bank real GDP data for the period 1988–2003 (starting from the beginning of available GDP data and ending with the peak year of TRL operations before the RITES concession), the METI study estimated the GDP elasticity of TRL freight traffic, predicting the "lost traffic", or, what could have been carried along the Central Railway if operations had not suffered a decline from the concession years. These results are shown below in Table 4.2:

Table 4.2: METI 2014 Study Measured vs. Predicted TRL Traffic for 2004–2012

Year	Measured Freight tons	Predicted Freight tons	Difference
2004	1,333,249	1,514,906	181,657
2005	1,128,508	1,594,071	465,563
2006	775,281	1,670,289	895,008
2007	545,241	1,754,972	1,209,731
2008	442,485	1,847,507	1,405,022
2009	403,573	1,926,539	1,522,966
2010	221,030	2,022,792	1,801,762
2011	239,208	2,115,402	1,876,194
2012	184,264	2,218,351	2,034,087
Total	5,272,839	16,664,829	11,391,990

Source: METI "Study on the Central Corridor Railway Revitalization and Energy Efficiency Project in the United Republic of Tanzania", 2014

Furthermore, the model was used to predict freight demand for future years, to 2037, using a GDP growth rate of 8.0%. A summary of these results for benchmark years are shown below in Table 4.3:

Table 4.3: METI 2014 Study Estimated Freight Traffic for Selected Years

Year	Estimated Freight Traffic
2013	2,344,081
2017	2,922,414
2025	4,542,347
2030	5,984,003
2037	8,802,134

Source: METI "Study on the Central Corridor Railway Revitalization and Energy Efficiency Project in the United Republic of Tanzania", 2014

The data produced by this analysis matched up closely with the base case produced in the RAHCO/CPCS report described in the previous section.

4.1.3 Review of JICA "Comprehensive Transport and Trade Master Plan in the United Republic of Tanzania" Demand Forecast

The JICA Master Plan (M/P) included a demand forecast for trade and transport in Tanzania, not just for the Central Railway, but for the entire country, by examining domestic traffic, imports, exports, and transit to/from neighboring landlocked countries. Forecasts were provided up to the year 2030, assuming a GDP growth rate of 8%.

In this analysis, rail/road modal shares were also estimated, in order to forecast Central Railway traffic. The projected freight volumes for rail and road for the Central Corridor are shown in Table 4.4, indicating a relatively conservative estimate of the Central Railway traffic.

Table 4.4: JICA 2014 M/P Projected Freight Volume for the Central Corridor

Item	2010	2030	2030/2010 ratio
Road + Rail (million ton)	13.87	103.00	7.43
Road (million ton)	13.52	97.86	7.24
Central Railway (million ton)	0.35	5.14	14.69
Rail share (%)	2.52	4.99	–

Source: JICA "Comprehensive Transport and Trade System Development Master Plan in the United Republic of Tanzania", 2014

4.1.4 Review of CANARAIL "Phase II of Dar-es-Salaam – Isaka – Kigali/Keza – Musongati Railway Project Study"

In March 2014, The Canadian consultant firm CANARAIL released the report: "Phase II of Dar es Salaam – Isaka – Kigali / Keza – Musongati Railway Project Study". It is a detailed study of the proposed rail link from Isaka to Keza (in Tanzania), splitting and then going to Kigali (Rwanda) and Musongati (Burundi). As part of this report, it conducted a passenger demand forecast. The methodology was as follows:

- A gravity model was developed, using the distance between stations and populations in a five-kilometer "attraction radius".
- The model was calibrated against population densities and current ridership (current OD pairs).
- Projected OD pairs between Kigali and Dar es Salaam (via Tabora) were created.
- Changes in population sizes, ticket pricing, and train frequency were used to adjust ridership. (Industry standards were used for elasticities.)

CANARAIL estimated the total number of passengers in 2020 (year 10) at 1,075,000 per year, with an average trip length of 677 km.

4.2 Traffic Demand Forecast

4.2.1 Freight

(1) GDP Performance

The table below shows GDP (in 2005 US$) performance and population for Tanzania and the neighboring countries of Uganda, Rwanda, Burundi, and the DRC. These GDP data will be used for the analyses to follow. In addition, based on the average of 2001-2013 GDP performance, GDP growth rate of 7.0% will be used for the forecast during the initial years (up to 2023).

Table 4.5: Tanzania and Neighboring Countries' GDP (2005 US$) and Population (2001–2013) (thousands)

	(thousands)	2001	2002	2003	2004	2005	2006	2007
Tanzania	GDP (US$)	10,664,101	11,428,029	12,214,989	13,171,215	14,141,917	15,094,712	16,173,697
	Population	34,895	35,806	36,761	37,765	38,824	39,942	41,120
Uganda	GDP (US$)	6,855,545	7,454,218	7,936,749	8,477,022	9,013,834	9,985,954	10,826,014
	Population	25,088	25,943	26,838	27,767	28,725	29,711	30,729
Rwanda	GDP (US$)	1,960,559	2,225,441	2,257,740	2,414,571	2,581,466	2,819,871	3,034,544
	Population	8,760	8,988	9,126	9,254	9,429	9,661	9,928
Burundi	GDP (US$)	1,023,796	1,069,320	1,056,234	1,107,289	1,117,254	1,177,415	1,233,764
	Population	6,839	7,038	7,264	7,511	7,770	8,043	8,328
DRC	GDP (US$)	9,716,829	10,003,258	10,561,222	11,272,876	11,964,484	12,601,116	13,389,700
	Population	48,167	49,517	50,972	52,487	54,028	55,591	57,188

	(thousands)	2008	2009	2010	2011	2012	2013	CAGR 2001–13
Tanzania	GDP (US$)	17,376,506	18,422,910	19,720,449	20,992,181	22,447,566	24,010,086	**7.00%**
	Population	42,354	43,640	44,973	46,355	47,783	49,253	**2.91%**
Uganda	GDP (US$)	11,768,825	12,622,188	13,362,035	14,246,653	14,732,537	15,616,913	**7.10%**
	Population	31,779	32,864	33,987	35,148	36,346	37,579	**3.42%**
Rwanda	GDP (US$)	3,373,273	3,584,710	3,846,848	4,148,900	4,513,520	4,724,956	**7.61%**
	Population	10,223	10,530	10,837	11,144	11,458	11,777	**2.50%**
Burundi	GDP (US$)	1,296,046	1,340,998	1,391,767	1,450,105	1,508,390	1,577,686	**3.67%**
	Population	8,624	8,927	9,233	9,540	9,850	10,163	**3.36%**
DRC	GDP (US$)	14,223,583	14,629,707	15,669,475	16,746,595	17,933,522	19,454,635	**5.96%**
	Population	58,819	60,486	62,191	63,932	65,705	67,514	**2.85%**

CAGR = Compound Annual Growth Rate
Source: World Bank

(2) Dar es Salaam Port Performance

In order for the Central Railway to capture significant levels of traffic, it must capture the traffic originating from, and terminating at, Dar es Salaam Port. This port is the most important in the country, and in the past several years, growth has been significant. It is generally expected that by 2017, it will be operating at its maximum design capacity. Table 4.6 below shows traffic at the Dar es Salaam Port since 2006 with the corresponding growth rates for those years:

As apparent in the table, with the exception of traffic to/from Uganda, traffic at Dar es Salaam Port has been rapidly growing. This traffic growth will be used in later sections, to forecast general cargo levels on TRL.

Table 4.6: Dar es Salaam Port Traffic, 2006–2013 (tons)

		2006	2007	2008	2009	2010	2011	2012	2013	CAGR 2006–13
Tanzania	Imports	2,352,011	2,615,644	2,559,175	3,018,133	3,130,854	3,482,248	4,363,277	4,687,819	**10.4%**
	Exports	458,764	651,133	555,468	621,699	661,053	784,947	858,343	832,364	**8.9%**
	Total	2,810,775	3,266,777	3,114,643	3,639,832	3,791,907	4,267,195	5,221,620	5,520,183	**10.1%**
Uganda	Imports	46,009	33,998	36,066	21,397	21,827	17,915	38,454	159,452	**19.4%**
	Exports	846	3,454	3,218	2,533	96	74	1,257	914	**1.1%**
	Total	46,855	37,452	39,284	23,930	21,923	17,989	39,711	160,366	**19.2%**
Rwanda	Imports	72,998	79,635	114,819	111,126	129,707	175,553	315,707	384,925	**26.8%**
	Exports	4,920	8,821	10,162	8,046	11,358	13,453	32,712	27,777	**28.1%**
	Total	77,918	88,456	124,981	119,172	141,065	189,006	348,419	412,702	**26.9%**
Burundi	Imports	85,869	89,587	100,411	148,927	203,762	168,436	152,135	170,339	**10.3%**
	Exports	10,023	25,116	14,547	18,766	13,716	17,863	18,215	14,106	**5.0%**
	Total	95,892	114,703	114,958	167,693	217,478	186,299	170,350	184,445	**9.8%**
DRC	Imports	247,236	329,403	370,961	230,013	342,452	373,305	462,551	401,441	**7.2%**
	Exports	86,895	97,610	96,229	76,070	143,224	199,574	262,007	292,963	**19.0%**
	Total	334,131	427,013	467,190	306,083	485,676	572,879	724,558	694,404	**11.0%**
Petroleum/Oil	Refined	-	-	-	-	-	-	261,021	-	**-**
	TAZAMA	399,836	536,707	452,973	546,542	635,893	603,340	641,570	-	**8.2%**
	Kurasini	1,441,897	1,354,361	1,539,424	1,911,353	2,271,538	2,684,013	2,784,291	-	**11.6%**
Empty Containers	Imports	7,680	8,608	4,500	3,583	2,533	1,841	10,799	2,038	**5.8%**
	Exports	144,237	169,775	223,265	216,918	245,354	302,232	334,621	365,449	**15.1%**

CAGR = Compound Annual Growth Rate
Source: TPA, JICA Study Team

(3) TRL Freight Performance

Table 4.7 below shows recent TRL freight performance, for the period 2009–2014.

Table 4.7: TRL Freight Traffic, 2009–2014

	2009	2010	2011	2012	2013	2014
Domestic						
Cement	8,880	22,600	8,560	9,720	8,360	16,120
Coffee	1,196	-	764	-	-	-
Cotton	106	48	-	-	-	-
Cotton Cake	10	1,422	1,400	225	-	-
Fertilizer	6,007	39,180	15,680	9,364	2,278	5,440
General Cargo	50,418	35,510	49,602	19,919	31,628	26,192
Grains	12,687	8,725	21,296	37,052	18,793	49,403
Gypsum	2,560	1,119	3,680	2,521	5,490	1,800
Livestock	516	223	171	-	157	460
Maize	31,624	20,460	50,116	40,369	25,340	17,080
Petroleum/Oil	52,416	23,743	32,036	12,454	20,272	21,803
Salt	5,890	4,080	8,000	6,160	6,000	4,440
Sugar	2,760	760	760	1,800	1,640	1,960
Timber	2,302	2,014	1,408	2,351	1,620	4,082
Tobacco	4,965	-	6,635	5,210	1,747	2,545
Parcels/Luggage	8,310	1,540	1,896	3,377	3,151	2,105
Subtotal	190,647	161,424	202,004	150,522	126,476	153,430
Transit						
Petroleum/Oil	-	-	-	-	-	-
Containers	11,746	480	720	300	1,520	4,978
TARC/EAHR	49,920	35,160	27,800	13,760	15,360	31,920
Others incl. WFP	201,450	59,126	36,484	*N/A*	*N/A*	*N/A*
Subtotal	263,116	94,766	65,004	14,060	16,880	36,898
Grand Total	**453,763**	**256,190**	**267,008**	**164,582**	**143,356**	**190,328**

Source: TRL and JICA Study Team

While the general trend is of decline (especially when the data starting from 2003 is examined), 2014 shows a slight increase in traffic: 11.3% over the year 2013.

However, overall, the last decade of TRL traffic is too inconsistent to be useful for creating a demand forecast, due to degradation of service quality. It is more valuable to examine the previous years' traffic data. Table 4.8 below shows traffic from the period 2001-2004 the years before the concession to RITES started:

Table 4.8: TRL Freight Traffic, 2001–2004

	2001	2002	2003	2004
Domestic				
Cement	119,806	85,516	81,511	97,054
Coffee	16,027	18,915	16,233	17,837
Cotton	38,565	44,646	33,418	19,919
Cotton Cake	13,824	16,809	25,351	9,005
Fertilizer	11,413	18,262	21,065	28,782
General Cargo	308,090	390,437	428,919	348,870
Grains	20,030	49,080	34,149	21,127
Gypsum	12,476	24,271	16,873	6,363
Livestock	11,899	13,539	19,405	16,716
Maize	26,755	59,942	48,276	40,204
Petroleum/Oil	131,358	151,829	146,422	132,569

	2001	2002	2003	2004
Salt	25,838	25,920	31,127	25,243
Sugar	40,047	41,890	45,806	46,763
Timber	8,792	11,072	13,153	12,501
Tobacco	21,995	18,462	21,622	24,530
Parcels/Luggage	20,155	17,731	14,237	11,175
Subtotal	*827,070*	*988,321*	*997,567*	*858,658*
Transit				
Petroleum/Oil	31,854	26,874	31,420	13,877
Containers	89,108	81,938	65,013	84,012
TARC/EAHR	153,850	153,770	118,776	111,712
Others incl. WFP	403,593	348,624	348,713	376,802
Subtotal	*678,405*	*611,206*	*563,922*	*586,403*
Grand Total	**1,505,475**	**1,599,527**	**1,561,489**	**1,445,061**

Source: TRL

Table 4.9 shows the corresponding share of traffic for each commodity for the same period:

Table 4.9: TRL Freight Commodity Shares, 2001–2004 (%)

	2001	2002	2003	2004
Domestic				
Cement	14.5	8.7	8.2	11.3
Coffee	1.9	1.9	1.6	2.1
Cotton	4.7	4.5	3.4	2.3
Cotton Cake	1.7	1.7	2.4	1.0
Fertilizer	1.4	1.9	2.1	3.4
General Cargo	37.3	39.5	43.0	40.6
Grains	2.4	5.0	3.4	2.5
Gypsum	1.5	2.5	1.7	0.7
Livestock	1.4	1.4	2.0	2.0
Maize	3.2	6.1	4.8	4.7
Petroleum/Oil	15.9	15.4	14.7	15.4
Salt	3.1	2.6	3.1	2.9
Sugar	4.8	4.2	4.6	5.5
Timber	1.1	1.1	1.3	1.5
Tobacco	2.7	1.9	2.2	2.9
Parcels/Luggage	2.4	1.8	1.4	1.3
Subtotal	*100*	*100*	*100*	*100*
Transit				
Petroleum/Oil	4.7	4.4	5.57	2.4
Containers	13.1	13.4	11.53	14.3
TARC/EAHR	22.7	25.2	21.06	19.1
Others incl. WFP	59.5	57.0	61.84	64.3
Subtotal	*100*	*100*	*100*	*100*

Source: TRL, JICA Study Team

(4) Methodology: Individual Commodity Demand Forecasts

The following sub-sections will present individual demand forecasts for the major commodities carried on the Central Railway. The methodology is as follows:

1. First, a review of the background of the commodity production/consumption, as well as any national development plans relevant to the commodity.
2. Estimate the elasticity of commodity growth in Tanzania to GDP growth in Tanzania (domestic cargo); or estimate the elasticity of commodity growth to neighboring countries' GDP growth (transit cargo). In order to perform this step, the Cobb-Douglass production model is used:

$$P = b * x^{E_d}$$	
P	is the production value (e.g., tons of a commodity)
x	is the independent variable (e.g., GDP)
E_d	is the elasticity of production value to the independent variable
b	is a constant coefficient

A logarithmic transformation is applied to both sides of the equation, which converts the exponential growth model into a linearized form:

$$\log(P) = \log(b * x^{E_d})$$
$$\Downarrow$$
$$\log(P) = \log(b) + E_d * \log(x)$$

From this equation, E_d can be estimated by a simple linear regression.

3. Use the average of 2001-2004 to generate a "base year" potential traffic level in 2013; or the level that TRL could have carried in 2013 with a more or less properly-functioning system.
4. Multiply the base year level by the GDP growth, and then by the elasticity value for that commodity.

Expressed as a formula, the calculation is as follows:

$$C_{i,t} = C_{i,t-1} * \Delta GDP_t * E_d$$	
$C_{i,t}$	is the estimated TRL traffic for a commodity in year t
ΔGDP_t	is the projected change in GDP in year t
E_d	is the elasticity of C_i to ΔGDP_t, estimated by linear regression of the Cobb-Douglass production function

(5) General Cargo (Domestic)

As demonstrated in Table 4.9 above, "general cargo" constituted a major share in TRL traffic during the period of normal operations, about 40% of overall domestic cargo. General cargo is a catch-all commodity for any containerized cargo that does not fall into one of the other break-bulk commodity categories. Since there are no national production/consumption statistics for "general cargo", Dar es Salaam Port performance is the best available proxy. Table 4.10 displays the Port performance versus GDP:

Table 4.10: Tanzania Imports/Exports at DES Port vs. GDP (in 2005 US$) (2006–2013)

	2006	2007	2008	2009	2010	2011	2012	2013
Tanzania Imports/Exports at DES Port (1,000 tons)	2,352	2,616	2,559	3,018	3,131	3,482	4,363	4,688
Tanzania GDP (1,000,000) (2005 US$)	15,095	16,174	17,377	18,423	19,720	20,992	22,448	24,010

Source: TPA, World Bank

Following the methodology previously outlined, the elasticity was estimated as follows:

Table 4.11: Elasticity of Dar es Salaam Port Domestic Imports and Exports to Tanzania GDP (Constant 2005 US$)

	vs. Tanzania GDP	
	elasticity	**p-value**
Dar es Salaam Port Tanzania Imports/Exports	1.455	0.0001

Source: TPA, World Bank, JICA Study Team

The way to interpret these results is as follows:

- For every 1% change in Tanzania GDP results there is a 1.455% change in domestic cargo (the sum of imports and exports) handled at Dar es Salaam Port.
- A p-value greater than 0.10 indicates the elasticity value is somewhat non-significant. A value less than 0.01 is considered extremely significant. This value is 0.0001, so it is extremely significant.

For general cargo, the demand forecast will use an elasticity of 1.455, and a base year value of 369,079 tons.

(6) Oil (Domestic)

At its peak, TRL had 20 petroleum/oil customers, accounting for 146,422 tons of liquid bulk (2003). This is unsurprising, as petroleum/oil products are a major import commodity in Tanzania as well as in its neighboring countries. However, of the original 20 customers, only two remain: Primefuels and GBP. Through interviews at the TRL Commercial Office (which is in charge of customer accounts/business promotion), it was confirmed that both customers favor rail over road transport, and reportedly would greatly expand their usage of TRL if it had the capacity to accommodate their uses. At the Isaka ICD, there is an integrated storage facility for oil, and as such the majority of the oil transported along the Central Railway ends up at that location.

At Dar es Salaam Port, oil is demarcated in three ways: the Kurasini Oil Jetty (KOJ) (generally for domestic refined oil), the TIPER (Tanzania Italian Petroleum Refining Company, Ltd.) Refinery for the TAZAMA pipeline, and as of 2012, a new single point mooring (SPM) for domestic diesel. (Refer to Table 4.6 for tonnage statistics.) For domestic cargo purposes, TAZAMA can be ignored, as it is strictly for Zambia, and the SPM is too recent to be included. Focusing on the KOJ, the port data can be compared to data from the United States Energy Information Administration (EIA), which tracks consumption.

Table 4.12: Tanzania Petroleum Consumption (2001–2013)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Tanzania Petroleum Consumption (1,000 barrels/year)	6,916	7,930	8,472	9,053	9,766	10,244	11,044

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Tanzania Petroleum Consumption (1,000 barrels/year)	11,927	12,571	11,224	12,775	17,389	19,170

Source: US EIA

Table 4.13: Elasticity of Tanzania Petroleum Consumption to GDP

	vs. Tanzania GDP	
	elasticity	**p-value**
Tanzania Petroleum Consumption	1.056	0.0000

Source: US EIA, World Bank, JICA Study Team

For oil (domestic), the demand forecast will use an elasticity of 1.056, and a base year value of 140,545 tons.

(7) Cement (and Gypsum)

In the past decade, there has been a huge demand for cement in Tanzania, driven mostly by increased urbanization rates. Cement demand follows closely with construction sector production, which includes both public infrastructure (rails, roads, public works projects) and private sector (building construction). For the Tanzanian domestic market, much of the overall cement production will remain in Dar es Salaam, the largest urban area in the country. The major cement production companies are Tanzania Portland Cement Company (often referred to as Twiga Cement, their product line name), located in Kunduchi (in the northern part of the greater Dar es Salaam urban area), and Tanga Cement (which operates out of Tanga).

Additional cement production plants are planned to open in Tanga, Arusha (to the north), and Lindi and Mtwara (both in the southeastern part of the country).

Consumption data reported to the East African Community (EAC) can be compared to GDP data; Table 4.14 and Table 4.15 show the results of this analysis:

Table 4.14: Tanzania Cement Consumption (2001–2011)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**
Tanzania Cement Consumption (1,000 tons)	903	1,139	1,318	1,368	1,446	1,514

	2007	**2008**	**2009**	**2010**	**2011**
Tanzania Cement Consumption (1,000 tons)	1,514	1,680	2,013	2,399	2,690

Source: EAC

Table 4.15: Elasticity of Tanzania Cement Consumption to GDP

	vs. Tanzania GDP	
	elasticity	**p-value**
Tanzania Cement Consumption	1.610	0.0000

Source: EAC, World Bank, JICA Study Team

Additionally, gypsum is a component used in cement production, and its growth should be assumed to be the same as the growth in cement traffic demand. The Tanzania Ministry of Energy and Minerals (MEM) releases data on production, as follows:

Table 4.16: Tanzania Gypsum Production (2001–2012)

	2001	2002	2003	2004	2005	2006
Tanzania Gypsum Production (tons)	72,000	78,650	32,232	59,231	63,377	32,798

	2007	2008	2009	2010	2011	2012
Tanzania Gypsum Production (tons)	2,730	55,730	8,105	26,918	3,288	91,610

Source: MEM

However, these production values are too volatile, and are not statistically significant when compared to both GDP and cement production. Consumption data, which would be more stable, is not available. As previously mentioned, gypsum should be consumed at the same pace as cement, and as such, our demand forecast will use the same elasticity found between cement consumption and GDP.

The demand forecast will use an elasticity of 1.610, and a base year value of 95,972 tons of cement, and 14,996 tons of gypsum.

It should be noted that in March 2016, TRL and Tanga Cement signed a Memorandum of Understanding (MoU) to transport the producer's products to its customers in Kigoma and Mwanza by rail, which is expected to increase TRL's cement traffic substantially in the future[1].

(8) Fertilizer

In order to meet Tanzania Agriculture and Food Security Investment Plan 2011/12–2020/21 (TAFSIP) goals, it is estimated that Tanzania will have to double its fertilizer imports to 528,000 tons (by 2015). (Fertilizer purchases are subsidized by the Government of Tanzania.)

There are two datasets for fertilizer statistics available, both from the Food and Agriculture Organization (FAO) of the United Nations. The first dataset is fertilizer imports of all types (potassium-based, nitrogen-based, ammonium-based, blends, etc.). The second dataset is an estimate of fertilizer consumption per hectare. Table 4.17 below shows the two datasets:

Table 4.17: Tanzania Fertilizer Imports vs. Fertilizer Consumption (2002–2012)

	2002	2003	2004	2005	2006
Tanzania Fertilizer Imports (tons)	109,419	91,777	164,554	205,793	160,594
Tanzania Fertilizer Consumption (tons/1,000 ha)	2.69	3.21	3.96	4.43	4.47

	2007	2008	2009	2010	2011	2012
Tanzania Fertilizer Imports (tons)	163,533	194,709	258,735	261,662	284,400	157,455
Tanzania Fertilizer Consumption (tons/1,000 ha)	4.33	4.06	6.20	4.99	-	-

Source: FAO

Testing the elasticity of each versus GDP growth, the following results are obtained:

[1] Source: http://www.thecitizen.co.tz/News/Business/Tanga-Cement--TRL-sign-transport-deal/-/1840414/3131854/-/2m6spk/-/index.html According to this article, the deal would pave the way for TRL to transport over 35,000 tons of cement per month, which is equivalent to one-third of Tanga's existing monthly production of 105,000 tons.

Table 4.18: Elasticity of Tanzania Fertilizer Imports and Consumption to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Fertilizer Imports	1.141	0.0120
Tanzania Fertilizer Consumption	1.091	0.0038

Source: FAO, World Bank, JICA Study Team

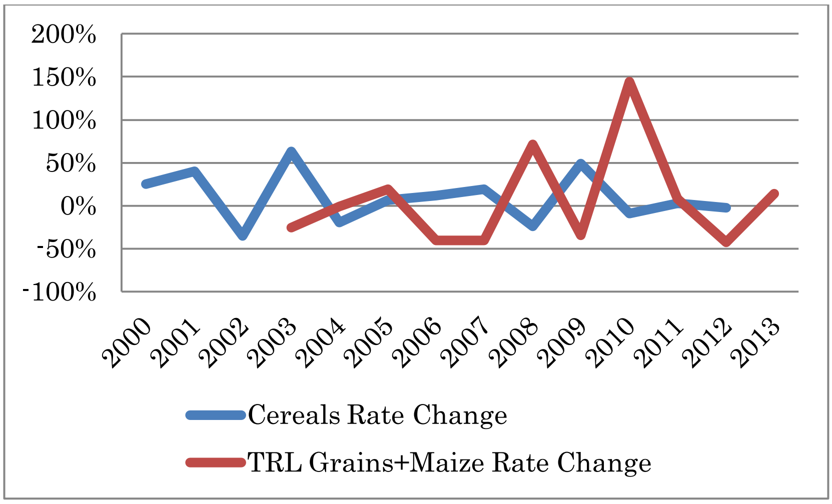
From Table 4.18 above, it is seen that a much more statistically significant relationship exists for the consumption dataset. This is likely because of inconsistencies in the import data; for example, in some years, there may be missing data for a certain type of fertilizer but not another, etc.

Therefore, the elasticity derived from the fertilizer consumption dataset will be used in lieu of the import statistics dataset. The demand forecast will use an elasticity of 1.091, and a base year value of 19,881 tons.

(9) Grains/Maize (Cereals)

Traffic demand in TRL for cereals, broken up into grains and maize in TRL accounting, has been extremely erratic over the past ten years. However, they constitute a major share of TRL traffic, warranting a detailed examination.

The Government of Tanzania has periodically used protectionist economic policies, issuing export bans on staple foods during poor harvest years in an attempt to keep prices down for domestic consumers. These policies were frequently applied to maize production, in particular. However, these policies proved to have the opposite effect, as producers reduced their production levels even further, leading to massive swings in production. In September 2012, Prime Minister Pinda lifted the ban on such exports. The erratic effects both on production and TRL traffic can be seen below in Figure 4.2, which shows national production alongside TRL traffic, and which plots their rates of change against each other.



Source: TRL, JICA Study Team

Figure 4.2: Rates of Change for Tanzania Cereals Production vs. TRL Grains and Maize Traffic

It is said that Tanzania could become a cereals supplier for East Africa as a whole, now that the export bans are lifted and seemingly will not return (USAID, et al., studied and publicized their harmful effects).

Table 4.19: Tanzania Grains and Maize Production, 2001–2013

	2001	2002	2003	2004	2005	2006
Tanzania Grains Production (1,000 tons)	1,876	1,951	1,486	2,039	2,245	2,302
Tanzania Maize Production (1,000 tons)	2,682	4,437	2,648	4,681	3,170	3,460

	2007	2008	2009	2010	2011	2012	2013
Tanzania Grains Production (1,000 tons)	2,725	2,195	2,466	3,895	3,607	3,005	3,500
Tanzania Maize Production (1,000 tons)	3,700	5,480	3,373	4,781	4,388	5,152	5,404

Source: FAO

Testing the elasticity of each versus GDP growth, the following results are obtained:

Table 4.20: Elasticity of Tanzania Grains and Maize Production to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Grains Production	0.937	0.0001
Tanzania Maize Production	0.622	0.0170

Source: FAO, World Bank, JICA Study Team

From these results, it is apparent that the various protectionist policies directed at maize had a particularly severe impact on the sensitivity of its growth to GDP growth. While the elasticity of 0.622 is statistically significant, it is a product of agricultural policies that no longer exist. Therefore, it is best to use the value for grains production, as realistically, grains and maize production should be very closely tied.

The demand forecast will use an elasticity of 0.937, and a base year value of 31,097 tons for grains and 43,794 tons for maize.

(10) Coffee

Coffee is Tanzania's largest export crop, due to intense international demand (the lead country being Japan). Domestic demand is incredibly low, only about 2% of all produced coffee is consumed in Tanzania, where tea is preferred.

Tanzania has a Coffee Industry Development Strategy 2011–2021, which aims to increase production to 100,000 tons, doubling production from the time of its inception.

Production data of unroasted coffee (green coffee) is available from the United States Department of Agriculture (USDA), as shown below in Table 4.21:

Table 4.21: Tanzania Coffee (Green) Production (2001–2013)

	2001	2002	2003	2004	2005	2006	
Tanzania Coffee Production (tons)	48,540	37,440	49,440	36,720	64,200	36,600	
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Tanzania Coffee Production (tons)	54,900	44,400	69,000	36,000	63,000	33,900	70,800

Source: USDA

Coffee is a biennial crop, and because of this, production data comes in pairs: a high-year and a low-year. Because of this, directly comparing it to GDP is challenging. The table below shows the results of an analysis using a two-year rolling average of both coffee production and GDP values, to attempt to stabilize the data:

Table 4.22: Elasticity of Tanzania Coffee (Green) Production to GDP

	vs. Tanzania GDP	
	elasticity	**p-value**
Tanzania Coffee Production	0.202	0.0228

Source: USDA, World Bank, JICA Study Team

For coffee, the demand forecast will use an elasticity of 0.202, and a base year value of 17,253 tons.

(11) Salt

The Tanzania Ministry of Energy and Minerals (MEM), via the United States Geological Service (USGS), releases statistics and salt production in Tanzania. Table 4.23 below shows production performance in recent years:

Table 4.23: Tanzania Salt Production, 2001–2012

	2001	2002	2003	2004	2005	2006
Tanzania Salt Production (tons)	65,000	65,650	58,978	57,062	135,410	34,798
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Tanzania Salt Production (tons)	35,224	25,897	28,444	34,455	32,297	34,016

Source: MEM/USGS

These data show that the level of production has been more or less stable after a significant drop that took place in 2006. Taking this trend into account, it will be assumed that the production and traffic levels of salt will continue to be stable, and that the base year traffic is decreased from the 2001-04 level by a factor of 0.524, which was computed from salt production figures as shown in the table below.

Table 4.24: Average Salt Production in 2001-04 and 2009-12

	(i) Average in 2001-04	(ii) Average in 2009-12	(ii)/(i)
Tanzania Salt Production (tons)	61,673	32,303	0.524

Source: MEM/USGS, JICA Study Team

Therefore, for salt, a constant traffic amount of 13,516 tons will be used.

(12) Sugar

Demand for sugar in Tanzania is extremely high. At present, Tanzania produces about 330,000 tons of both industrial and domestic sugar, but demand is estimated at 590,000 tons. The gap in production is actually met by illegal imports smuggled into the country.

For the 2014/2015 fiscal year, the Sugar Board of Tanzania banned imports of domestic sugar, and only permitted imports of industrial sugar, by permit. The Board introduced a plan to increase production to 540,000 tons by 2016, a goal that is unlikely to be met as early as planned. Table 4.25 below shows production data for sugarcane and raw, centrifugal (processed) sugar in Tanzania, via FAO:

Table 4.25: Tanzania Sugarcane and Processed Sugar Production, 2001–2013

	2001	2002	2003	2004
Tanzania Sugarcane Production (tons)	1,500,000	1,750,000	2,000,000	2,000,000
Tanzania Raw, Centrifugal Sugar Production (tons)	135,000	163,000	218,000	211,000
Yield (%)	9.0%	9.3%	10.9%	10.5%

	2005	2006	2007	2008
Tanzania Sugarcane Production (tons)	2,300,000	2,480,000	2,440,000	2,500,000
Tanzania Raw, Centrifugal Sugar Production (tons)	278,000	257,000	267,000	286,000
Yield (%)	12.1%	10.4%	10.9%	11.4%

	2009	2010	2011	2012	2013
Tanzania Sugarcane Production (tons)	2,700,000	3,000,000	3,021,000	2,717,000	2,992,000
Tanzania Raw, Centrifugal Sugar Production (tons)	286,000	289,000	284,000	330,000	333,000
Yield (%)	10.6%	9.6%	9.4%	12.1%	11.1%

Source: FAO

A yield of 7% or less indicates poor quality sugarcane or processing techniques, while 10% or greater is considered ideal. The yields in Tanzania are generally high, indicating that production is healthy and should continue to increase. Testing the elasticity of processed sugar production versus GDP growth, the following results are obtained:

Table 4.26: Elasticity of Processed Sugar Production to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Raw, Centrifugal Sugar Production	0.911	0.0000

Source: FAO, World Bank, JICA Study Team

For sugar, the demand forecast will use an elasticity of 0.911, and a base year value of 43,627 tons.

(13) Timber

A large share of timber production in Tanzania comes from the vast Eastern Arc Mountains, through which the Central Railway passes. However, it is believed that most of the timber production from this region is consumed more locally, in cities within the mountain range (Iringa and Morogoro) and their surrounding settlements, and only about 10% of the produced timber in this area makes its way to Dar es Salaam. (Timber production is generally reported in volume, and not in tonnage.)

As for the rest of the sources of timber in Dar es Salaam, it is more difficult to determine, as no direct study has been conducted. With no clear direct domestic source area (unlike for the cities in the Eastern Arc Mountains area), it is possible that a great deal of it is from illegal logging, and from northern regions, both of which are reasons that it would not find its way onto the Central Railway and instead be transported via trucking.

Nevertheless, a major source of timber consumption is for the production of wood-based charcoal. Timber yields charcoal at a ratio of about 25%, which is inefficient, but nevertheless cheaper than other alternatives (such as propane). FAO keeps statistics on wood-based charcoal production, as shown below in Table 4.27:

Table 4.27: Tanzania Wood-Based Charcoal Production (2001–2013)

	2001	2002	2003	2004	2005	2006
Tanzania Wood-Based Charcoal Production (1,000 tons)	1,203	1,243	1,285	1,328	1,372	1,416

	2007	2008	2009	2010	2011	2012	2013
Tanzania Wood-Based Charcoal Production (1,000 tons)	1,462	1,509	1,558	1,609	1,658	1,658	1,762

Source: FAO

Testing the elasticity of wood-based charcoal production versus GDP growth, the following results are obtained:

Table 4.28: Elasticity of Wood-Based Charcoal Production to GDP

	vs. Tanzania GDP	
	elasticity	**p-value**
TanzaniaWood-Based Charcoal Production	0.459	0.0000

Source: FAO, World Bank, JICA Study Team

For timber, the demand forecast will use an elasticity of 0.459, and a base year value of 11,380 tons.

(14) Tobacco

Tobacco is farmed throughout Tanzania, and generally sent to Morogoro for processing. After completion of the Ten Year Tobacco Production Programme, it was reported that 120,000 tons of tobacco leaves were harvested (versus 27,423 tons in 2002). Tobacco processing requires a large amount of firewood, and while there are recent efforts to limit deforestation in Tanzania, it is unlikely that the demand for tobacco products will decrease as a result of this. Table 4.29 below shows production values for raw tobacco:

Table 4.29: Tanzania Raw Tobacco Production (2001–2013)

	2001	2002	2003	2004	2005	2006
Tanzania Raw Tobacco Production (tons)	24,522	27,423	28,000	34,000	47,000	52,000

	2007	2008	2009	2010	2011	2012	2013
Tanzania Raw Tobacco Production (tons)	50,600	50,800	58,700	60,900	130,000	120,000	86,359

Source: FAO

Testing the elasticity of raw tobacco production versus GDP growth, the following results are obtained:

Table 4.30: Elasticity of Raw Tobacco Production to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Raw Tobacco Production	1.889	0.0000

Source: FAO, World Bank, JICA Study Team

For tobacco, the demand forecast will use an elasticity of 1.889, and a base year value of 21,652 tons.

(15) Livestock

Tanzania has one of the highest livestock to human ratios in Africa. Three-fifths of rural households report income from livestock activities, earning on average 22% of their income from this. Demand is growing as urban areas grow and incomes rise. A good measure of the demand for livestock transport is the amount of processed primary cattle goods (i.e., meats) that are produced. Table 4.31 below shows the growth in production:

Table 4.31: Tanzania Cattle Meat Production (2001–2013)

	2001	2002	2003	2004	2005	2006
Tanzania Cattle Meat Production (1,000 tons)	181	182	183	184	205	209

	2007	2008	2009	2010	2011	2012	2013
Tanzania Cattle Meat Production (1,000 tons)	181	219	225	244	263	290	300

Source: FAO

Testing the elasticity of cattle meat production versus GDP growth, the following results are obtained:

Table 4.32: Elasticity of Cattle Meat Production to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Cattle Meat Production	0.639	0.0000

Source: FAO, World Bank, JICA Study Team

For livestock, the demand forecast will use an elasticity of 0.639, and a base year value of 15,390 tons.

(16) Cotton/Cotton Cake

Recently (2014), the Government of Tanzania has successfully courted Chinese companies to invest heavily in expanding production in the Shinyanga region. The cotton plant yields two commodities: the cotton itself, and the byproduct of cotton cake, cotton seeds are smashed and processed into feed for cattle or other livestock, providing another source of income for farmers and making it an attractive crop. Production data is shown below in Table 4.33.

Table 4.33: Tanzania Cotton and Cotton Cake Production (2001–2013)

	2001	2002	2003	2004	2005	2006
Tanzania Cotton Production (1,000 tons)	50	61	51	114	125	44
Tanzania Cotton Cake Production (1,000 tons)	153	81	120	200	225	82

	2007	2008	2009	2010	2011	2012	2013
Tanzania Cotton Production (1,000 tons)	67	124	89	60	69	109	87
Tanzania Cotton Cake Production (1,000 tons)	125	228	170	168	103	142	224

Source: FAO

Testing the elasticity of cotton/cotton cake production versus GDP growth, the following results are obtained:

Table 4.34: Elasticity of Cotton/Cotton Cake Production to GDP

	vs. Tanzania GDP	
	elasticity	p-value
Tanzania Cotton Production	0.485	0.2420
Tanzania Cotton Cake Production	0.371	0.3746

Source: FAO, World Bank, JICA Study Team

Although the estimated p-values are relatively high due to the erratic production levels over the period, there has been an increasing trend for both cotton and cotton cake production[2], which is considered to reflect a positive correlation with GDP growth. Therefore, a judgment is made that the demand forecast will use an elasticity of 0.485 and a base year value of 34,137 tons for cotton, and an elasticity of 0.371 and a base year value of 16,247 tons for cotton cake.

(17) Parcels/Luggage

TRL allows customers who do not have enough cargo to fill an entire wagon to load their cargo into a “shared” container. The customer receives a ticket with a package number from the stationmaster, and retrieves their cargo at the destination station. The growth of parcels/luggage is functionally the same as the growth of “general cargo”, as is it not possible to determine the contents of this cargo. Therefore, the demand forecast for parcels/luggage will adopt the elasticity of general cargo (1.455), with a base year value of 15,825 tons.

[2] The slope of the trend line for both cotton and cotton cake production is positive over the period 2001-2013.

(18) Transit Cargo (Neighboring Countries' Traffic)

One methodology for determining transit containers is the same as the methodology for forecasting domestic general cargo for Tanzania, except that the traffic at the Dar es Salaam Port is tested against GDP growth for each individual country. Table 4.35 below shows the results of these analyses:

Table 4.35: Elasticity of Dar es Salaam Port Transit Imports and Exports to Neighboring Countries' GDP (constant 2005 US$)

	vs. country's GDP	
at Dar es Salaam Port	**elasticity**	**p-value**
Uganda Imports + Exports	0.842	0.6541
Rwanda Imports + Exports	3.152	0.0002
Burundi Imports + Exports	2.398	0.1264
DRC Imports + Exports	1.809	0.0066
Weighted Average	2.325	

Note: Container and break-bulk only; liquid cargo data is incomplete and was excluded
Source: TPA, World Bank, JICA Study Team

A weighted average of these elasticity values would be 2.325, by using each country's contribution to traffic at the port. The weightings are as follows: Rwanda: 32.0%; Burundi: 14.3%; DRC: 53.8%. Uganda is excluded from this weighted average because of its erratic traffic levels as represented by its high p-value (it is mostly served by Mombasa Port / the Northern Corridor).

The initial GDP growth rate (for the forecast up to 2023) will be set at 6.19%, a weighted average of Rwanda, Burundi, and the DRC's GDP values, as per Table 4.36. The base year traffic volume will be 1,529,840 tons, the 2001–2004 average.

Table 4.36: GDP Growth Rate for Transit Cargo

	2002–2012 Average	Weighting	2014 Composite
Rwanda GDP	7.6%	0.320	2.43%
Burundi GDP	3.7%	0.143	0.53%
DRC GDP	6.0%	0.538	3.23%
	Weighted Average		6.19%

Source: World Bank, JICA Study Team

(19) Mining

At present, it is not believed that significant levels of tonnage come from existing mining operations. A summary of mining potential is summarized below in Table 4.37:

Table 4.37: Summary of Mining/Resource Extraction in Tanzania

Resource	Comments
Diamonds and Gold	Tanzania is a significant producer of diamonds and gold, and most resource extraction investment is focused on this, explaining the general lack in other sectors. However, neither of these is produced on a scale significant to rail traffic, nor would they ever be transported over rail for security reasons.
Nickel	Recently, 500,000 tons were identified in Northwest Tanzania, but no plans exist to extract it.
Cooper	Recently, 75,000 tons were identified in Northwest Tanzania, but no plans exist to extract it.
Cobalt	Recently, 45,000 tons were identified in Northwest Tanzania, but no plans exist to extract it.
Ferrous Metals	Iron ores exist in great abundance in Southwest Tanzania, a region with no relevance to the Central Railway.
Tin/Tungsten	Exists in the "extreme" northwest of Tanzania, but is not considered a major potential source of traffic.
Gemstones, including Tanzanite	Exist in abundance in various locations in the country, many of them in the south. However, none of them are a considerable source of tonnage and would be unlikely to be transported by rail, much like diamonds/gold.
Phosphate	Around 45,000 tons per year are extracted in Arusha, an area not relevant to the Central Railway.
Carbonates	Multiple carbonates have been identified, which could be a source of rare earth elements, niobium, and phosphates; however, no plans exist for their extraction, and none of them are a considerable source of tonnage.
Coal	Is extracted mainly in Southern Tanzania, and is not relevant to the Central Railway.

Source: Tanzania Mineral & Mining Sector Investment and Business Guide, RAHCO/CPCS, JICA Study Team

As for potential traffic from current or new projects in neighboring countries, these projects as well are surrounded by too much uncertainty. Therefore, any adjustments to include potential domestic/international traffic from resource extraction have been excluded from the demand forecast.

However, we will make note of one major potential source of traffic: nickel mining in Burundi. Massive nickel deposits (150 million tons) were discovered in Burundi in 1974, but no mining has ever occurred, because of poor infrastructure, the civil war, and various other problems. However, in May 2014, the Council of Ministers of the Government of Burundi granted Burundi Mining Metallurgy (BMM) an exploitation permit (following the 2008 exploration permit). However, as with any other private-sector mega-project, there is still uncertainty surrounding the project. The mining could yield between 1-5 million tons per year; Table 4.38 shows the potential exports and required inputs of this project. The project has not been included in the demand forecast at this time, but should be monitored.

Table 4.38: Potential Burundi Nickel Mining Exports and Inputs (thousands)

Total Mine Production	Output for Export	Inputs: Gas	Inputs: Hydrolysis
1,000	469	111	14
2,000	938	177	23
3,000	1,407	266	34
5,000	2,345	434	56

Source: BMM, via CANARAIL

(20) Assumptions of GDP Growth

The initial GDP growth rate (for the forecast up to 2023) for Tanzania, and the neighboring countries, was established at 7.0% and 6.19%, respectively (Section (1) and (18)).

In order to approximate the decline in GDP growth over time, starting in 2024 the rates are assumed to decrease at a factor of 2% per year for Tanzania and 1.5% per year for neighboring countries as it was considered reasonable to assume that the GDP growth rate would be comparable among these countries in the long run (e.g., in 30 years). Using these assumptions, the resulting GDP growth rates for Tanzania and the neighboring countries gradually decrease to 4.4% per year by 2046 as shown in the table below. These rates will be used for future analyses.

Table 4.39: GDP Growth Rate Assumptions

Year	2014	2016	2021	2026	2031	2036	2041	2046
Tanzania GDP Growth Rate	7.0%	7.0%	7.0%	6.6%	6.0%	5.4%	4.9%	4.4%
Neighboring Countries' GDP Growth Rate	6.2%	6.2%	6.2%	5.9%	5.5%	5.0%	4.7%	4.4%

Source: JICA Study Team

(21) Assumptions of Elasticity Change

Based on the previous sections, the initial elasticity values for commodities relative to GDP growth rates were calculated as follows:

Table 4.40: Initial Elasticity Values for Commodities

Commodity	Elasticity vs. GDP
Cement	1.610
Coffee	0.202
Cotton	0.485
Cotton Cake	0.371
Fertilizer	1.091
General Cargo	1.455
Grains	0.937
Gypsum	1.610
Livestock	0.639
Maize	0.622
Parcels/Luggage	1.455
Petroleum/Oil	1.056
Salt†	--
Sugar	0.911
Timber	0.459
Tobacco	1.889
Transit Cargo††	2.325

† Kept at no growth (see Subsection (11)).
†† Versus neighboring countries' GDP growth rate, not Tanzania's.
Source: JICA Study Team

From 2024 onward, these elasticity values were de-escalated, considering that the production of bulk commodities generally tends to grow at an increasingly slower pace relative to GDP as the economic growth progresses, and that the rail share in cargo hauling tends to decrease due to increasing competition with trucking. The elasticity values are de-escalated as per the following assumptions:

Table 4.41: Year 2024 Onward, Elasticity Forecast Assumptions

Type of Cargo	Forecast Reduction	Considerations Made
High-Elasticity Commodities (Cement, General Cargo, Gypsum, Parcels/Luggage, Tobacco)	• Starting at 1.2 in 2024 • Gradual decrease to 1.0 by 2033 • Gradual decrease to 0.8 by 2046	• For general cargo, relevant international trade is expected to continue to grow faster than GDP but the pace would slow down gradually. In addition, competition with trucking would be intensified, expected to cause a slower increase in rail traffic of general cargo than GDP in the 30-year period. • The production of construction materials is also expected to continue to grow faster than GDP due to a high construction demand as the developing economy grows. The pace would, however, be slower in the longer term as the country's economy is shifted gradually toward the tertiary sector, thereby leading to slower growth in construction material production than GDP in the 30-year period.
Low-Elasticity Commodities (Coffee, Cotton, Cotton Cake, Fertilizer, Grains, Livestock, Maize, Petroleum/Oil, Salt, Sugar, Timber)	• Gradual decline by a factor of 1.5% per year throughout the forecasting period (2024-2046)	• Production for these low-elasticity crops and agriculture-related inputs/byproducts is expected to grow even more slowly relative to GDP growth in the medium to long term. Transport of these bulky commodities would also increasingly face competition with trucking that is expected to be more efficient in the future. • It is therefore reasonable to assume that the elasticities for these commodities will decline but at a slow and gradual pace, which can be represented by the assumption that was set out here.
Transit Cargo (All types)	• Starting at 1.4 in 2024 • Gradual decrease to 0.8 by 2033 • Held constant at 0.8 through 2046	• In the medium term, international trade of the neighboring countries would continue to grow faster (relative to GDP growth) than that of Tanzania as trade potential of these countries is unleashed. Therefore, the elasticity as of 2024 was assumed to be higher than that of domestic (Tanzania's) general cargo. • While the transit cargo would consist mostly of general cargo in the short to medium term, the proportion of bulk commodities such as primary commodities would increase in the long run. Since production of these commodities would grow more slowly than GDP, it was judged reasonable to assume that the elasticity for transit cargo will decline relatively fast.

Source: JICA Study Team

The accelerated declines for high-elasticity commodities and transit cargo provide a conservative assumption for growth over the long forecasting period. Table 4.42 displays the 2046 (Year 30) elasticity values, following these assumptions:

Table 4.42: 2046 (Year 30) Elasticity Values for Commodities

Commodity	Elasticity vs. GDP
Cement	0.80
Coffee	0.14
Cotton	0.34
Cotton Cake	0.26
Fertilizer	0.77
General Cargo	0.80
Grains	0.66
Gypsum	0.80
Livestock	0.45
Maize	0.44
Parcels/Luggage	0.80
Petroleum/Oil	0.75
Salt	0.00
Sugar	0.64
Timber	0.32
Tobacco	0.80
Transit Cargo†	0.80

† Versus neighboring countries' GDP growth rate, not Tanzania's.
Source: JICA Study Team

(22) Combined Traffic Demand Forecast: 2014 vs. 2023

Using the parameters established in the previous section, the full freight demand forecast is derived as below. Table 4.43 displays the total freight tonnage for benchmark years; Table 4.44 displays the individual commodity tonnage and share in 2046 (Year 30); Figure 4.3 displays the forecasted total cargo for 2014-2046.

Table 4.43: TRL Tonnage Demand Forecast

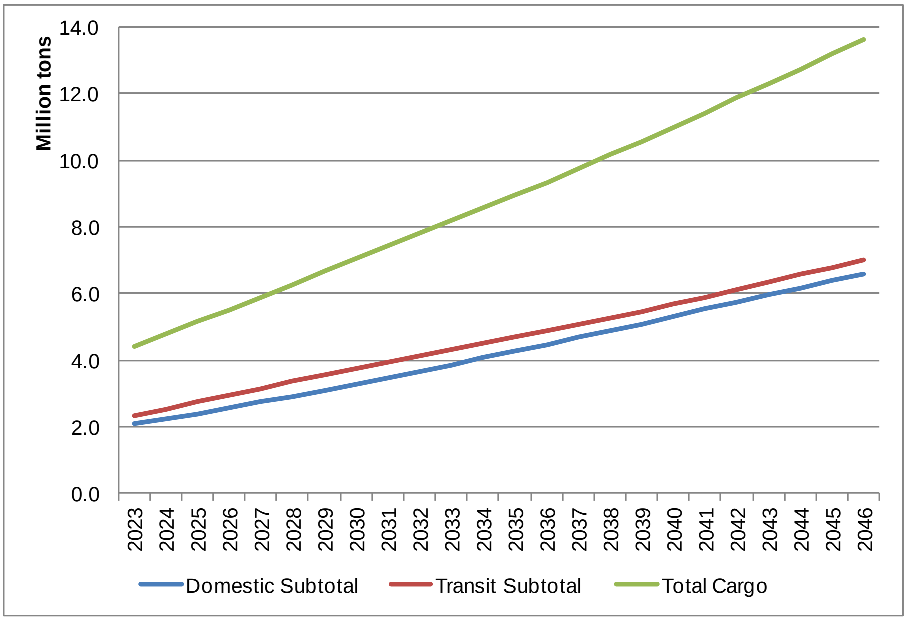
Year	2023	2026	2031	2036	2041	2046
Total Tons	4,429,172	5,520,517	7,429,756	9,342,098	11,420,273	13,633,120

Source: JICA Study Team

Table 4.44: Combined Commodity Traffic Demand Forecast, 2046 (Year 30)

	Commodity	Tons	Share
Domestic	Cement	961,854	7.1%
	Coffee	24,682	0.2%
	Cotton	80,100	0.6%
	Cotton Cake	31,263	0.2%
	Fertilizer	131,157	1.0%
	General Cargo	3,354,452	24.6%
	Grains	158,267	1.2%
	Gypsum	150,291	1.1%
	Livestock	47,114	0.3%
	Maize	130,208	1.0%
	Petroleum/Oil	874,277	6.4%
	Salt	13,516	0.1%
	Sugar	212,477	1.6%
	Timber	25,523	0.2%
	Tobacco	258,246	1.9%
	Parcels/Luggage	143,824	1.1%
	Domestic Subtotal	6,597,252	48.4%
Transit	**Transit Subtotal**	7,035,868	51.6%
	Grand Total	13,633,120	100.0%

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3: Forecasted Total Cargo (2023 to 2046)

4.2.2 Passenger

(1) TRL Passenger Rail Performance

TRL operates two forms of passenger rail services: a "commuter rail" which operates a 12 km route between Dar es Salaam Central Station and Ubungo Maziwa, the location of an important bus terminal, and the traditional long-distance "passenger rail", with services from Dar es Salaam to Kigoma and Mwanza. Table 4.45 below shows TRL performance for passenger rail, from 1991–2014:

Table 4.45: TRL Passenger Rail Traffic, 1991–2014

Year	Passengers	Year	Passengers
1991	1,714,000	2003	683,481
1992	1,442,000	2004	627,969
1993	1,747,000	2005	674,029
1994	1,517,000	2006	594,089
1995	1,251,000	2007	585,310
1996	1,009,000	2008	458,846
1997	557,000	2009	543,001
1998	570,000	2010	290,358
1999	617,000	2011	373,218
2000	631,000	2012	506,934
2001	727,851	2013	492,377
2002	684,796	2014	295,490

Source: TRL

This traffic has fluctuated greatly over time for two main reasons: (i) bus options for inter-city transport have greatly expanded over this time, largely driven by an ever-growing import market for second-hand buses and mini-buses; and (ii) in more recent years, the decline in TRL traffic during the concession years further pushed more passengers to choose buses.

(2) Forecast Parameters

Passenger Tendencies

However, a market for passenger rail still exists: it is generally cheaper than buses for long-distance trips (cross-country, for example), and it also allows people relocating or moving business goods to bring their cargo on the same train as parcels/luggage.

Base-Year Figure

In determining a base-year figure for passenger rail demand, a figure of 1,000,000 passengers per year in 2023 was selected, for two reasons: (i) examining previous traffic, 1996 (1,009,000 passengers) was the last year before a major drop-off in ridership, due to a decrease in train frequency; and (ii) the CANARAIL traffic demand forecast, following a gravity model / O-D pair methodology, set a 2020 traffic level of 1,075,000 passengers per year.

Growth Rate Assumption

Population growth would be one major factor for the future increase in intercity railway passenger traffic. According to the 2012 Revision of the World Population Prospects by the United Nations,[3] the population of Tanzania is projected to increase as shown in Table 4.46 for the medium-variant fertility rate case.[4] The annual average growth rate in 2023–2046 is about 2.6% per year.

[3] Source: http://esa.un.org/wpp/
[4] There are multiple fertility rate cases produced by the UN: high, low, medium, instant-replacement-fertility, constant-fertility, constant-mortality, no change, and zero-migration. For a description of each case, refer to the UN World Population Prospects Methodology website: http://data.un.org/Resources/Methodology/PopDiv.htm

Table 4.46: Tanzania Population Projection (Medium-Variant Fertility Case)

Year	Projected Population	Year	Projected Population
2023	65,633,689	2035	90,506,522
2024	67,459,562	2036	92,865,708
2025	69,329,165	2037	95,265,661
2026	71,243,658	2038	97,704,076
2027	73,203,092	2039	100,178,146
2028	75,207,959	2040	102,685,558
2029	77,258,385	2041	105,224,765
2030	79,354,326	2042	107,795,085
2031	81,495,828	2043	110,396,126
2032	83,682,691	2044	113,027,891
2033	85,914,157	2045	115,690,083
2034	88,189,152	2046	118,381,971

Source: UN Population Division

The overall intercity railway passenger traffic would also be affected by the country's income levels, which can be measured by per capita GDP. Therefore, the passenger traffic demand is assumed to increase at the growth rates of GDP (population times per capital GDP) that were used for the freight demand forecast. The rates (as first presented in Table 4.39) are reproduced below.

Table 4.47: GDP Growth Rate Assumptions for Passenger Traffic Demand Growth

Year	2014	2016	2021	2026	2031	2036	2041	2046
Tanzania GDP Growth Rate	7.0%	7.0%	7.0%	6.6%	6.0%	5.4%	4.9%	4.4%

Source: JICA Study Team

(3) Passenger Rail Demand Forecast

Using the parameters established in the previous section, the passenger demand forecast is derived as in Table 4.48:

Table 4.48: TRL Passenger Rail Demand Forecast, 2023–2046

Year	Passengers	Year	Passengers
2023	1,000,000	2035	2,047,246
2024	1,068,600	2036	2,157,452
2025	1,140,440	2037	2,271,268
2026	1,215,576	2038	2,388,692
2027	1,294,061	2039	2,509,718
2028	1,375,942	2040	2,634,331
2029	1,461,262	2041	2,762,517
2030	1,550,061	2042	2,894,251
2031	1,642,373	2043	3,029,506
2032	1,738,226	2044	3,168,252
2033	1,837,644	2045	3,310,449
2034	1,940,646	2046	3,456,057

Source: JICA Study Team

5. Implementation of Flood Risk Assessment and Proposal for Urgent Countermeasures

5.1 Background

Until the implementation of the long-term countermeasures for flood protection to be proposed by this Study, about 5–6 years will pass. Over this period, the section between Kilosa and Gulwe will continue to be flooded. Therefore, it is necessary to undertake effective urgent protection measures before, or in the midst of, the rainy season in 2015.

In this regard, in order to confirm and to identify the most critical sections for preventive measures in the target sections, a rapid Flood Risk Assessment was conducted by walk-through and trolley between Kilosa and Gulwe at the beginning of the current study in December 2014. The results of the Flood Risk Assessment and recommendations on the urgent measures were compiled in the report of "Recommendation on Urgent Protection Measures for incoming Rainy Season 2015 (Results of Flood Risk Assessment), December 2014, JICA". The Report was submitted to MOT, RAHCO and TRL on 26 December 2014.

As for the implementation of the urgent measures, it was expected that the Government of Tanzania would finance the works, to minimize the need to spend time waiting on donor agencies or other outside sources of funding. This chapter first summarizes the results of the Flood Risk Assessment, and then presents the status of the implementation of the urgent flood protection measures by the responsible agencies in January 2016.

5.2 Objective

The objectives of the Flood Risk Assessment were to:

(1) To clarify the current conditions of the crucial railway section between Kilosa and Gulwe,
(2) To screen the high-risk areas to be protected, and
(3) To formulate a plan of urgent protection measures to cope with the anticipated floods in rainy season of 2015 (and onward).

5.3 Schedule

The field reconnaissance was conducted by both the Railway Group and River Group of the Study Team, together with the staff of RAHCO and TRL, by dividing into four parties. The daily schedule and responsible railway sections investigated by each party are tabulated in Table 5.1.

Table 5.1: Field Reconnaissance Schedule of Flood Risk Assessment

Date	Activities	Railway Sections Inspected
1 Dec. 2014 (Mon.)	General field reconnaissance (all members together) – Day 1	Kilosa→Kidete→Gulwe→Dodoma
2 Dec. (Tue.)	Detailed field reconnaissance Day 2	Dodoma→Gulwe⇔Godegode
3 Dec. (Wed.)	Do – Day 3	Godegode⇔Kidete
4 Dec. (Thu.)	Do – Day 4	Kidete ⇔ Km 300 (2 km from Munisagara Station)
5 Dec. (Fri.)	Do – Day 5	Kidete ⇔ Km 300

Source: JICA Study Team

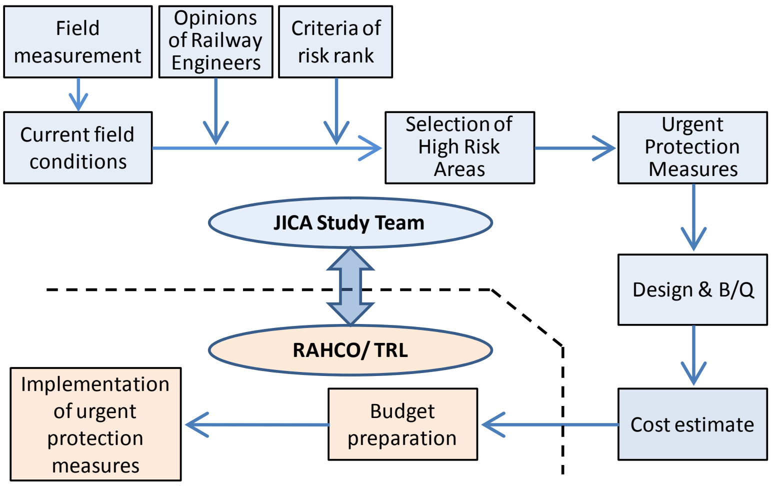
Each group consisted of staff from RAHCO/TRL, JICA Study Team members, and local supporting staff of the Study Team. A total of 13 people participated in the field reconnaissance of the Flood Risk Assessment. Railway Group "A" mainly inspected sites by trolley, while the three River Groups ("B", "C", and "D") conducted field measurements mainly by walkthrough for four days, from Day 2 to Day 5.

5.4 Methodology

(1) Procedure

Figure 5.1 shows the applied procedure of the Flood Risk Assessment. The procedure was set up in accordance with the Minutes of Meetings on the current Preparatory Survey between the Ministry of Transport and JICA (August 2014). This procedure was explained at the Technical Committee Meeting on 12 December 2014 and accepted by the Tanzanian side. The key concept on implementation by use of its own financial resources of the Government of Tanzania was applied, in consideration of the proposed speedy implementation of the protection measures by the JICA Study Team.

Although originally, cost estimates were assumed to be conducted by the initiative of RAHCO/TRL, mainly due to lack of human resources, the JICA Study Team conducted the cost estimates by itself, in reference to the price list of major work items provided by RAHCO to the Study Team.



Source: JICA Study Team

Figure 5.1: Procedure of Flood Risk Assessment

(2) Field Measurement

The measurements conducted at the field particularly aimed to confirm the current status of railway track embankments against riverbank erosion, as shown in Figure 5.2. The distances between riverbanks and track embankments, and height of riverbanks were measured by tape and staff gauge. In order to secure the stability of the track embankments and their foundation against riverbank erosion, the approximate horizontal length of 5 m from the center of railway track was offset, considering the stability of embankments themselves, as illustrated in Figure 5.2. The results were recorded in the form of an "Inventory Sheet of Channel" and are complied in Appendix E.

On the other hand, since the current status of culverts is one of the most crucial issues to assess flood risk in the target railway sections, major dimensions such as width, height (opening height) and length of each culvert were measured, as shown in Figure 5.3. The results were recorded in the form of an "Inventory Sheet of Culvert" and are complied in Appendix F.

Field Measurements for River Bank Erosion

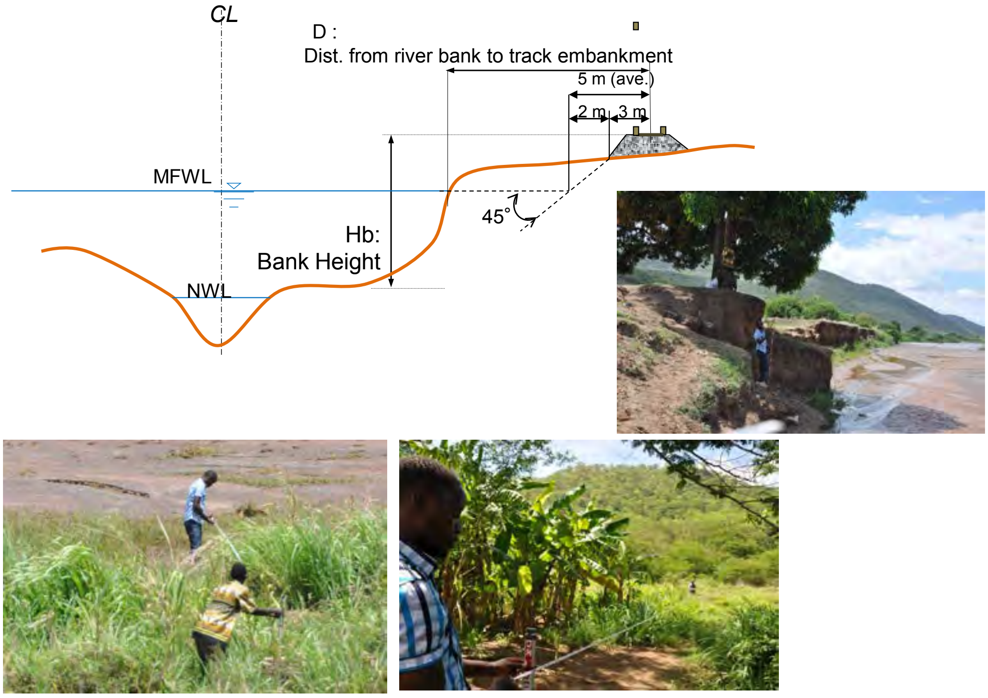


Figure 5.2: Field Measurement of Riverbank Erosion

Field Measurements for Culvert

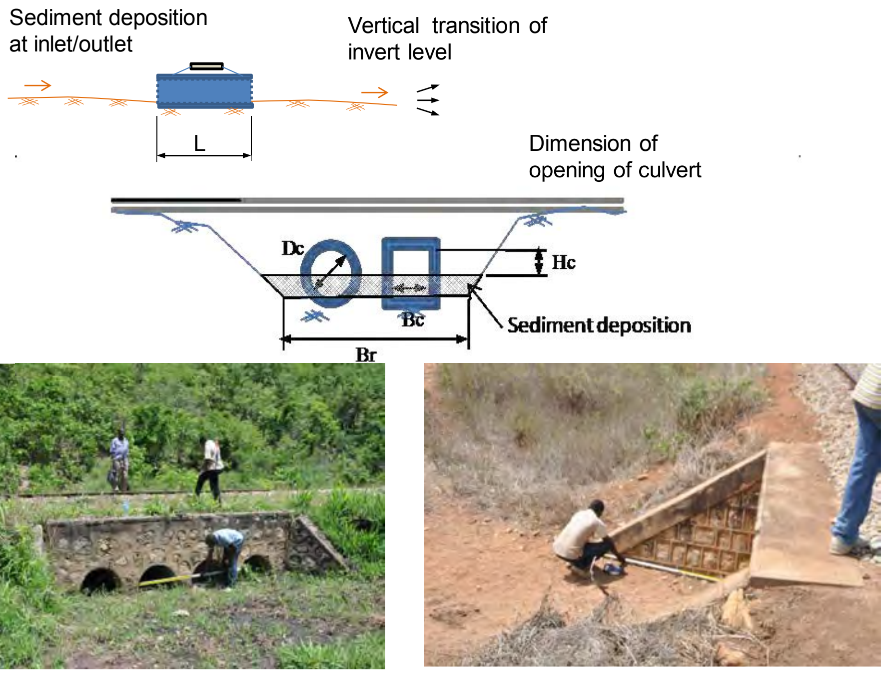


Figure 5.3: Field Measurement of Culvert

(3) Notable Characteristics of River Channel and Conditions of Structures

In this section, some notable river characteristics, as well as river structures, are described in detail:

1) From Kilosa (Km282.7) to Munisagara (Km298.3)

- ❑ Construction of a new bridge at Km293 was completed in August 2014, but the height of bridge girder is almost the same as previous one.
- ❑ At many sections, the riverbed has been aggravated and threatened by overtopping by floodwaters. (i.e. Km296–297 and Km298, etc.)
- ❑ The Mdukwi River meets with the Mkondoa River at Km289.8.

2) From Munisagara (Km298.3 km) to Kidete (Km325.5)

- ❑ River training works were carried out by TRL at Km302 in 2014.
- ❑ A new bridge has been completed in 2014 at 304 kmafter the shifting of the railway alignment toward the mountain side. The bridge and the railway tracks were damaged by the 2010 flood.
- ❑ Encroaching of riverbanks is progressive at Km304.
- ❑ Restoration works at Km315.0 to 315.7 to protect the riverbank are underway by TRL.
- ❑ The Lumuma River meets with the Kinyasungwe River at Km325.9.

3) From Kidete (Km325.5) to Godegode (Km349.1)

- ❑ The old dam was collapsed and huge amount of sediment was washed out to downstream due to the devastated flood in 1998. Although reconstruction of new dam (Kidete Dam) started in 1999, but it has been suspended till date because of financial issues.
- ❑ Overtopping of track embankment has been habitually occurred by floods between Km336 and 341.

4) From Godegode (Km349.1) to Gulwe (Km365.9)

- ❑ The Maswala River meets with the Kinyasungwe River at Km349.4B to 349.8B. River training works, etc., have been conducted by TRL.
- ❑ The Kidibo River meets with the Kinyasungwe River at Km355.5. In terms of a smooth flow emptying into the Kinaysingwe River, the confluence point is unfavorable.
- ❑ Many culverts having a high clogging rate of sediment deposition are observed between Km359 to 364, where the railway track is running though low-lying terrain.
- ❑ The Mzase River meets with the Kinyasingwe River at Km366. A flash flood caused heavy damages, such as the washing away a locomotive, a train, rails and ballast at the crossing box culvert on 30 March 2014.

The results of observance of river conditions during field measurements as abovementioned were utilized for selection of appropriate flood protection measures subsequently.

5.5 Selection of High-Risk Area

The results of field measurements are compiled in Appendix E and F for current channel conditions and culverts, respectively. Further, the inventory of existing structures is tabulated in the form of a “Straight Line Diagram”, with the rate of flood risk for selection of high-risk areas as attached in Appendix G.

5.5.1 Flood Damage Patterns

The flood disaster risks identified through the site inspection are classified into different types of risk, referring to the pattern of flood damages and the results of field reconnaissance as below:

(1) Riverbank Erosion

In between Kilosa and Gulwe, there is serious bank erosion along the Kinyasungwe and the Mkondoa Rivers. Rapid encroachment and retrieval of riverbank shoulder is one of crucial risks of habitual damage to the railway facilities. Therefore, as for the urgent protection measures, bank erosion should be considered.

(2) Flood Flow Overtopped Railway Track Embankment

Several railway sections have experienced overtopping by flood flows from mainstream as well as flood flows from small catchments in the hinterlands. In recent years, although TRL is suffering from frequent occurrences of such damage, the restoration works can be quickly carried out by a maintenance group (they are called a "Gang", in local terms).

(3) Clogging of Culvert

It was found that many culverts are clogged by sediment deposition, which interrupts smooth flow from the hinterlands. Associated with the clogging in barrel of culverts, some risks are found in the deterioration of the track embankment stability beside the culverts.

(4) Flooding at Confluence of Tributary

At the confluence of some tributaries with the mainstreams of the Kinyasungwe and the Mkondoa Rivers, heavy sediment deposition is observed, which will cause overtopping and lateral erosion of riverbanks near the railway alignment. The catchment areas and location map of major tributaries are shown in Table 5.2 and Figure 5.4 respectively.

Table 5.2: Catchment Areas of Major Tributaries between Kilosa and Gulwe

Code No.	Name	Catchment Area (km^2)
Gulwe	Upstream of Gulwe	12,529
L1	Muvuma	127
L2	Mkondoa	553
L3	Mangweta	1,179
L5	Sikoko	181
R1	Mdukwe	496
R4	Lumuma	656
R5	Maswala	566
R6	Kidibo	183
R7	Mzase	126
Kilosa	Subtotal d/s of Gulwe	4,066
	Total	16,595

Source: JICA Study Team

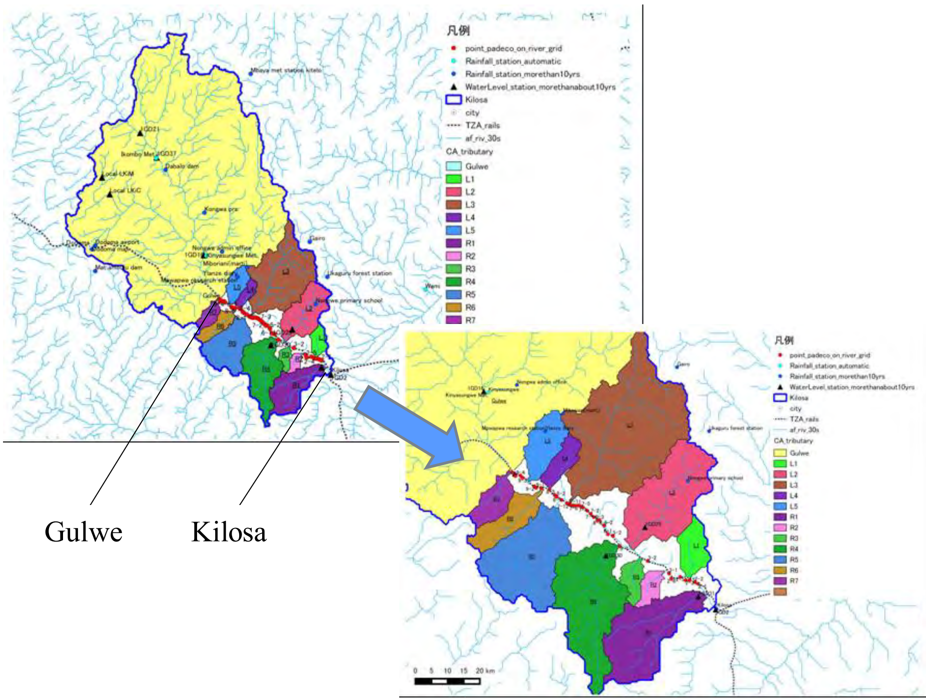


Figure 5.4: Major Tributaries of the Wami River Basin between Kilosa and Gulwe

5.5.2 Criteria

(1) Criteria for Riverbank Protection

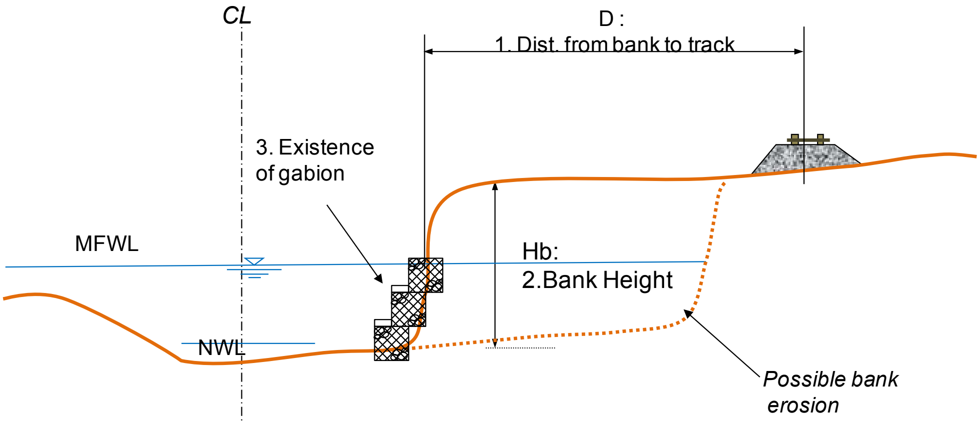
A lot of progressive bank erosions can be observed along the main river, in particular at water-hit areas of the river channel. From the viewpoint of safety of the railway against riverbank erosion, there needs to be a certain distance between the riverbank and railway track, as well as provision of urgent riverbank protection works. Taking these into account, the following three criteria for riverbank protection are adopted for the Flood Risk Assessment of riverbank erosion.

Criteria 1: Distance from riverbank to railway track (D)
Criteria 2: Riverbank height at eroded section (Hb)
Criteria 3: Sufficiency of existing revetment

Table 5.3: Criteria for Riverbank Protection

Riverbank Erosion		Criteria 1: Distance from bank to track		
Criteria 2: Bank height (Hb)	**Criteria 3: Sufficiency of existing revetment**	D < 40 m	40 m < D < 110 m	110 m < D < 180 m
Hb > 3 m	Insufficient revetment	**High**	Medium	Low
	Sufficient revetment	Medium	Low	Low
Hb < 3 m	Insufficient revetment	Medium	Low	–
	Sufficient revetment	Low	–	–

Risk Level: High: Likely damaged in next rainy season
Medium: Likely damaged in next 2–3 years
Low: Likely damaged, but not serious at present (assumed to be flood-resistant for 5 more years)
– :No Risk
Source: JICA Study Team



Source: JICA Study Team

Figure 5.5: Criteria for Riverbank Protection

Criteria 1: Distance from Riverbank to Railway Track (D)

To establish Criteria 1, the annual erosion rate of a riverbank is assumed to be 35 m/year, based on the following conditions:

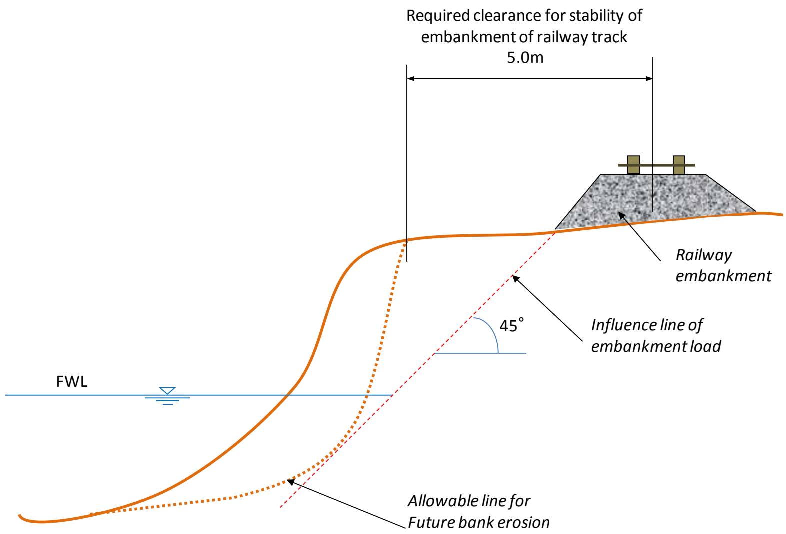
i) Empirical formula for bank erosion rate in Japan:
Be =5 x Hb (in the section of riverbed slope is gentler than 1/400)
where,
Be: Maximum bank erosion width likely occurred by an extreme flood event (m)
Hb: Riverbank height (m)

ii) Actual bank erosion rate at site (ex. around 50–70 m per 2 years for riverbank at km 315).

Referring to the said formula i), while bank height (Hb) varies at each site (ranging from 1 m to 6 m), the maximum bank erosion width likely occurred because of an extreme flood event (Be), and can be estimated between 5–30 m. This value closely corresponds to the actual bank erosion rate of items i) and ii). It is considered reasonable to adopt the annual erosion rate of 35 m/year in the objective area.

In addition to the above requirements, a required clearance of 5 m from the center of the railway track to the allowable bank line for future bank erosion is considered for the stability of embankment and foundation of the railway track as shown below.

The minimum requirement for the distance from the riverbank to the railway track against flood in one rainy season is set at 40 m (=35 m of annual erosion rate + 5 m of required clearance).

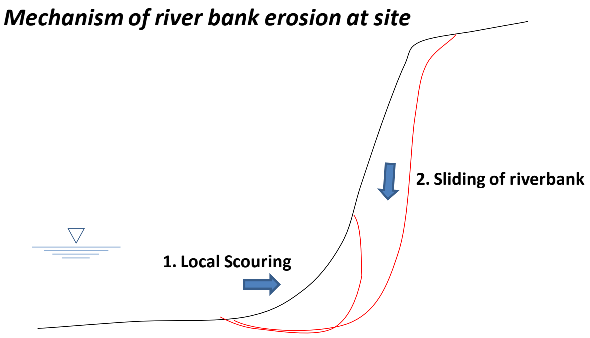


Source: JICA Study Team

Figure 5.6: Required Clearance for Stability of Embankment of Railway Track

Criteria 2: Riverbank Height at Eroded Section (Hb)

Higher riverbanks have a greater risk against bank erosion, as shown in Figure 5.7. The mechanism of riverbank erosion in the objective area is: i) at first, the toe of riverbank is eroded due to local scouring by flood, and ii) eventually the riverbank slope fails due to slope sliding. In this assessment, a bank height of 3 m is set as the criteria considering both the previously cited formula used in Japan and also a consideration of actual site conditions. In case the riverbank height is lower than 3 m, the rating of flood risk level is assessed down by one rank.



Source: JICA Study Team

Figure 5.7: Mechanism of Riverbank Erosion

Criteria 3: Sufficiency of Existing Revetment

In some erodible sections, revetments by gabion or stone masonry/stone pitching are already installed for riverbank protection of low water channel. These structures are assessed working well to protect against bank erosion at sites during the field reconnaissance. It is, therefore, the "sufficiency of existing revetment" is applied as one criterion. In case a revetment exists, the rating of flood risk is assessed down the level of one rank.

The railway sections where restoration and/or remedial works are underway by RAHCO/TRL are classified in "High-risk" area, even if the original conditions (without restoration works) are categorized as "High-risk" by the above criteria.

Further, regarding the physical factors which will affect the speed of riverbank erosion, soil characteristics, water hitting point and vegetation cover might, in general, be closely connected. However, it was concluded that these three factors for setting criteria might dominate the riverbank erosion determinations, whereas the available information about soil mechanics and current land use are insufficient. Even so, the location of the water hitting point was considered for the assessment of risk of riverbank erosion.

(2) Criteria for Treatment of Existing Culverts

As the result of field measurements of existing culverts, it was verified that some of them were completely or partially clogged at the opening of their barrel(s), and are in a dangerous state, which will cause overtopping of floodwaters on railway track, erosion of embankment and washout of ballast, etc., if the present conditions remain. RAHCO/TRL has experiences in conducting immediate protection measures, such as additional filling/fixing of ballast by concrete and placement of gabions, etc., at crossing points of culverts. Under such circumstances, there are three crucial factors which will govern the damage risk of railway are: (a) opening of barrel, (b) possibility of inundation due to clogging, and (c) existence of protection (beside railway track). Based on the combination of the factors, risk rank is divided into three categories: “High”, “Medium”, and “Low”, as follows:

Table 5.4: Criteria for Treatment of Culverts

Case	Sediment Deposition in Barrel	Possibility of Inundation due to Clogging	Existence of Protection (beside railway track)	Risk Rank
1	> 50% of height	Yes	None	**High**
2	> 50%	Yes	Exists	**High**
3	> 50%	No	None	**High**
4	> 50%	No	Exists	Medium
5	< 50%	Yes	None	Medium
6	< 50%	Yes	Exists	Medium
7	< 50%	No	None	Low
8	< 50%	No	Exists	Low

Source: JICA Study Team

It was assumed that the function of drainage would drastically deteriorate if 50% of flow areas are occupied by sediment and/or other debris.

(3) Criteria for Overtop of Track Embankment

After the field reconnaissance, it was confirmed that overtopping risks by flood occurrences still remained at many sections, although TRL continues restoration works to mitigate the damage to railway facilities. It can be observed that flood damages caused solely by the overtopping of floodwaters were not so serious, compared with damage due to riverbank erosion. As for the damages of track embankment by overtopping, remedial woks such as filling of ballast and embankment material can be practically conducted as part of TRL’s common maintenance works, even if certain minor damages occur. The areas with potential of overtopping were preliminarily identified by examination of the record of past similar flood damages. The areas were confirmed through field reconnaissance and are summarized in Section 5.5.3 (3).

In addition to the aforementioned structural measures commonly provided as part of urgent protection works by TRL, it is necessary to establish a safety management system of train operations at the time of an overtopping and/or inundation occurrence which endangers the stability of track embankment. It is also recommended that construction materials such as soil for embankment, ballast, and stones of gabions, etc., should be reserved near the designated sections which are identified as having high potential of overtopping, in order to facilitate the quick progress of urgent remedial works.

5.5.3 Selected Areas to be Protected by Urgent Measures

(1) Railway Section for Urgent Protection Measures

The selected area with "High-risk" in terms of riverbank erosion is summarized in Table 5.5.

Table 5.5: Selected Areas for Urgent Protection Measures at Riverbank

Section	Location	Existing Measures/ Structures and River Conditions, etc.	Bank Height (m)	Distance btw. Riverbank and Railway Track (m)	On-going Restoration Works by RAHCO/TRL and Proposed Plan for Urgent Protection Measures
1. From Kilosa (Km282.7) to Munisagara (Km298.3)	Km 293.0 Bridge	• A bridge was damaged by the 1998 and 2010 floods • In July 2014, it was restored by Chinese Contractor immediately upstream of the old bridge, which was composed of two bridges previously • Clearance under the bridge is reduced due to sediment deposition in the river channel • The gabion installed downstream of the bridge is damaged. • The height of the gabions on the upstream bank of the bridge are low, considering the water hitting portion and floodwaters level	2.3 m –4.5 m	-	Completed construction works - New Bridge (L = 90.0 m, W = 9.5 m, 3 spans) - Construction of gabion revetment (left: L = 66.0 m, right L = approx. 1,100.0 m) - Improvement of local drainage **Proposed Plan** • Heightening of the existing dike by gabion, L = 26.0 m • Improvement of the drainage outlet (pipe culvert D = 0.5 m) • Rehabilitation of the existing gabion L=5.0 m
2. From Munisagara (Km298.3) to Kidete (Km325.5)	301.7–302.3	• The river is curving to the left side and the railroad is located at right riverbank side, which is the water colliding front side.	3 m	5 m	On-going works Gabion installation for riverbank protection by TRL (The length covered by gabion seems insufficient; this is to be confirmed) **Proposed Plan** • Backfilling with compaction, trimming of bank slope, installation of gabion L = 700 m (In particular, extension toward upstream will be necessary)
	315.0-315.8	• In March 2014, riverbank was seriously eroded during a flood event. At present, urgent restoration works are	6.0 m	6.3 m (Km 315.2)	On-going works Around 60% completion of the urgent restoration works by TRL (Dec. 2014) - Diversion of railway

Section	Location	Existing Measures/ Structures and River Conditions, etc.	Bank Height (m)	Distance btw. Riverbank and Railway Track (m)	On-going Restoration Works by RAHCO/TRL and Proposed Plan for Urgent Protection Measures
		being undertaken by RAHCO/TRL.			track (300 m) to the inland side by 18 m - Trimming of eroded slope and backfilling at most eroded section - Installation of gabions (3 steps) at the toe of riverbank - Installation of two culverts at Km 315.0 and Km 315.7 **Proposed Plan** • None (Detailed Plan of TRL was not available in Dec. 2014: to be confirmed)
3. From Kidete (Km325.5) to Godegode (Km349.1)	337.2–337.7 (approx. 500 m)	• Previously, railway track had been diverted may times in this section. At present, serious bank erosion (approx. 35 m/year) is observed at the water hitting portion in this section, which is affected by the existence of a confluence of tributaries in the upstream area. • No bank protection is installed in the section. There is a possibility that this area will be damaged during next rainy season.	4.5 m	18 m	On-going works None **Proposed Plan** • Protection at the water-hitting point is required. - Installation of gabion - Backfilling with compaction - Trimming of riverbank slope L=550m - Spur dike L=25m @ 50m; 11 units in total • Steel frame made with used steel sleepers can be fabricated and placed around the spur dike (as an option)
4. From Godegode (Km349.1) to Gulwe (Km365.9)	349.4B – 349.9B	• Railroad culverts have been deposited by the sediment in the tributary of the Maswala River, and river flow prevention has occurred.	—	—	On-going works Canal dredging **Proposed plan** • Excavation of network channel - upstream of the railway: L = 2,500 m - downstream of railway: L = 1,500 m - Excavation of main channel L = 900 m - Channel filling with compaction - Reclamation of 2 spoil bank yards (total 73,800 m^3)

Section	Location	Existing Measures/ Structures and River Conditions, etc.	Bank Height (m)	Distance btw. Riverbank and Railway Track (m)	On-going Restoration Works by RAHCO/TRL and Proposed Plan for Urgent Protection Measures
	355.0 – 356.0 Confluence of Kidivo River,	• Bank protection of SSP (Steel Sheet Pile) at the left bank downstream of the bridge is tilted due to the pressure of back soil. It should be urgently repaired. • The existing gabion (3 steps) installed at the transition between the SSP and the original riverbank at the confluence can be heightened to protect from overtopping. • Old Kidivo River flowed across the railway at km 355.6. The river channel was diverted to the present alignment.	—	—	On-going works Construction of guide dike (around L = 200 m) at the confluence (Dec. 2014) **Proposed Plan** • The guide dike being constructed in the middle of river channel should be protected by toe and slope protection works so that it will sustain against erosion and scouring during floods. • Removal of sediment in river channel and installation of toe protection of guide dike, L=approx. 500 m • Rehabilitation of existing steel sheet pile
	366.0 Confluence of Mzase River	• A locomotive, a freight wagon as well as rails were washed away by flash flood that occurred on 28 March 2014 at the crossing point of the Mzase River. • The box culvert was heavily silted and clogged. • After the accident, the recovery of railway alignment on the culvert was immediately completed to allow the railway to pass on 1 Apr. 2014.	1.0 m – 2.0 m	—	On-going works The ballast was fixed by concrete to prevent from repeated washaways. **Proposed Plan** • Excavation along the Mzase River L = 2,000 m, W = 40 m (ave.) D = 1.0 m V = 80,000 m^3 (approx.) Including excavation of riverbed at the confluence with the Kinyasungwe River = 10,000 m^3 (approx.)

Source: JICA Study Team

(2) Culvert for Urgent Protection Measures

In accordance with the criteria as shown above, the risk rank of existing culverts between Kilosa and Gulwe were classified as tabulated in the Straight Line Diagram compiled in Appendix G and further summarized in Table 5.6. As for the proposed protection measures for culverts, the following works are recommended:

(1) Removal of debris (sediment) in the barrel of culvert
(2) Removal of debris at inlet and outlet basins and in connected canals
(3) Placement of gabion mattress to protect slope of track embankment against overtopping of floodwaters (if applicable, not included in the Bill of Quantities)

Table 5.6: Selected Culverts for Urgent Protection Measures (High-risk Area)

Section	Location (km)	Type of Culvert	Major Dimensions (m)	Proposed Plan for Urgent Protection Measures
1. From Kilosa (Km282.7) to Munisagara (Km298.3) **11 culverts**	287.15	Box Culvert	Hc0.0, Bc0.0, L6.0 (2)	(1), (2), (3)
	287.25	Box Culvert	Hc0.9, Bc7.0, L5.0 (1)	(1), (2), (3)
	287.3	Box Culvert	Hc0.1, Bc0.9, L5.0 (1)	(1), (2), (3)
	290.4	Box Culvert	Hc1.3, Bc3.0 (1)	(1), (2), (3)
	291.7	Box Culvert	Hc0.0 (1)	(1), (2), (3)
	295.1	Box Culvert	Hc0.9, Bc3.9, L3.6 (2)	(1), (2), (3)
	295.9	Box Culvert	Hc0.9, Bc3.9, L3.6 (2)	(1), (2), (3)
	297.1	Box Culvert	Hc0.8, Bc1.9, L3.6 (1)	(1), (2), (3)
	297.6	Box Culvert	Hc1.2, Bc0.9, L3.6 (1)	(1), (2), (3)
	299.3	Pipe culvert	D1.1, L3.9 (4)	(1), (2), (3)
	299.7	Pipe culvert	D1.2, L10.6 (3)	(1), (2), (3)
2. From Munisagara (Km298.3) to Kidete (Km325.5) **3 culverts**	300.1	Pipe Culvert	Hc0.2, Bc0.9, L5.0 (1)	(1), (2), (3)
	308.3	Box Culvert	Hc0.0, Bc3.6, (1)	(1), (2), (3)
	309.9	Box Culvert	Hc0.4, Bc2.0, (1)	(1), (2), (3)
3. From Kidete (Km325.5) to Godegode (Km349.1) **10 culverts**	325.70	Pipe Culvert	Hc0.36, Bc0.9, L6.0 (2)	(1), (2), (3)
	325.75	Pipe Culvert	Hc0.45, Bc0.9, L7.0 (2)	(1), (2), (3)
	333.1	Box Culvert	Hc0.4, Bc2.0, (1)	(1), (2), (3)
	334.7	Box Culvert	Hc0.9, Bc1.8, (1)	(1), (2), (3)
	334.8	Box Culvert	Hc0.5, Bc2.0, (1)	(1), (2), (3)
	335.0	Box Culvert	Hc0.5, Bc2.0, (1)	(1), (2), (3)
	336.1	Box Culvert	Hc0.85, Bc2.0, (1)	(1), (2), (3)
	347.5	Box Culvert	Hc0.5, Bc2.9, L4.0 (1)	(1), (2), (3)
	347.5	Box Culvert	Hc0.5, Bc2.0, L4.0 (1)	(1), (2), (3)
	348.0	Box Culvert	Hc0.8, Bc2.0, L4.0 (2)	(1), (2), (3)
4. From Godegode (Km349.1) to Gulwe (Km365.9) **12 culverts**	354.3	Box Culvert	Hc0.55, Bc2.0 (1)	(1), (2), (3)
	355.6	Box Culvert	Hc0.95, Bc3.0 (1)	(1), (2), (3)
	356.1	Box Culvert	Hc0.8, Bc3.0 (1)	(1), (2), (3)
	360.6	Box culvert	Hc0.6, Bc5.0, L3.6 (1)	(1), (2), (3)
	361.1	Box culvert	Hc0.6, Bc2.0, L3.7 (1)	(1), (2), (3)
	361.9	Box culvert	Hc0.3, Bc5.0, L3.6 (1)	(1), (2), (3)
	362.1	Box culvert	2 steps	(1), (2), (3)
	362.5	Pipe culvert	D0.8, L8.6 (2)	(1), (2), (3)
	362.9	Box culvert	2 steps	(1), (2), (3)
	363.3	Box culvert	Hc0.2, Bc2.0, L5.0 (2)	(1), (2), (3)
	363.7	Box culvert	Hc1.6, Bc (no data), L5.0 (1)	(1), (2), (3)
	364.2	Box culvert	Hc0.3, Bc2.5, L5.0 (2)	(1), (2), (3)
Total 36 culverts				

Note: In the "Major Dimensions" column, the number in parentheses refers to the number of barrels.
Source: JICA Study Team

(3) Potential High-risk Areas by Overtopping

There is also the possibility of overtopping occurring from two directions: the river side and the inland side, as shown in Figure 5.8:

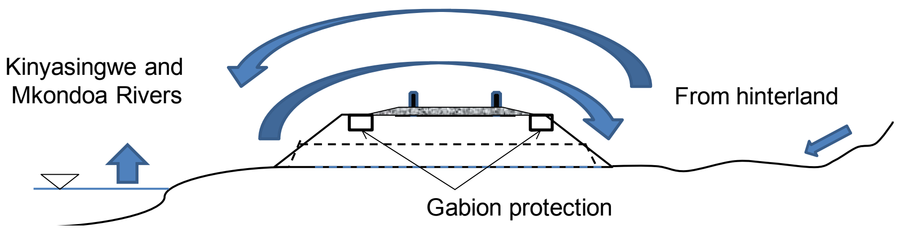


Figure 5.8: Overtopping of Floodwaters above Track Embankment

These high-risk areas of overtopping are identified and summarized based on the experiences of recent floods as well as the current conditions confirmed through site reconnaissance, as tabulated in Table 5.7. During the incoming rainy season, daily monitoring and preventive measures, if necessary, shall be conducted by the TRL's Gangmen and/or River Gang in particular at those sections.

Table 5.7: High Potential Areas of Overtopping to be Closely Monitored (incoming Rainy Season in 2015)

Section	Location (km)	Structures to be Monitored
1. From Kilosa (Km282.7) to Munisagara (Km298.3)	293	New bridge (right bank abutment will be threatened by overtopping)
	293	Track embankment/culvert
	294.1	Track embankment/culvert
2. From Munisagara (Km298.3) to Kidete (Km325.5)	299.55	Track embankment
	300.25	Track embankment/culvert
	302	Track embankment
	302.5	Track embankment/culvert
	303.8	Track embankment/bridge
	305.45	Track embankment/bridge
	308.7	Track embankment/culvert
	312.2	Track embankment
	313.3	Track embankment/culvert
	315	Track embankment
	315–317	Track embankment (restoration works ongoing)
3. From Kidete (Km325.5) to Godegode (Km349.1)	329.8	Track embankment
	330.6	Track embankment
	331.65	Track embankment
	331.1	Track embankment
	337	Track embankment
	337.45	Track embankment
	338.4	Track embankment/culvert
	341.55	Track embankment
	342	Track embankment
	342.1	Track embankment/culvert
	343.3	Track embankment/culvert
	343.8	Track embankment
4. From Godegode (Km349.1) to Gulwe (Km365.9)	345.8	Track embankment
	349	Track embankment/road bridge (under construction)
	355.2	Track embankment
	356	Track embankment
	359.7	Track embankment
	368	Track embankment/box culvert (crossing Mzase River)

Source: JICA Study Team (based on the results of field reconnaissance by Railway Group "A")

5.6 Proposed Urgent Protection Measures

5.6.1 Applied Structural Measures

In order to select structures for urgent protection measures, which are assumed to be implemented before the rainy season in 2015 (from March to April), using chiefly the resources of RAHCO/TRL, the following conditions were taken into account:

(1) Removal (shifting) of existing rails is not included.
(2) Simple structures which are nevertheless still resistant to external forces shall be selected.
(3) Construction material that can be procured in local markets shall be utilized.
(4) Labor-intensive work items are mainly applied with limited heavy construction equipment.
(5) Construction works can be implemented mainly by force account of TRL, taking into consideration the time constraints assumed to exist from budget preparation toward implementation.

Based on the above provisions, the following structures were selected for the urgent protection measures between Kilosa and Gulwe to cope with floods in the rainy season in 2015 and onward:

(1) Riprap, gabion mattress and backfilling of soil material at riverbank endangered by serious erosion
(2) Removal and disposal of sediment deposited in barrel and inlet/outlet of culverts including placement of gabion mattress to protect of slope of track embankment against overtopping
(3) Removal and disposal of debris and trees, etc. in tributaries and connected drainage channels
(4) Reinforcement of bridge abutments by additional gabion mattressing against the scouring of the backfilled portion
(5) River training works (channel excavation and backfilling in depression) in mainstream and tributaries including placement of spur dikes
(6) Land treatment of spoil bank yards in order to prevent dumped sediment material from backflowing into the river

5.6.2 Preliminary Design of Spur Dike between Km 337.2 and Km 337.7

(1) Comparative Study

For the preliminary design of urgent flood protection works against bank erosion for incoming rainy season in the section between Km 337.2 and Km 337.7, the following two options are compared, as shown in Table 5.8:

Option 1: Revetment with channel excavation
Option 2: Revetment with spur dikes

Table 5.8: Comparison of Urgent Bank Protection Measures between Km 337.2 and Km 337.7

Items of Comparison	Option 1	Option 2	Remarks
Urgent Bank Protection Measures	Revetment with channel excavation	Revetment with spur dikes	
Description of Measures	- To protect erodible riverbanks of low water channels by revetment of gabions - To urgently mitigate damage of flood-affected areas by heavy water flows from a tributary joining immediately upstream, river training works by channel excavation is implemented to reorient the flow direction to the opposite bank.	- To protect erodible riverbank of low water channel by revetment of gabion - To reduce flow velocity along the riverbank and to deflect the flow direction to opposite bank, spur dikes are installed along the riverbank together with the revetment.	
Main Structures	1) Revetment: - L = 550 m, H = 3.0 m - Gabion 3 steps - With back filling 2) Channel excavation - L = 700 m	1) Revetment: - L = 550 m, H = 3.0 m - Gabion 3 steps - With back filling 2) Spur Dike - L = 25 m, H = 2.0 m, interval of 50 m, 11 units - Gabion 2 steps	Ref. Appendix I [07: Km 337.2 –337.7]
Preliminary Estimation of Direct Construction Cost	TZS 1,339 Million	TZS 625 Million	Referring to unit prices provided from RAHCO.
Merit	- Channel excavation is easier and faster than spur dike construction. - Effects of channel excavation is realized immediately	- Construction cost is low - Since the construction site of spur dikes is located over the elevated flood pain, it can be constructed during rainy season. - A spur dike can be upgraded if it is recommended as long-term measure.	
Demerit	- Construction cost is high - It would be difficult to excavate the river channel during rainy season. - Periodical maintenance dredging is necessary	- Spur dike construction takes longer. - Periodical maintenance and rehabilitation of spur dikes is necessary.	
Evaluation	-	Adopted	

Source: JICA Study Team

(2) Structural Types

There are mainly two kinds of structural types of spur dikes, as shown in Table 5.9. In the preliminary design, the structural type best suited for the reduction of flow velocity is adopted considering the urgency of the works and site condition.

Table 5.9: Structural Type of Spur Dikes

No.	Purpose	Height	Weight	Type of Permeability	Arrangements	Evaluation
1	Reduction of flow velocity	Low	Light	Permeable or Impermeable with low height	Group units	Adopted
2	Deflection of flow direction	High	Heavy	Impermeable	Single or a few unit	-

Source: JICA Study Team

(3) Direction

The direction of the spur dike is designed as perpendicular to the riverbank, which is the most economical option (Table 5.10).

Table 5.10: Direction of Spur Dikes

No.	Direction of Spur Dike	Characteristics	Evaluation
1	Toward upstream (10–15 degree)	It can be adopted for accelerating sediment deposition between spur dikes in case of a sandy river	-
2	Perpendicular to the riverbank	Most economical option	Adopted
3	Toward downstream	It can be adopted to mitigate local scouring at the toe of the spur dike.	-

Source: JICA Study Team

(4) Length, Height and Interval

The spur dike is designed through adopting the following criteria for length, height, and interval to protect from damage from riverbank erosion, as well as to mitigate the impact to opposite banks (Table 5.11).

Table 5.11: Basic Dimension of Spur Dikes

No.	Basic Dimension of Spur Dike	Criteria	Adopted
1	Length	less than 10% of river width	25.0 m
2	Height	0.2–0.3 times the design floodwaters depth, and higher than normal water level by 0.5–1.0 m	2.0 m
3	Interval	2–4 times the length of the spur dike, 10–30 times the height	50.0 m
4	Slope	Downward slope of 1/20–1/100 toward the center of river	Downward slope toward the center of river

Source: JICA Study Team

(5) Spur Dike Materials

The material of the spur dike will be gabion, which is also used for the slope protection works of low-water channels in the objective area. To sustain the gabions against the tractive force of the river flow, it is recommended to tie each gabion to each other with wire, and also to provide supporting works (wooden piles and steel frame made with used sleepers) along the toe of the spur dike.

(6) Plan of Spur Dike between Km 337.2 and Km 337.7

The plan of a spur dike between Km 337.2 and Km 337.7 is presented in Appendix I, Sheets [07: Km 337.2–337.7].

5.6.3 Recommended Priority Order of Urgent Protection Works

Considering the size of the urgent protection works (required budget) at high-risk areas, it seems rather difficult to implement all construction works by means of the remaining available budget of fiscal year 2014. Therefore, it is recommended to implement the protection works with the highest priority, considering the risk level at each site. In order to set the priority, the following issues were taken into consideration:

(1) 1st Group

RAHCO/TRL has commenced restoration works at Km 315 and Km 302 because the existing bank was rapidly encroaching upon the existing track embankment. In order to avoid further serious bank erosion, earlier completion of the works at these two sites should be prioritized at highest. Considering the actual construction work progress at field, Km 315 was set at first priority and Km 302 was set as the second.

(2) 2nd Group

Among the selected high-risk areas determined by the results of the Flood Risk Assessment, it should be noted that the riverbank at Km 337 needs to be protected at the earliest possible stage because of its high risk of possible bank erosion, and presumed potential resulting damage to the track embankment and railway alignment. Therefore, if the budget is immediately available, earlier commencement of protection works are recommended in parallel with the ongoing works at Km 302 and Km 315.

(3) 3rd Group

Aside from the site of bank protection where encroachment is rapidly progressing (such as at Km 337), risks at the confluences of some tributaries are relatively high, in terms of the extent of potential damage to the railway facilities. In particular, three tributaries, namely the Maswala, Kidibo and Mzase (from downstream, all joining from right side), have been frequently observed to have massive sediment transport by flash floods in recent years. Among the three tributaries, the (i) Maswala, (ii) Mzase and (iii) Kidibo River is the priority in which the river works should be conducted.

(4) 4th Group

Although the construction works of a new bridge at Km 293 (around 10 km from Kilosa) has been completed in August 2014, overflow risks by the Mkondoa River at the bridge site still remained because the new steel truss structure has been placed at almost same elevation as the original one. Further, it should be noted that the bridge piers are skewed toward the flow direction, which is disadvantageous in terms of open channel hydraulics. If an overtopping of the bridge girder happens, an inundation of the neighboring lands and a collapse of the adjacent existing revetment are anticipated. In order to mitigate the damages, therefore, supplemental protection on the existing revetment is proposed.

(5) Existing Culverts

A total of 36 exiting culverts were selected as “High-risk” sites in terms of (i) clogging rate of barrel, (ii) possibility of inundation in the vicinity, and (iii) existence of protection works (as listed in Table 5.6). At these sites, removal of sediment material can proceed in parallel with other works as proposed in the order of priority. In particular, it is recommended that restoration works between Godegode and Gulwe are to be prioritized from those with the highest density of clogged culverts. The inland drainage condition might deteriorate compared with other sections.

The recommended priority is summarized in Table 5.12.

Table 5.12: Recommended Priority Order for Urgent Protection Works

Priority	Selected Sites for Protection
1	Km 315.0–315.8
2	Km 301.7–302.2
3	Km 337.2–337.7
4	Km 349.4B–349.8B
5	Km 366
6	Km 355.0–356.0
7	Bridge Km 293
-	Existing culverts

Source: JICA Study Team

5.7 Work Quantities and Cost Estimates

The major dimensions of the proposed structural measures and their associated work quantities at selected areas are tabulated together with the layout plan and preliminary design drawings of protection measures in Appendix I. The unit cost of the typical civil work items and cost estimates of urgent protection measures are presented in Appendix J, which were collected from RAHCO in December 2014, as the prevailing prices in Tanzania. The total cost of the recommended urgent protection works was preliminarily estimated at approximately TZS 3.0 billion, in Table 5.13.

Although the cost was estimated based on RAHCO's prevailing unit prices, further detailed examination by RAHCO/TRL engineers was recommended for preparing the budget plan by January 2015.

Table 5.13: Summary of Cost Estimate of Recommended Urgent Protection Works (In order of Priority Recommended)

Priority	Work Item	Amount (TZS)	Note
1	Works at Km 315.0–315.8	0*	TRL's ongoing works
2	Works at Km 301.7–302.2	0*	TRL's ongoing works
3	Works at Km 337.2–337.7	624,412,800	Option 2: Spur Dike
4	Works at Km 349.4B–349.8B	1,013,284,800	Maswala River confluence
5	Works at Km 366	972,000,000	Mzase River confluence
6	Works at Km 355.0–356.0	271,886,400	Kidibo River confluence
7	Works at Bridge Km 293	13,007,520	Supplement protection
-	Works for removal of sediment deposition in existing culverts	62,441,280	Total 36 culverts
	Total	**TZS 2,957,032,800** **US$ 1,689,700** **JPY 199,384,600**	US$ 1.0 = TZS 1,750 US$ 1.0 = JPY 118.0

Remarks: * It is assumed that the required budget for completion of the work has been secured already by RAHCO/TRL.
Source: JICA Study Team

5.8 Recommendations

In December 2014, following recommendations were presented in the report of the Flood Risk Assessment as well as the Progress Report (April 2015) to realize strengthening of preparedness to the flood disasters in the project area:

(1) Prioritization of Construction Site Depending on Availability of Budget

Although it was considered desirable that all construction works as recommended herein were to be completed by the end of February 2015, the available time was quite short, considering the time required for budget preparation by the Ministry of Transport. In reality, construction works of urgent protection measures will continue even after entering into the rainy season, beyond May 2015. Under this situation, the prioritization of urgent protection measures will be essential to mitigate the flood damages to railway operations in accordance with the discussion and recommendations as described in Section 5.6.3.

(2) Requirement of Update and Review of Structural Measures

It should be noted that the urgent protection measures proposed herein were prepared during the field reconnaissance and subsequent studies, totaling three weeks, in December 2014. Therefore, an update and review of the structural measures at selected high-risk areas shall be reviewed by RAHCO/TRL based on the current experiences and ongoing restoration works at the target stretches between Kilosa and Gulwe.

(3) Review of Preliminary Cost Estimate

Due to limited discussions and insufficient information on current unit prices, which required the joint efforts of JICA Study Team and RAHCO/TRL engineers in the course of planning and design of structure measures and cost estimates, a verification of the unit prices applied will be a prerequisite before budget appraisal in the Ministry of Transport. The Flood Risk Assessment was originally planned such that the cost estimate would be conducted by the initiative of the Tanzanian side, taking into account the potential for a smooth and seamless budget preparation process. However, the JICA Study Team conducted it without particular discussions on the basic conditions for cost estimation. Therefore, substantial review of the cost estimate is required by RAHCO/TRL engineers.

(4) Periodical Review of High-Risk Areas

High-risk areas were identified based on the latest information obtained through field measurements. Such comprehensive field observations of riverbanks and existing culverts is the first such attempt after the concession finished 2007. Therefore, it is highly recommended to create a database (inventory of channels and culverts) for periodical checking of critical sections (high-risk areas). This will lead to strengthening of skills and capability of preventive flood protection in the target railway section between Kilosa and Gulwe.

(5) Designation of Spoil Bank Yards

Through the field reconnaissance, it was confirmed that excavated soil from barrel(s) of culverts were temporarily placed beside the culverts in most of the cases. In such cases, the soil will easily move back to the fore bay or outlet apron of culverts during rainfall. In order to avoid this unfavorable situation, the excavated soil material shall be transported to previously-designated spoil bank yards. The appropriate disposal sites shall be pre-determined based on the following requirements:

(a) 1st Priority: Depression in the river channel area
(b) 2nd Priority: Flat area in the river channel area (as temporary measure)

(c) 3rd Priority: At the skirts of mountainside in hinterlands

In order to select the location, accessibility to the sites by vehicles should be considered.

(6) Safe Train Operation and Recovery Works during Rainy Season

The following measures are recommended for safe train operations and recovery of the railway in a short time.

1) Suspension of train operations during overtopping of water and inundation above rail level, since train operations in these conditions are extremely dangerous, because the overflowing water wash away roadbed materials.
2) Suspension of train operation during inundation above ballast, because hydrous roadbed is easily damaged when train load is applied.
3) Stockpiling of rehabilitation materials such as ballast, gabion and soil for embankment near the site exposed to floods.
4) Sharing of the results of this Flood Risk Assessment among the engineering staff of TRL and Gangs who are in charge of routine maintenance works between Kilosa and Gulwe

The possible sites of stockpiling might be vacant space at the Gang camps, which are located on average every 7-8 km along the railway track. This placement of materials will be advantageous in terms of management/observation of materials, as well as ease in loading/unloading and transportation of the materials.

(7) Application of Spur Dikes at Km 337.2–337.7

From a hydraulics point of view, the spur dike is recommended to mitigate the riverbank erosion at Km 337.3–337.7. A total of 11 units of spur dikes with gabion structures are recommended considering the accustomed construction sequence of and material available to RAHCO/TRL in routine maintenance/restoration works. However, aiming at assuring flexible and resistant structure, the option of larger size boulders with random dumping by layers is more recommendable. Therefore, it should be noted that further discussion on the appropriate choice between the JICA Study Team and RAHCO/TRL's engineers will be a prerequisite before making any determinations for the design of construction works.

5.9 Current Status of Implementation of Urgent Protection Measures

5.9.1 Current Status of Sections at High-risk

Through the Flood Risk Assessment, a total of seven sites of railway section were identified which required urgent protection works, because of their natural propensity for flood damage occurrences. The JICA Study Team conducted site reconnaissance to confirm the latest status of those sites with TRL Dodoma staff on 11 February 2015. The results of the reconnaissance are summarized as follows:

(1) Bridge Km 293

No significant change at the section of new bridge crossing was observed upon inspection on 11 February 2015 with TRL Dodoma staff.

Figure 5.9: Completed New Bridge at km 293

(2) Km 301.7–302.2

This site was heavily eroded and the embankment was totally washed away by the flood in March 2014. Then, TRL provided riverbank protection by gabion, completing in February 2015.

Figure 5.10: Completed Revetment by Gabion at Km 302

(3) Km 315.0–315.8

This site has been considered as the most dangerous site for bank erosion, because in August 2014 only a few meters are left between the existing track alignment and the shoulder of riverbank. Then, in October 2014 TRL started restoration works, including shifting the railway alignment toward the mountainside at maximum 20 m. Shifting of the rail has been completed. On the other hand, the revetment by gabion boxes (upper portion) has been suspended in the middle of this section in February 2015. It is reported that the budget for restoration works has run out and a resumption of work is pending, waiting on a release of funds to complete the remaining section. Construction works of a new box culvert located at Km 316.5 have been completed.

Figure 5.11: Completed Shifting of Railway Alignment at Km 315

Figure 5.12: Suspension of Installation Works of Gabion

Figure 5.13: Completed Feature of Revetment Works by Gabion Boxes (Lower Level)

Figure 5.14: New Pipe Culvert (4 Pipe Culverts) at u/s Side of the Old Box Culvert (2 Barrels, Rectangular)

(4) Km 337.2–337.7

In December 2014, among the stretches excluding the section where restoration works were undertaken by TRL, this site was considered to be the most crucial portion susceptible to bank erosion caused by directly hitting of floodwaters. The riverbank at Km 337.4 remained at a distance of about 15 m in February 2015, as shown below:

Figure 5.15: Panoramic View toward Upstream at Km 337.4 (11 Feb. 2015)

In the early morning of 6 March 2015, the riverbank heavily encroached approximately 15 to 20 m toward Km 337.4 due to the strong currents of the Kinyasungwe River. As per an interview with the Assistant Chief Civil Engineer of TRL, the damage to railway structures is summarized as follows:

- Site of damage: Vicinity of Km 337.5
- Damaged condition: The foundation under the rail was scoured at a length of 7 m
- Urgent restoration: The existing railway shall be shifted for at least 10 to 15 m toward the mountain side
- Procedure: TRL will prepare cost estimates for urgent restoration works and report it to RAHCO. RAHCO will separately prepare a cost estimate and then will decide who should be responsible to implement the works. If the cost is beyond US$ 100,000, RAHCO will be responsible.

Prior to the occurrence of this accident, TRL had cut the rail and moved it away, because they anticipated an occurrence of serious erosion at the point. This damaged section was restored and restarted railway operations on 16 March. Further, it is reported that RAHCO is preparing a plan for more comprehensive restoration works by the end of March 2015.

(5) Km 349.4B–349.8B

It is noteworthy that the existing railway alignment is running on the under-developing alluvial fan near the confluence of the Maswala and the Kinyasungwe Rivers between Km 349.4B and Km 349.9B. Since the sediment yield of the upstream of the Maswala River is huge, this section is suffering from frequent overtopping sediment discharge, which causes washaways of ballast material and collapsing of railway embankments, etc. In fact, on 1 February 2015, a small-scale flash flood occurred in the Maswala River and hit the railway section and all culverts (five in total: CL349.4, CL349.5, CL349.6, CL349.8 and CL349.9) underneath the railway have been buried completely. TRL deployed their work gangs from neighboring sections and immediately restored the damaged section as an urgent measure. The following photos were taken on 11 February 2015.

Figure 5.16: Near CL349.5B (buried)

Figure 5.17: Near CL 349.8B (buried)

Figure 5.18: New Box Culvert Constructed by TANROADS

On 5 March 2015, a flash flood occurred and the strong currents of the Maswala overtopped the railway. The flood flow ran in parallel to the existing railway embankment toward the downstream. JICA Study Team took a short video of the flood event to utilize the information in the subsequent hydrological and sediment analyses.

(6) Km 355.0–356.0

The Kidibo River meets with the Kinyasungwe River at Km 355.0. The existing railway crosses the Kidibo River just upstream of the confluence. The river channel downstream of the Kidibo is protected by steel sheet piles to protect from bank erosion at both sides. Although sediment deposition in the Kidibo River seems progressive, no serious damage to the structures can been confirmed. The span of the Kidibo Bridge is rather short compared with the river channel width of the upstream stretches. Therefore, the bridge section makes an unfavorable bottleneck and forces the water level to rise in the upstream stretch during floods. Further, since the Kidibo flows into the Kinyasungwe at almost a right-angle, channel improvements to make more smooth flow will be necessary.

Figure 5.19: Confluence with Kinyasungwe

Figure 5.20: Kidibo Bridge (Railway)

Figure 5.21: Upstream View from Bridge

(7) Km 366

A serious accident happened on 28 March 2014 due to a flash flood of the Mzase River. Although the catchment area of the Mzase is rather small, huge sediment discharge brought about serious problems at this section. The following photos show the conditions of box culvert crossing the Mzase River on three different dates:

22 Jul. 2014 (1)

2 Dec. 2014 (2)

11 Feb. 2015 (3)

Figure 5.22: Cross Culvert at Mzase River (Three Different Time)

(1) After the flooding on 28 March 2014, the debris and soil were totally removed from the culvert. After then, the situation has been maintained because of dry weather conditions.
(2) This shows the conditions after light rain on the previous day. The opening was 1.65 m by measurement with a hand staff gauge.
(3) The rainy season has started and sediment deposition has occurred in the culvert.

5.9.2 Status of Financial Arrangement for Proposed Urgent Protection Measures as of July 2015

It was confirmed that, upon receiving the report of "Recommendation on Urgent Protection Measures for Incoming Rainy Season 2015 (Results of Flood Risk Assessment), December 2014" by the JICA Study Team, RAHCO submitted their proposal to MOT to secure the budget for the works. The JICA Study Team further followed up on this issue by interview with MOT on 25 February 2015. Through the interview, the following issues were clarified:

- A supplementary budget request (a part of budget for Year 2014/2015) was submitted to MOF by MOT in the middle of January 2015.
- Appraisal of the budget request is ongoing by MOF. It will certainly be approved by MOF since the supplementary budget for the urgent protection measures is a priority matter within MOT.
- Upon approval by MOF, the budget will be immediately released to RAHCO and implementation of the protection works can be undertaken smoothly.

On the other hand, the JICA Study Team received a document[1] from RAHCO which contains a cost estimate of repair works of the railway section between Godegode (Km 344) and Kikombo (Km 426). The construction period of the repair works is estimated at 50 days. In addition, the documents noted that further studies on the siltation problem at Km 365 (Mzase) and Km 349 (Maswala) are required after the repair works, because the problem extends beyond railway reserve. The total cost of the repair works are estimated at TZS 529 mil. (approx. JPY 32mil.)

5.9.3 Status of Financial Arrangement for Proposed Urgent Protection Measures as of January 2016

The latest status of the financial arrangement for the proposed urgent flood protection measures was confirmed several times, at the Technical Committee meeting (27 Nov. 2015) and at Biweekly Meetings (7 Dec. & 18 Dec. 2015) with RAHCO and MOT. According to the management staff of the counterpart agencies, official concurrence for the budget by MOF had been secured. However, no funds have been released yet to RAHCO for implementation of the protection measures as proposed due to delays in administrative procedures between the concerned agencies.

On the other hand, through interview with the Assistant Chief Civil Engineer of TRL regarding flood damages recorded in 2015, it was clarified that TRL (District Civil Engineer's Office of Dar es Salaam) had estimated the required budget for urgent restoration works between Kilosa and Igandu at selected high-risk areas, which were identified through their site inspection conducted on 26-27 November 2015. The summary presented in the estimate is extracted as shown in Table 5.14.

[1] "Godegode, Gulwe, Igandu, Msagali to Kikombo Track Repair and Cross Drainage Improvements", RAHCO

Table 5.14: Summary of Requested Budget for Urgent Protection Measures in TRL

Item No.	Location	Proposed Works	Amount Total (TZS)
1	-	Mobilization	51,145000
2	Km293.8-294.4	River training by machine to Mkondoa River 150 m away from rail embankment	14,710,500
3	Km297.2-297.8	River training to drive Mkondoa River 155 m away from rail embankment, this includes excavation of 10 x 1.5 x 600m trench, and excavation to remove 200 x 10 x 2.0m raised rock on the opposite river bank	29,452,000
4	Km299.8-300.7	River training by machine to drive Mkondoa River 150 m away from rail embankment	11,171,500
5	Km302.7-303.4	Embankment widening, gabion walling protection and river training	147,391,000
6	Km315.0-316.0	Embankment widening, gabion walling protection and river training	216,370,000
7	Km337.2-337.8	River diversion by machine and labor	27,772,500
8	Km349/4A	Culvert desilting and demolition of road erected drainage structure	58,830,000
9	Km349/6C	Excavation of culvert inlet channel to divert to the culvert	11,218,500
10	Km397.5-397.8	Excavation catch water drains	18,140,000
		Grand total	581,201,000 (Approx. JPY34.9 mil)

Source: A letter from District Civil Engineer/Dar es Salaam to Chief Civil Engineer of TRL, dated 2 December 2015

Since further flood damages are anticipated in the rainy season from January to April 2016, immediate budget arrangement in TRL and quick implementation is expected. In particular, progressive devastation was confirmed at the stretches of Km 315.0-316.0, Km 337.2-337.8, Km 349/4A and Km 349/6C, and repeatedly identified as the most vulnerable areas through the site reconnaissance conducted in November 2015. Further, the record of accidents due to flooding in January 2016 was delivered to the Study Team from RAHCO as presented in Table 5.15.

Table 5.15: Flood Damages in January 2016

No.	Location	Extent of Damage	Date*
1	Km 315.3 Mzaganza - Kidete	Damage 155 m x 2 x 6 Line opened 14:30, 16 Jan. 2016	1 Jan. 2016
2	Km 365.2 -366.3	Rail hanging unsupported 26 x 4 x 1 Track twisted and shifted by 1.2 m from center. Requirements: Boulders 4 no. HLB wagons	16 Jan.
3	Km 402.9 and 403.3 (near village Igandu)	Damage: Track covered by heap of quarry dust which was off loaded by 862 at km 397.9 – 397.6 Requirements: same to be removed by Permanent Way Staff Line opened: 03:00, 18 Jan. 2016	18 Jan.
4	Km 308.9 Munisagara - Mzaganza	Damage: Formation washed away. 4 rails hanging at Km308.9 Requirements: Boulders and quarry dust Expected time to open line: 7 days from 20 Jan. 2016	18 Jan.
5	Km 315.4	Washe-away, repair is on-going.	21 Jan.

Source: RAHCO
Note: * To be confirmed whether the dates refer to the occurrences of accidents concerned.

In order to avoid further accident by flooding, rapid implementation of the structural measures proposed in the report of the Flood Risk Assessment is highly recommended.

6. Hydrological and Hydraulic Analyses

This chapter provides the hydrological and hydraulic analyses used to set the hydraulic conditions for preliminary design of flood counter-measures. It considers the rainfall characteristics, rainfall runoff processes, and river channel hydraulics in the target area between Kilosa and Gulwe.

6.1 Data Collection and Review

The collected hydrological data and information on climate change are reviewed in this chapter, whereas geology, topography, and land cover are reviewed in Chapter 7.

6.1.1 Hourly Hydrological Data

Hydrological analysis depends heavily upon the rainfall records for a catchment area and the water level and discharge records for the rivers. Having such hydrological data, recorded on an hourly time-step basis, is crucial for flood analysis. Therefore, hourly hydrological data was collected and reviewed.

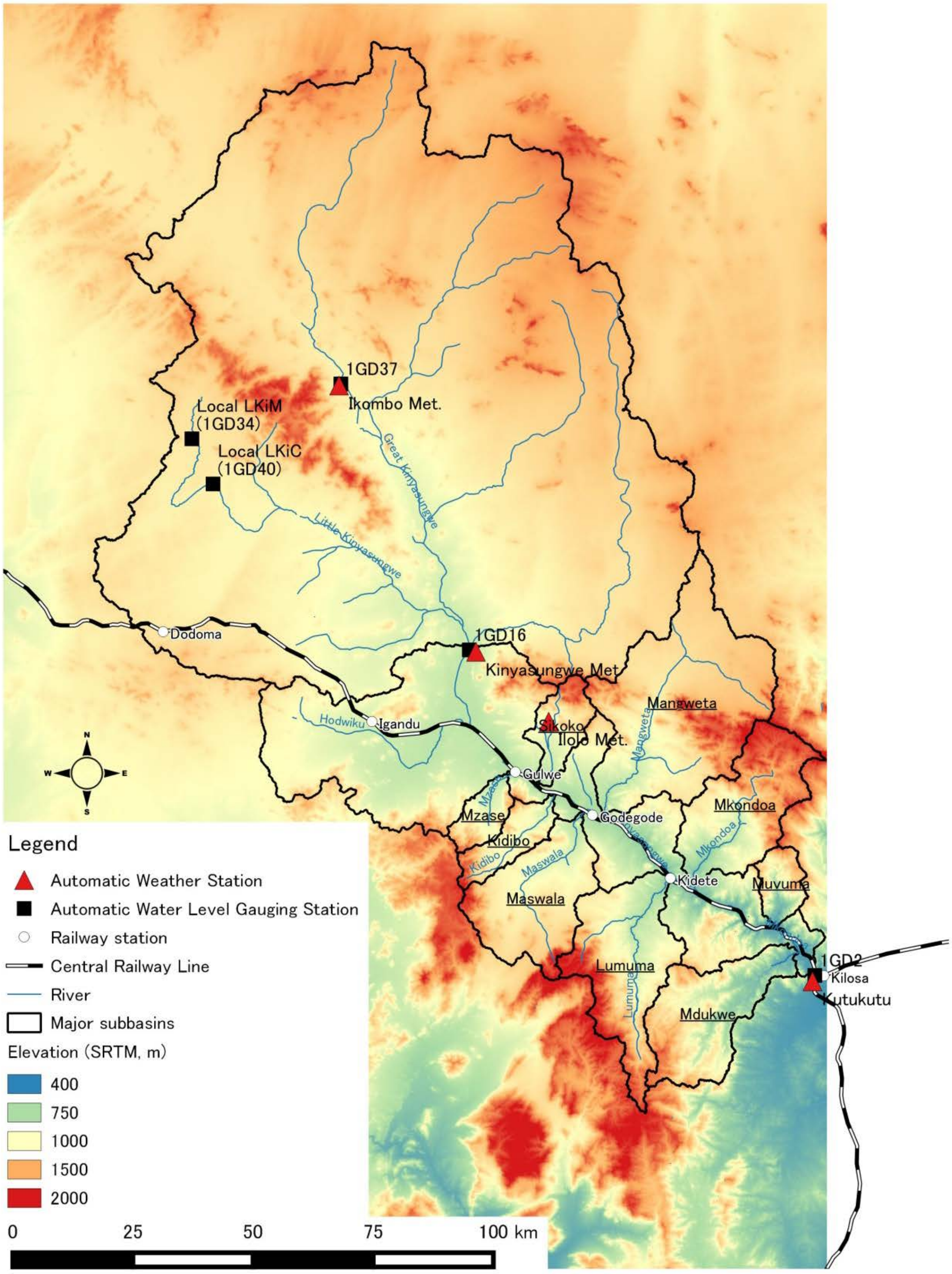
(1) Hourly Rainfall

Hourly rainfall in the Wami River basin has been measured by automatic weather stations (AWS), managed by the Wami/Ruvu Basin Water Office (WRBWO). AWS observes climate variables on an hourly basis, not only for rainfall, but for temperature, humidity, radiation, actual sunshine duration, wind direction, and wind speed. Table 6.1 and Figure 6.1 show a list of AWS in the upstream areas of Kilosa and their locations, respectively. WRBWO has installed four AWS in the upstream areas of Kilosa since 2006. Figure 6.2, Figure 6.3, and Figure 6.4 show the current conditions of the AWS at Kutukutu, Kinyasungwe and Ikombo, respectively. Tanzania Meteorological Agency (TMA) also manages AWS in Tanzania. However, no AWS has been installed in the Wami River basin.

Table 6.1: List of Automatic Rainfall Stations in the Upstream Area of Kilosa

WMO Code	Station Name	Location	Lat.	Long.	Status (Feb. 2015)	Available data	Establish	Condition	Remark
9536017	Ikombo Met.	Ikombo village	−5.719	36.082	Not functional	Jun. 2012–Oct. 2014	2006	Solar panel vandalised	-
9636020	Kinyasungwe Met.	Ng'hambi	−6.221	36.340	Not functional	Jun. 2012–Oct. 2014	—	Solar panel vandalised	-
-	Ilolo Met.	Mpwapwa	−6.353	36.477	Functional	Not Available	Jun. 2014	-	Connection error of automatic rainfall gauge to logger
-	Kutukutu Secondary School	Kilosa	−6.843	36.974	Functional	Nov. 2012–Aug. 2013	Nov. 2012	-	Connection error of automatic rainfall gauge to logger after 26 Oct. 2013

Source: JICA Study Team



Source: JICA Study Team

Figure 6.1: Location of Automatic Weather Stations and Automatic Water Level Gauging Stations Managed by WRBWO in the Upstream Areas of Kilosa

Overall view

Data collection

Automatic rainfall gauge (near side) and manual rainfall gauge (far side)

Automatic weather station with a solar panel and a control panel

Automatic rainfall data has not been recorded due to a connection error between the gauge and the data logger in the control panel.

Source: JICA Study Team

Figure 6.2: Kutukutu Automatic Weather Station

Signboard

Overall view

Solar panel of automatic weather station was stolen. Control panel was removed by WRBWO. Manual daily rainfall is only measured.

Source: JICA Study Team

Figure 6.3: Kinyasungwe Automatic Weather Station (9636020)

Overall view

Automatic weather station

Solar panel of automatic weather station was stolen. Only daily rainfall is measured, manually.

Source: JICA Study Team

Figure 6.4: Ikombo Automatic Weather Station (9536017)

(2) Hourly Water Level

Hourly water levels in the Wami River basin are observed with automatic water level gauging stations. Table 6.2 and Figure 6.1 show a list of automatic water level gauging stations in the upstream areas of Kilosa and their locations, respectively. Five stations have been installed and measure water levels at stilling wells with a data logger. The 1GD2 (Kilosa) and 1GD37 (Ikombo) stations are currently functional, whereas other two stations are not, due to vandalizing. Figure 6.5Figure 6.5 through Figure 6.9 show the current conditions of 1GD2 (Kilosa), 1GD16 (Kongwa), 1GD37 (Ikombo), LKiC (Chihanga) and LKiM (Mayamaya), respectively.

Generally, officers from the Morogoro main office of the WRBWO visit those stations every three months to collect data from the automatic loggers and renew their batteries. However, the data collection has not been conducted regularly due to a lack of funding, and recorded data was sometime lost after the loggers' batteries died before the data could be collected.

Table 6.2: List of Automatic Water Level Gauging Stations in the Upstream Area of Kilosa

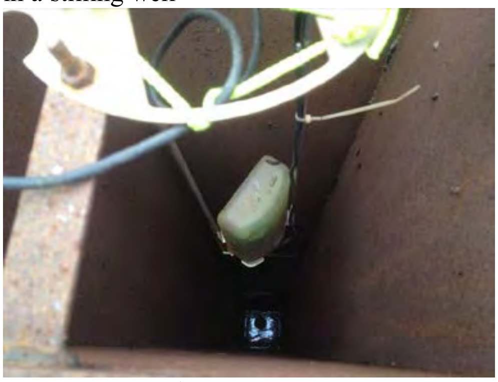
Station	River Name	Location	Lat.	Long.	Elevation (m)	Status of Water Level Gauge (as of Feb. 2015) Manual	Status of Water Level Gauge (as of Feb. 2015) Automatic	Type of Automatic Gauge
1GD2	Mkondoa	Kilosa	−6.832	36.978	495	Functional	Functional	Float
1GD16	Kinyasungwe	Kongwa/Dodoma (Old Dodoma Rd. Br.)	−6.218	36.327	855	Functional	Not Functional	Pressure
Local LKiC	Little Kinyasungwe	Chihanga	−5.905	35.844	-	Functional	Vandalised	Float
Local LKiM	Little Kinyasungwe	Mayamaya	−5.819	35.804	1153	Functional	Not Functional	Float
1GD37	Great Kinyasungwe	Ikombo	−5.716	36.085	-	Functional	Functional	Float

Source: JICA Study Team

An overall view with a gauge reader

Staff gauge in the stream

Float-type automatic water level gauge in a stilling well



Data logger

Source: JICA Study Team

Figure 6.5: Mkondoa at Kilosa Water Level Gauging Station (1GD2)

Signboard

Staff gauges

Staff gauges

Stilling well (not functional)

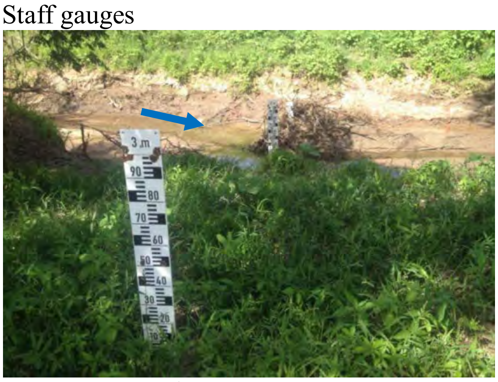
Source: JICA Study Team

Figure 6.6: Kongwa Water Level Gauging Station (1GD16)

Signboard

Stilling well (functional)

Staff gauges



Cross-section

Source: JICA Study Team

Figure 6.7: Ikombo Water Level Gauging Station (1GD37)

Signboard

Stilling well (not functional)

Staff gauges

Cross-section

Source: JICA Study Team

Figure 6.8: Chihanga Water Level Gauging Station (LKiC)

Signboard

Stilling well(not functional)

Staff gauges

Cross-section

Source: JICA Study Team

Figure 6.9: Mayamaya Water Level Gauging Station (LKiM)

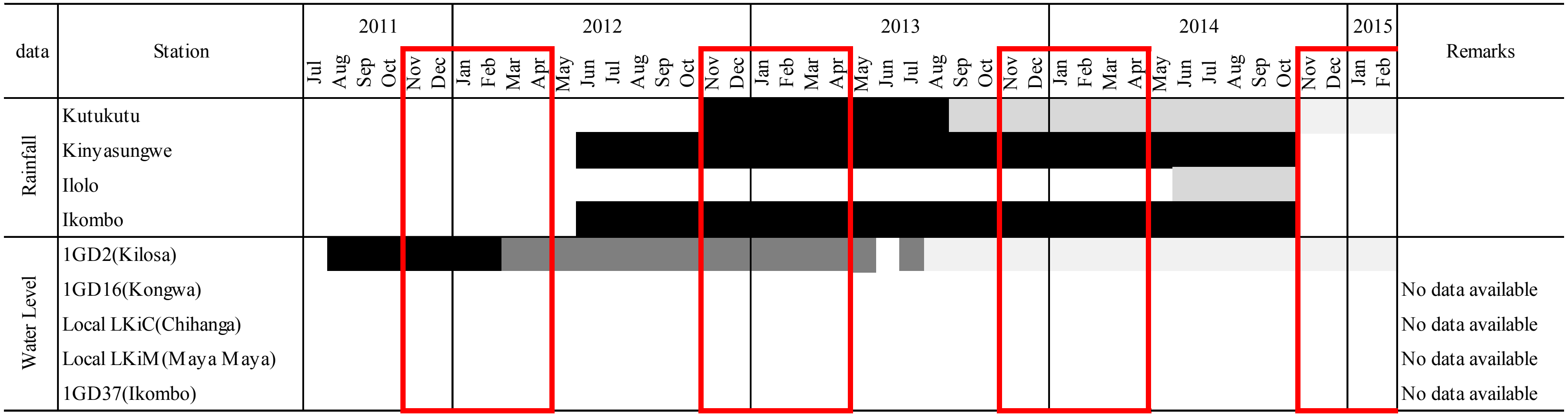
(3) Hourly Discharge

Although hourly water levels are measured, hourly discharge data is not available at the WRBWO.

(4) Availability of Hourly Hydrological Data

Table 6.3Table 6.3 shows the availability of hourly hydrological data collected from the WRBWO. Hourly rainfall data is available for Kinyasungwe and Ikombo from June 2012 to October 2014 and Kutukutu from November 2012 to August 2013. At Kutukutu, hourly rainfall data after September 2013 are all zero due to a connection problem with the automatic-logger. Ilolo also has same problem and no data of hourly rainfall is available after installation. Water level data for every hour is available from August 2011 to February 2012 at the 1GD2 (Kilosa) gauging station. After March 2012, semi-daily or sometimes more frequent data records only exist at 1GD2 due to a loss of battery power, according to an officer from the WRBWO. Further, no water level data at the 1GD37 (Ikombo) gauging station is available at the WRBWO. Therefore, the period for which both hourly rainfall and hourly water level data are available is limited to the rainy season in 2012/2013, although the water level records nevertheless contain missing data.

Table 6.3: Availability of Hourly Hydrological Data in the Upstream Area of Kilosa



Note:
- Hourly data is available in each day
- Hourly data is available in each day, but including missing data
- Hourly data was recorded, but all are zero value due to connection problem to auto logger
- Hourly data was not recorded due to running out of battery and/or memory shortage
- Rainy season

Source: JICA Study Team

6.1.2 Daily Hydrological Data

(1) Collection of Daily Hydrological Data

Daily hydrological data, such as daily rainfall, daily average water level, and daily average discharge amounts, were mostly collected from the Water Resources Management Database of the WRBWO, which was established by the previous JICA Study[1]. Table 6.4 and Table 6.5 show the lists of daily rainfall stations and water level and discharge gauging stations in the upstream areas of Kilosa, respectively. The database stores daily rainfall data at 35 stations, daily average water level data at 13 stations, and daily average discharge data at six stations in the target area. In addition, daily rainfall data was collected from TMA at four stations that were selected based on the list of stations provided by TMA, in order to complement the missing stations/fill-in the missing periods in the database of the WRBWO.

[1] JICA, 2013. The Study on Water Resources Management and Development in Wami/Ruvu Basin in the United Republic of Tanzania. Final Report.

Table 6.4: List of Daily Rainfall Station in the Upstream Area of Kilosa

WMO code	Station Name	Lat.	Long.	Elevation (m)	Managed by WRBWO	Present Status	Period of data available in Database of WRBWO	Period of data available in TMA	Period of original data available
9535005	Hombolo primary school	−5.880	35.920	1097	Yes	Functional	2008–2014	N/A	2008–2015
9535006	Zanka primary school	−5.880	35.750	1133	Yes	Functional	2008–2014	N/A	2008–2015
9535007	Makutupora Maji	−5.970	35.720	1080	Yes	Functional	2008–2010, 2013	N/A	N/A
9536000	Kibaya Met station Kitelo	−5.283	36.567	1457	No	N/A	1934–1961, 1964–1975, 1977–1992	N/A	N/A
9536002	Itiso primary school	−5.630	36.030	1219	Yes	Functional	2008–2014	N/A	2008–2014
9536004	Dabalo dam	−5.780	36.130	1524	Yes	Functional	1962–1991, 2008–2009, 2012–2014	N/A	2008–2013
9536005	Zoisa primary school	−5.670	36.380	914	Yes	Functional	2008–2014	N/A	2008–2014
9536011	Njoge primary school	−5.950	36.680	N/A	Yes	Functional	2008–2014	N/A	2008–2014
9536017	Ikombo Met.	−5.719	36.082	1077	Yes	Functional	2006–2009, 2012–2014	N/A	1971–2002, 2006–2014
9635001	Dodoma airport	−6.170	35.770	1120	No	N/A	1932, 1935–2013	1961–2013	N/A
9635012	Dodoma Maji	−6.188	35.753	1141	Yes	Functional	1961–1990, 2008–2014	N/A	N/A
9635014	Matambulu dam	−6.300	35.770	1067	No	N/A	1962–1995	N/A	N/A
9636000	Mpwapwa research station	−6.330	36.500	1037	No	N/A	1925–1961	N/A	N/A
9636002	Buigiri mission	−6.130	36.030	1066	Yes	Functional	2008–2013	N/A	2008–2013
9636004	Kibakwe mission	−6.720	36.400	N/A	No	N/A	N/A	1994–2000, 2002–2004, 2011	N/A
9636006	Kiboriani (Marti)	−6.280	36.550	1783	No	N/A	1938–1966, 1970, 1973, 1975–1976, 1986–1992, 1994	N/A	N/A
9636008	Vianze dairy	−6.530	36.880	1067	No	N/A	1947–1992, 1994–1995	N/A	N/A
9636013	Kongwa P.R.S	−6.030	36.330	914	No	N/A	1953–1985, 1987–1995	N/A	N/A
9636018	Ukaguru forest station	−6.330	36.950	1676	No	N/A	1956–1987, 1990–1991, 1993–1995	N/A	N/A
9636020	Kinyasungwe	−6.221	36.340	873	Yes	Functional	1960–1979, 2008–2014	1961–2013	1975–1999, 2001–2014
9636026	Gairo	−6.150	36.870	1786	No	N/A	1970–1989	N/A	N/A
9636027	Nongwe primary school	−6.470	36.900	1880	No	N/A	1970–1993	N/A	N/A
9636029	Kongwa admin. office	−6.200	36.420	914	No	N/A	1972–1990	N/A	N/A
9636030	Sagara	−6.270	36.550	1219	Yes	Functional	2008–2009, 2012–2014	N/A	2008–2014
9636031	Mlali village	−6.300	36.770	1524	Yes	Functional	2008–2012	N/A	2008–2014
9636032	Mseta village	−6.380	36.720	1524	Yes	Functional	2008–2009, 2012–2014	N/A	2008–2014
9636033	Pandambili	−6.070	36.730	1219	Yes	Functional	2008–2014	N/A	2008–2014

WMO code	**Station Name**	**Lat.**	**Long.**	**Elevation (m)**	**Managed by WRBWO**	**Present Status**	**Period of data available in Database of WRBWO**	**Period of data available in TMA**	**Period of original data available**
9636034	Chamkoroma pr. school	−6.330	36.670	N/A	Yes	Functional	2008–2014	N/A	2008–2014
9636037	Chilomwa pr. school	−6.030	36.130	N/A	Yes	Functional	2008–2014	N/A	2008–2015
9636038	Mtanana primary school	−6.050	36.580	N/A	Yes	Functional	2008–2014	N/A	2008–2014
9636049	Lufusi MAJI	−6.850	36.620	1143	No	N/A	N/A	1990-1992, 1999-2000, 2002-2004	N/A
9736007	Ulaya	−7.070	36.900	610	No	N/A	1960–1989	N/A	N/A
Unknown 1	Chihanga Primary School	−5.969	35.953	N/A	Yes	Functional	2008–2014	N/A	2008–2015
Unknown 2	Mayamaya Primary School	−5.844	35.839	N/A	Yes	Functional	2008–2014	N/A	2008–2015
Unknown 3	Kikombo Primary School	−6.220	35.990	N/A	Yes	Functional	2008–2009, 2012–2014	N/A	2008–2014
Unknown 4	Ibwaga Primary School	−6.295	36.557	N/A	Yes	Functional	2008–2012, 2014	N/A	2008–2012, 2014
Kutukutu	Kutukutu Secondary School	−6.843	36.974	N/A	Yes	Functional	2012–2014	N/A	N/A
Ilolo	Ilolo MET	−6.353	36.47652	N/A	Yes	Functional	N/A	N/A	2012–2014
Azimio	Azimilo Pr. School (Ikowa)	−6.2019	36.21592	909	Yes	Functional	N/A	N/A	2008–2014

N/A: Not Available

Source: JICA Study Team

Table 6.5: List of Water Level and Discharge Gauging Station in the Upstream Area of Kilosa

									Water Level		Discharge	
Station	**River Name**	**Location**	**Lat.**	**Long.**	**Elevation (m)**	**Gauge Range (m)**	**No. of Gauges**	**Establish**	**Period of data available in Database of WRBWO**	**Period of original data available**	**Period of data available in Database of WRBWO**	**Period of original data available**
1GD2	Mkondoa	Kilosa	−6.832	36.978	495	5.0	4	13-Mar-52	1952–1988, 2006–2014	2006–2014	1952–1985	N/A
1GD14	Kinyasungwe	Gulwe	−6.450	36.414	-	-	-	28-Nov-56	1957–1983	N/A	1957–1977	N/A
1GD16	Kinyasungwe	Kongwa/Dodoma (Old Dodoma Rd. Br.)	−6.218	36.327	855	5.0	6	28-Feb-58	1958–1997, 2000–2014	1958–1986, 1988–1997, 2004–2014	1958–1984	N/A
1GD17	Kinyasungwe	Godegode	−6.541	36.574	-	-	-	01-Nov-60	1976–1979	1960–1984*	N/A	N/A
1GD21	Kinyasungwe	Itiso	−5.590	36.000	-	3.0	3	17-Nov-71	2004–2014	1962–1992, 2009–2014	N/A	N/A
1GD29	Mkondoa	Mbarahwe	−6.600	36.780	-	5.0	-	02-Mar-69	1969–1991, 2013	1987–1988	1969–1982	N/A
1GD30	Lumuma	Kilimalulu	−6.680	36.670	-	4.0	-	10-Mar-69	1969–1995	1989–1995	1969–1975	N/A
1GD31	Mdukwe	Mdukwe	−6.795	36.930	-	4.0	-	29-Mar-69	1969–1979	N/A	1969–1989	N/A
1GD32	Mkondoa	Railway Bridge	−6.762	36.933	-	4.0	-	13-Mar-73	1974–1975	N/A	N/A	N/A
1GD33	Masena	Ibumila	−5.903	36.390	-	-	-	24-Dec-72	N/A	N/A	N/A	N/A
Local LKiC	Little Kinyasungwe	Chihanga	−5.905	35.844	-	3.0	3	13-Sep-06	1974–1990, 2006–2014	2006–2014	N/A	N/A
Local LKiM	Little Kinyasungwe	Mayamaya	−5.819	35.804	1153	3.0	3	28-Feb-74	2006–2014	2006–2014	N/A	N/A
1GD37	Great Kinyasungwe	Ikombo	−5.716	36.085	-	4.0	4	30-Oct-71	2006–2014	1974–1990, 2006–2014	N/A	N/A

(shaded) : Present observing stations that gauge readers are assigned
N/A: Not Available
*: illegible due to aging
Source: JICA Study Team

(2) Review of Daily Hydrological Data

However, the collected data contain some unreliable data, as follows:

- Daily rainfall data collected from WRBWO and TMA do not coincide completely.
- Same rainfall data were stored in two stations.
- Consistency of water level and discharge data were not confirmed.

Therefore, original data, such as records by gauge readers, were also collected from the main office of the WRBWO in Morogoro and the sub-office of the WRBWO in Dodoma to confirm the reliability of the database. The periods of original data that were collected are shown in the right-most columns of Table 6.4 and Table 6.5. The original data for rainfall and water levels for recent years (after 2008) are generally available, whereas the data prior to this (before 2008) are limited, only available at a handful of stations, such as rainfall data at 9536017 and 9636020 and water level data at 1GD16, 1GD29, 1GD30, and 1GD37. The original discharge data are not available at the WRBWO. According to an officer at the WRBWO, the discharge data in the database were basically provided from the study of the Wami River Initial Environmental Flow Assessment (2008) during the previous JICA Study.

A review of daily rainfall and water level data was conducted under the rules shown in Table 6.6.

Table 6.6: Rules of Data Review

Original data	Database of WRBWO		Correction based on
Available	Available	→	Original data
Available	Not available	→	Original data
Not available	Available	→	No correction

Source: JICA Study Team

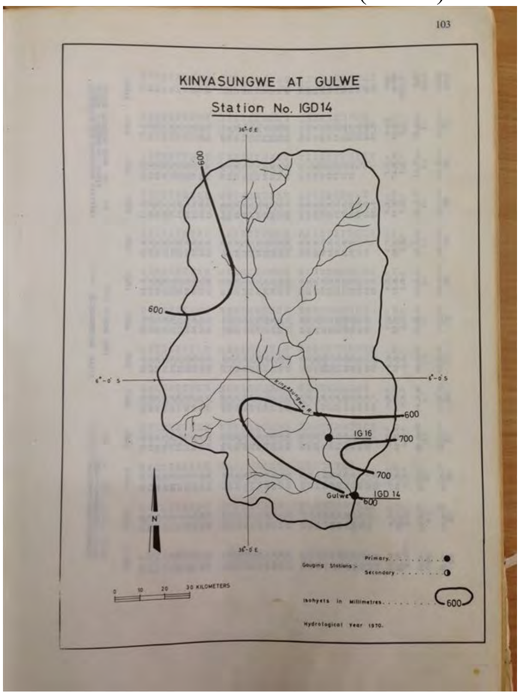
In order to check the reliability of the discharge data in the database, hydrological year-books and historical rating curves were collected. The year books contain daily discharge data in a tabular format and information on discharge gauging stations in Tanzania, such as location, catchment area, type of gauge, form of control, duration of records, extremes, and general remarks. Table 6.7 and Figure 6.10 show the list of the hydrological year-books and examples of their pages, respectively. The rating curves were collected from the Hydrology Section of the Ministry of Water (MOW) and they are in the either functional or tabular format. The discharge data in the database were compared with the discharge data in the year-books and the discharge calculated from water level by applying the rating curves. However, the discharge data in the database are different from both of these. Therefore, reliability of discharge data cannot be confirmed.

Table 6.7: Hydrological Year-Book

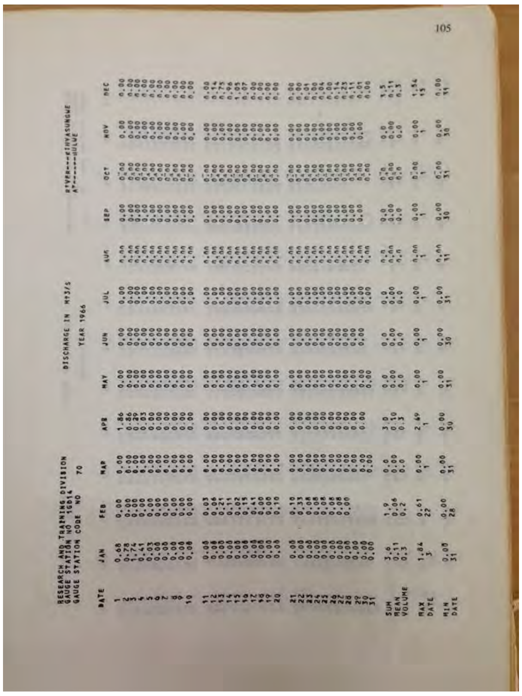
Volume	Compiled by	Published Year	Data available in the upstream area of Kilosa
Hydrological Year-Book 1950–1959	Water Development & Irrigation Division, Ministry of Agriculture	1963	Daily discharge for 1GD2 (Kilosa) from 1952 to 1959
Hydrological Year-Book 1965–1970.	Ministry of Water Development and Power	1976	Daily discharge for 1GD2 (Kilosa) from 1964 to 1970 1GD14 (Gulwe) from 1965 to 1970 1GD31 (Mdukwe) from 1969 to 1970 1GD29 (Mbarawe) from 1969 to 1970 1GD30 (Kilimalulu) from 1969 to 1970

Source: JICA Study Team

Catchment area of 1GD14 (Gulwe)



Daily discharge at 1GD14 (Gulwe) in tabular format



Source: Hydrological Year-Book 1965–1970

Figure 6.10: Example of a Hydrological Year-Book

Table 6.8 shows the availability of daily hydrological data for the upstream areas of Kilosa. Hatched cells indicate that the collected daily data were checked against original data. Figure 6.11 shows the location of daily rainfall stations and daily water level/discharge gauging stations in the target area. Results of collection and review are summarized as follows:

Rainfall

- Daily rainfall data is available at 39 stations in the target area.
- Reliability of data at 22 stations was confirmed, but the periods of original data available are limited mostly to recent years (after 2008).
- Two stations, the 9636004 station (Kibakwe Mission) and the 9636049 station (Lufusi Maji), were newly added to the database since data was collected from TMA, and they have not yet been stored in the database.
- Two stations, the Ilolo meteorological station and the Azimio primary school, were newly added to the database since the original records were collected from the WRBWO, but they have not yet been stored in the database.
- The latitude and longitude points for the 9636008 station (Vianze Dairy) were corrected through confirmation with TMA.
- Daily rainfall at the 9636013 station (Kongwa P.R.S) after 2007 was deleted because data of another station was input over it.

Water Level

- Daily average water level is available at 13 stations in the target area.
- Reliability of the water level data at eight stations was confirmed, but the periods of original data available are limited mostly to recent years (after 2008).

Discharge

- Daily average discharge is available at six stations in the target area.
- Reliability of the discharge data cannot be confirmed since original data is not available, and they differ from both the discharge data from the hydrological year-books and the discharge calculated by applying rating curves.

Table 6.8: Availability of Daily Hydrological Data in the Upstream Areas of Kilosa (1/2)

Data	No.	Station Code	Name	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Rainfall	1	9535005	HOMBOLO PRIMARY SCHOOL																																									
	2	9535006	ZANKA PRIMARY SCHOOL																																									
	3	9535007	MAKUTUPORA MAJI																																									
	4	9536000	KIBAYA MET STATION KITELO										△	△	△	△	△	●	●	●	●	●	●	●	●	●	●	△	△	●	●	●	△	●	●	●	●	●	●	△			△	●	△	●	●	●
	5	9536002	ITISO PRIMARY SCHOOL																																							△				
	6	9536004	DABALO DAM																																					●	●	●	●	●	●	●	●
	7	9536005	ZOISA PRIMARY SCHOOL																																									
	8	9536011	NJOGE PRIMARY SCHOOL																																									
	9	9536017	IKOMBO MET.																																									
	10	9635001	DODOMA AIRPORT								●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	11	9635012	DODOMA MAJI																																				△	●	△	△	△	△	●	●	△
	12	9635014	MATAMBULU DAM																																					●	●	△	△	●	●	●	●
	13	9636000	MPWAPWA RESEARCH STATION	△	●	△	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●								
	14	9636002	BUIGIRI MISSION																																									
	15	9636004	KIBAKWE MISSION																																									
	16	9636006	KIBORIANI (MARTI)														●	△	△	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	△	●	●	●			
	17	9636008	VIANZE DAIRY																							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	△
	18	9636013	KONGWA P.R.S																													●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	△
	19	9636018	UKAGURU FOREST STATION																																△	△	△	●	●	●	△	●	●	●	●	△	●	●
	20	9636020	KINYASUNGWE																																				△	△	●	●	△	△	△	●	●	●
	21	9636026	GAIRO																																									
	22	9636027	NONGWE PRIMARY SCHOOL																																									
	23	9636029	KONGWA ADMIN. OFFICE																																									
	24	9636030	SAGARA																																									
	25	9636031	MLALI VILLAGE																																									
	26	9636032	MSETA VILLAGE																																									
	27	9636033	PANDAMBILI																																									
	28	9636034	CHAMKOROMA PR. SCHOOL																																									
	29	9636037	CHILOMWA PR. SCHOOL																																									
	30	9636038	MTANANA PRIMARY SCHOOL																																									
	31	9636049	LUFUSI MAJI																																									
	32	9736007	ULAYA																																				△	△	●	●	●	●	●	●	●	△
	33	Chihanga	Chihanga Primary School																																									
	34	Mayamaya	Mayamaya Primary School																																									
	35	Kikombo	Kikombo Primary School																																									
	36	Ibwaga	Ibwaga Primary School																																									
	37	kutukutu	Kutukutu Secondary School																																									
	38	Ilolo	Ilolo Met.																																									
	39	Azimio	Azimio Primary School																																									
Water Level	1	1GD2	Mkondoa at Kilosa																												△	●	●	●	●	●	●	●	△	△	●	△	△	●	●	●	△	●
	2	1GD14	Kinyasungwe at Gulwe																																	△	△	△	△	△	△	△	△	△	△	△	△	△
	3	1GD16	Kinyasungwe at Kongwa																																		△	△	●	△	△	△	△	△	△	△	△	△
	4	1GD17	Kinyasungwe at Godegode																																									
	5	1GD21	Kinyasungwe at Itiso																																									
	6	1GD29	Mkondoa at Mbarahwe																																									△
	7	1GD30	Lumuma at Kilimalulu																																									△
	8	1GD31	Mdukwe at Mdukwe																																									△
	9	1GD32	Mkondoa at Railway Bridge																																									
	10	1GD33	Masena at Ibumila																																									
	11	1GD37	Great Kinyasungwe at Ikombo																																									
	12	LKiM	Little Kinyasungwe at Mayamaya																																									
	13	LKiC	Little Kinyasungwe at Chihanga																																									
Discharge	1	1GD2	Mkondoa at Kilosa																												△	●	●	●	●	●	●	●	△	△	△	△	△	●	●	●	△	●
	2	1GD14	Kinyasungwe at Gulwe																																	△	△	△	△	△	△	△	△	△	△	△	△	△
	3	1GD16	Kinyasungwe at Kongwa																																		△	△	△	△	△	△	△	●	●	△	△	△
	4	1GD29	Mkondoa at Mbarahwe																																									△
	5	1GD30	Lumuma at Kilimalulu																																									△
	6	1GD31	Mdukwe at Mdukwe																																									△

Source: JICA Study Team

● : Data is available through a year
△ : Data contains missing data
: Confirmed by original records

Table 6.8: Availability of Daily Hydrological Data in the Upstream Areas of Kilosa (2/2)

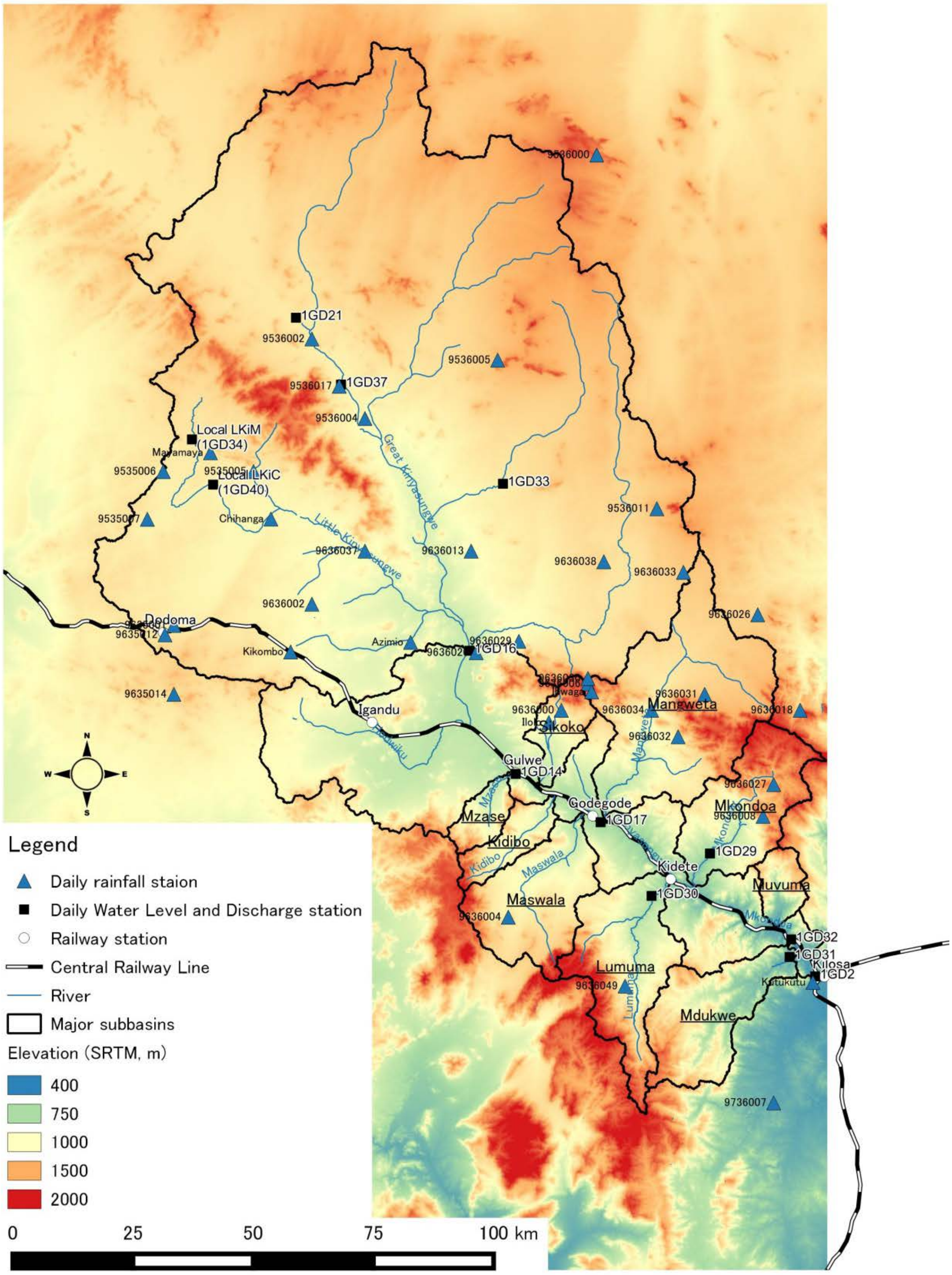
Data	No.	Station Code	Name	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Rainfall	1	9535005	HOMBOLO PRIMARY SCHOOL																																							△	●	●	●	●	●	△
	2	9535006	ZANKA PRIMARY SCHOOL																																							△	△	●	●	●	●	●
	3	9535007	MAKUTUPORA MAJI																																							△	●	△			●	
	4	9536000	KIBAYA MET STATION KITELO	△	△	●	●	●	△		△	●	●	△	●	△	●	●	●	●	△	△	●	△	●	△																						
	5	9536002	ITISO PRIMARY SCHOOL		●	△	●	●	●	●												●	●	●	●																△	●	●	●	●	●	●	△
	6	9536004	DABALO DAM	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△																	△	●	●	●	●	●	△
	7	9536005	ZOISA PRIMARY SCHOOL																																							△	●	●	●	●	●	△
	8	9536011	NJOGE PRIMARY SCHOOL																																							△	●	●	●	●	●	△
	9	9536017	IKOMBO MET.		△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△				△	●	●	●	●	●	●	●	△
	10	9635001	DODOMA AIRPORT	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	11	9635012	DODOMA MAJI	△	△	△	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●																		●	△	●	●	●	●	△
	12	9635014	MATAMBULU DAM	△	●	△	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	△	△	●	△	△	△	△																			
	13	9636000	MPWAPWA RESEARCH STATION																																													
	14	9636002	BUIGIRI MISSION																																							△	●	●	●	●	●	
	15	9636004	KIBAKWE MISSION																									△	●	●	●	●	△	△		△	△	△							△			
	16	9636006	KIBORIANI (MARTI)	△			●		●	●										△	△	●	△	●	△	●		●																				
	17	9636008	VIANZE DAIRY	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	△	●		●	△																			
	18	9636013	KONGWA P.R.S	△	●	●	●	●	△	●	●	●	△	●	●	●	●	●	△		△	△	●	●	△	△	●	●	●																			
	19	9636018	UKAGURU FOREST STATION	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			△	△		△	●	△																			
	20	9636020	KINYASUNGWE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●
	21	9636026	GAIRO	●	●	△	△	●	△	△	△	△	●	●	●	△	●	△	△	△	△	△	△																									
	22	9636027	NONGWE PRIMARY SCHOOL	△	△	●	●	●	●	●	△	△	●	●	●	△	●	●	△	△	△	△	△	△	△	△	△																					
	23	9636029	KONGWA ADMIN. OFFICE			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	△																								
	24	9636030	SAGARA																																							△	●	●	●	●	●	△
	25	9636031	MLALI VILLAGE																																							△	△	●	●	●	●	●
	26	9636032	MSETA VILLAGE																																							△	●	●	●	△	●	△
	27	9636033	PANDAMBILI																																							△	●	●	●	●	●	△
	28	9636034	CHAMKOROMA PR. SCHOOL																																							△	●	●	●	●	●	△
	29	9636037	CHILOMWA PR. SCHOOL																																							△	△	△	△	●	●	△
	30	9636038	MTANANA PRIMARY SCHOOL																																							△	●	●	●	●	●	△
	31	9636049	LUFUSI MAJI																					△	△	△							△	△		△	△	△										
	32	9736007	ULAYA	●	△	△	●	△	●	●	△	●	△	●	●	●	△	●	△	△	△	●	△																									
	33	Chihanga	Chihanga Primary School																																							△	△	●	●	●	●	●
	34	Mayamaya	Mayamaya Primary School																																							△	●	●	●	●	●	△
	35	Kikombo	Kikombo Primary School																																							●	●	●	●	●	●	△
	36	Ibwaga	Ibwaga Primary School																																							△	△	●	●	●		△
	37	kutukutu	Kutukutu Secondary School																																											△	●	●
	38	Ilolo	Ilolo Met.																																											△	●	●
	39	Azimio	Azimio Primary School																																							△	●	●	●	●	●	△
Water Level	1	1GD2	Mkondoa at Kilosa	●	●	●	△	△	●	△	△	△	△	△	△	△	△	△	△	△	△	△																		△	●	●	●	△	△	△	△	△
	2	1GD14	Kinyasungwe at Gulwe	△	△	△	△	△	△	△	△	△	△	△	△	△	△																															
	3	1GD16	Kinyasungwe at Kongwa	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△			△	△	△	△	△	△	△	△	△	△	△	●	●	●	△
	4	1GD17	Kinyasungwe at Godegode							△	△	△	△																																			
	5	1GD21	Kinyasungwe at Itiso																																			●	△	●	△	△	△	●	●	●	●	△
	6	1GD29	Mkondoa at Mbarahwe	△	●	●	●	●	●	△	△	△	●	△	●	△	●	●	●	△	△	●	△	△	△																						△	
	7	1GD30	Lumuma at Kilimalulu	●	●	●	●	●	△	●	△	△	●	△	△	△	△	△	●	●	△	●	△	●	△	△	△	△	△																			
	8	1GD31	Mdukwe at Mdukwe	●	△	●	△	●	●	●	●	●	△																																			
	9	1GD32	Mkondoa at Railway Bridge					△	△																																							
	10	1GD33	Masena at Ibumila																																													
	11	1GD37	Great Kinyasungwe at Ikombo					△	△	△	△	△	△	△	△	△	●	△	△	△	△	△	△	△																△	△	●	●	●	●	●	△	△
	12	LKiM	Little Kinyasungwe at Mayamaya																																					△	●	●	●	●	●	●	●	△
	13	LKiC	Little Kinyasungwe at Chihanga																																					△	●	●	●	△	●	●	△	△
Discharge	1	1GD2	Mkondoa at Kilosa	●	●	●	△	△	●	△	△	△	△	△	△	△	△	△	△																													
	2	1GD14	Kinyasungwe at Gulwe	△	●	△	△	△	△	△	△																																					
	3	1GD16	Kinyasungwe at Kongwa	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△																														
	4	1GD29	Mkondoa at Mbarahwe	△	●	●	△	●	●	△	△	△	●	△	●	△																																
	5	1GD30	Lumuma at Kilimalulu	●	●	●	●	●	△																																						
	6	1GD31	Mdukwe at Mdukwe	●	△	●	△	△	●	●	●	△	△	●	△	△	●	△	△	△	△	●	●																									

Source: JICA Study Team

● : Data is available through a year

△ : Data contains missing data

(shaded) : Confirmed by original records



Source: JICA Study Team

Figure 6.11: Location of Daily Rainfall Station/Daily Water Level and Discharge Gauging Stations in the Upstream Areas of Kilosa

6.1.3 Climate Change

TMA (2015)[2] reports climate change projections for Tanzania. Table 6.9 and Figure 6.12 show their results for the projection of annual and seasonal rainfall change in the central region, where the target area of this Study is located. These results indicate that future rainfall during the rainy season from December to February might increase in the years 2025, 2050, 2075, and 2100 as compared with the present climate, whereas the future rainfall from March to May might not change drastically.

Since projections for instantaneous rainfall event that might cause flood damages to the Central Railway are not available in the TMA report, their results can be used as one of the references for the possibility of future change of rainfall characteristics in the target region, but cannot be used for the planning of flood countermeasures for the Central Railway.

According to the latest report by the Intergovernmental Panel on Climate Change (IPCC)[3], it is very likely that extreme precipitation events will become more intense and frequent in many regions. In order to assess the impact of climate change in the target area, monitoring of storms, floods, and resulting sediment deposition and/or erosion in the river channels is required.

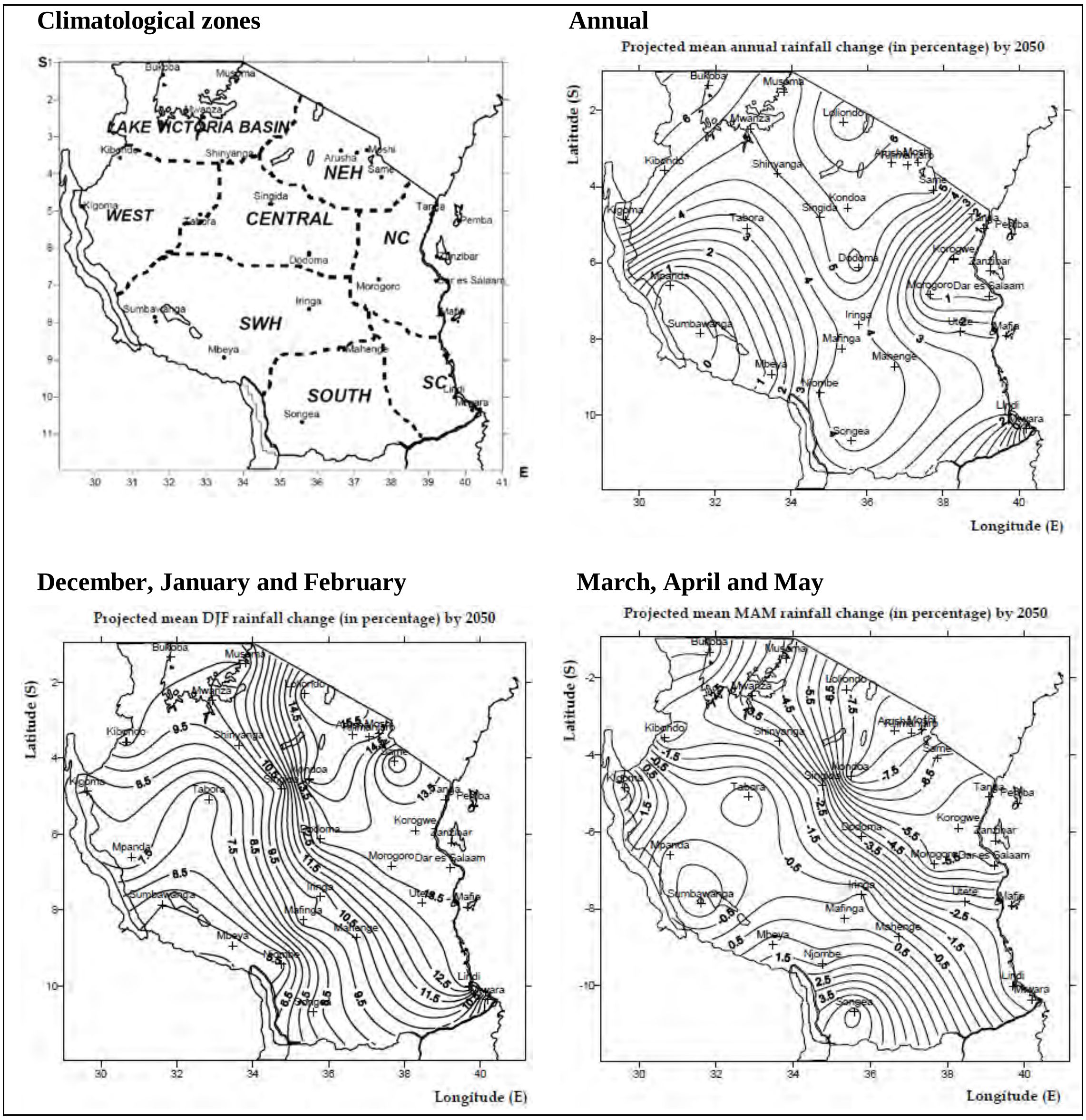
Table 6.9: Projected Percentage Change in Rainfall

Climatological zone	**Season**	**Projected percentage change (%)**			
		2025	**2050**	**2075**	**2100**
Central (Dodoma, Singida and part of Tabora)	Annual	2.3 – 2.5	5.0 – 5.7	6.2 – 7.7	9.4 – 10.4
	December, January and February	4.8 – 6.1	9.8 – 13.7	14.9 – 20.8	18.7 – 25.6
	March, April and May	−1.2 – 0.2	−3.7 – −2.8	−3.5 – 4.2	−4.3 – 5.1

Source: TMA, 2015. Climate Change Projection for Tanzania. Tanzania Meteorological Agency (TMA), Ministry of Transport, United Republic of Tanzania. ISBN 978-9987-9981-0-5. pp.37. Modified by the JICA Study Team

2 TMA, 2015. Climate Change Projection for Tanzania. Tanzania Meteorological Agency (TMA), Ministry of Transport, United Republic of Tanzania. ISBN 978-9987-9981-0-5. pp.37.

3 IPCC, 2014. Climate Change 2014 Synthesis Report Summary for Policymakers. pp.31.



Source: TMA, 2015. Climate Change Projection for Tanzania. Tanzania Meteorological Agency (TMA), Ministry of Transport, United Republic of Tanzania. ISBN 978-9987-9981-0-5. pp. 37. Modified by the JICA Study Team

Figure 6.12: Projected Percentage Change in Rainfall for the Year 2050

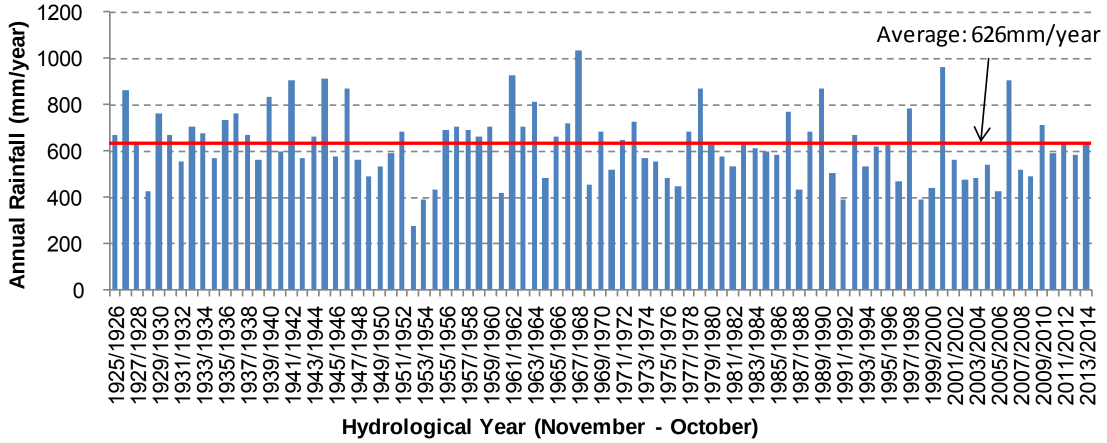
6.2 Hydrological Characteristics

Rainfall and runoff characteristics in the upstream areas of Kilosa were investigated from hydrological data collected from WRBWO and TMA, and publicly available dataset.

6.2.1 Rainfall Characteristics

(1) Annual and Monthly Rainfall

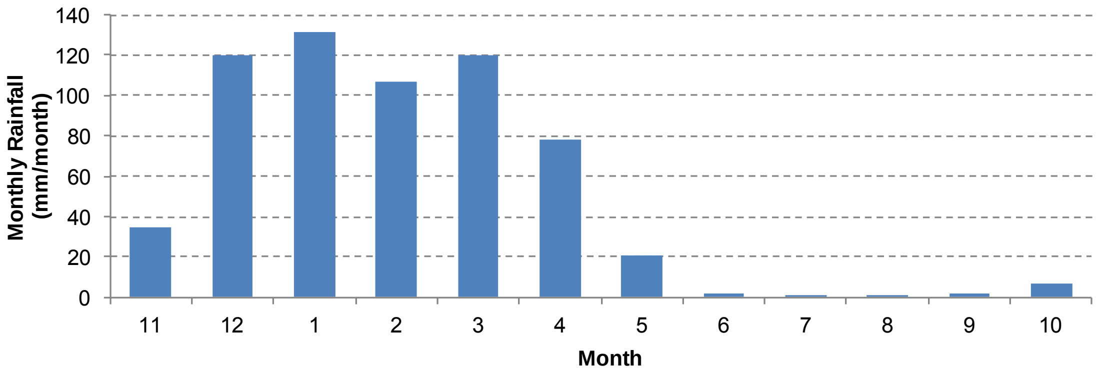
Annual rainfall in the upstream areas of Kilosa for the hydrological year from November to October was calculated from catchment average daily rainfall amounts at the 1GD2 gauging station (Mkondoa River at Kilosa), which were estimated by using the Thiessen method with ground-observed daily rainfall data. Figure 6.13 shows the inter-annual variability of annual rainfall in the target area. Amounts of annual rainfall vary from year to year. The maximum of annual rainfall was 1031 mm/year in 1967/1968, the minimum was 277 mm/year in 1952/1953. The average annual rainfall is 626 mm/year and the standard deviation is 149 mm/year.



Source: JICA Study Team

Figure 6.13: Inter-annual Variability of Annual Rainfall in the Hydrological Year (November to October) in the Upstream Areas of Kilosa

Figure 6.14 shows the monthly rainfall in the target area. The monthly rainfall was averaged over a period from November 1925 to October 2014. The target area receives rainfall from November to May, mostly during December to April.



Source: JICA Study Team

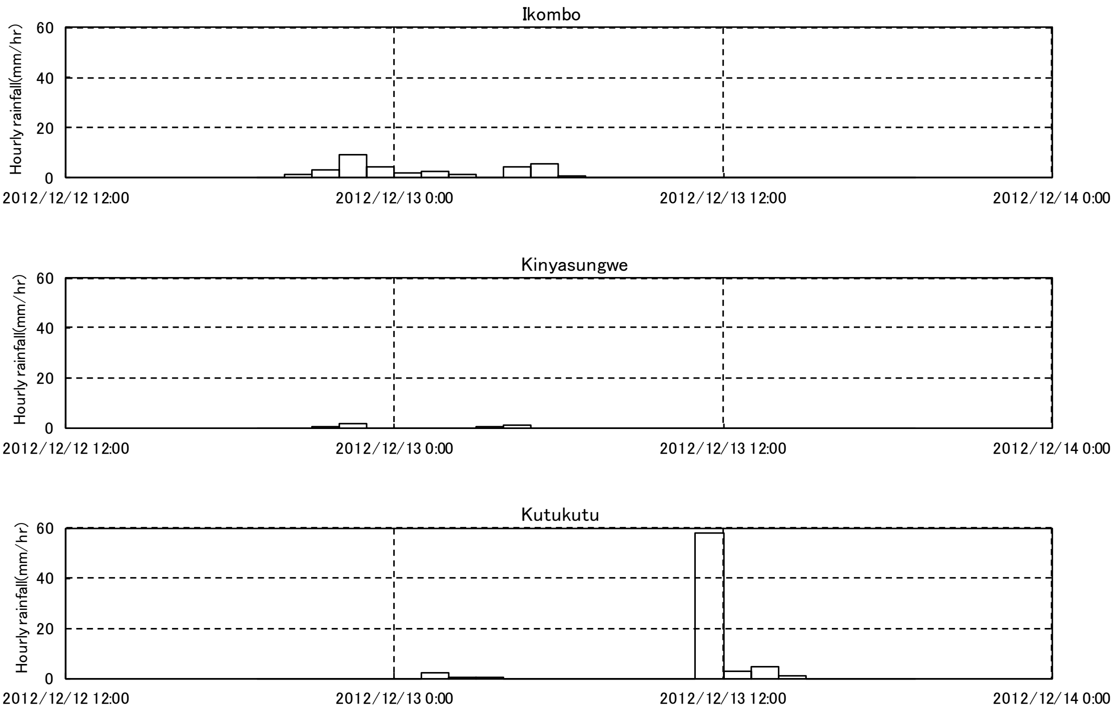
Figure 6.14: Monthly Rainfall in the Upstream Areas of Kilosa

(2) Rainfall Characteristics (Depth, Area, and Duration)

Rainfall characteristics in terms of depth, area, and duration in the upstream areas of Kilosa were identified from the collected hourly rainfall data. Figure 6.15 through Figure 6.17 show the time series of hourly rainfall during the maximum storm events at the Kutukutu, Kinyasungwe, and Ikombo stations, respectively. The results are summarized as follows:

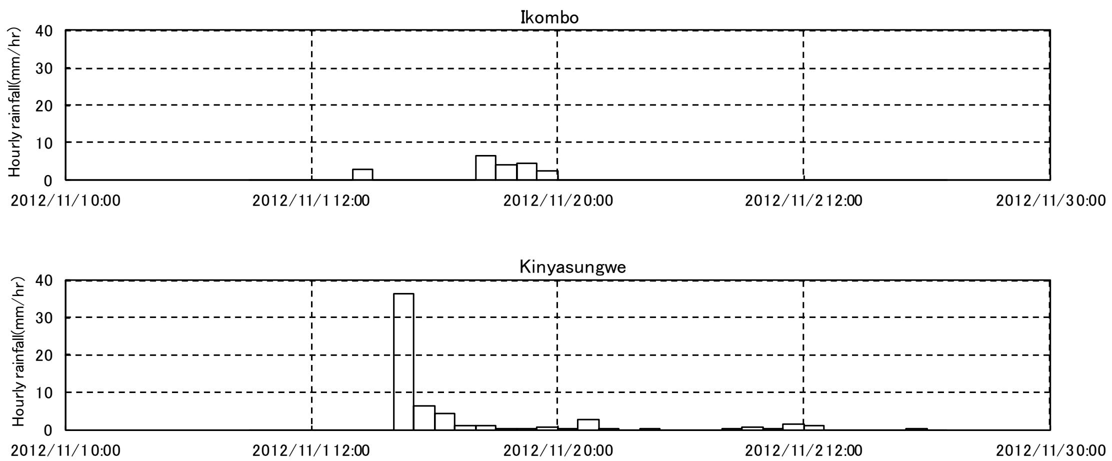
- High-intensity hourly rainfall was observed at all three stations: 58 mm/hr at Kutukutu, 36.2 mm/hr at Kinyasungwe, and 43.2 mm/hr at Ikombo.
- All of these heavy rainfall events were observed to be completed within one hour, and did not last more than one hour.

- All of these heavy rainfall events were observed at only one station at a time. No rainfall was observed at another station at the same time. These stations are distant from each other more than 50 km.
- Rainfall characteristics in the target area can be summarized as high-intensity, small area, and short duration, although the availability of hourly rainfall data is limited.



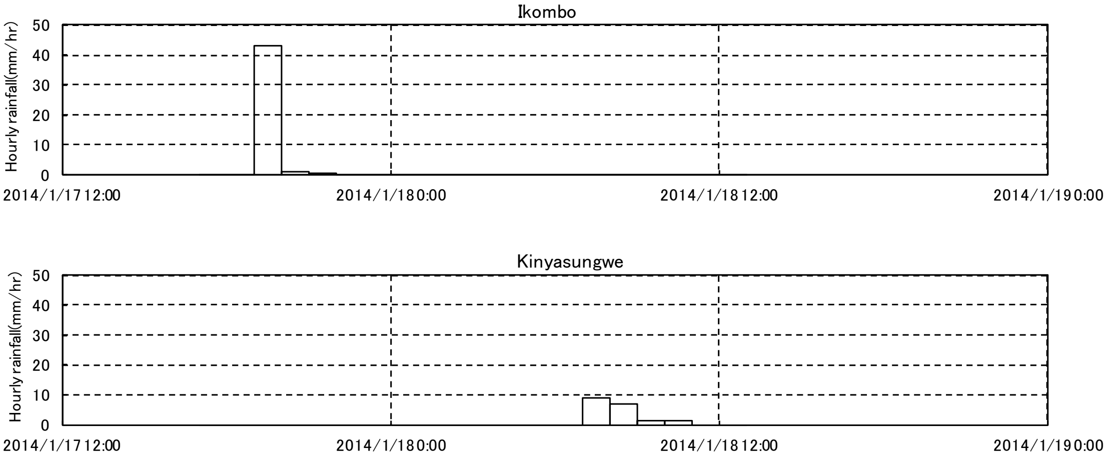
Source: JICA Study Team

Figure 6.15: Hourly Rainfall during the Maximum Storm at Kutukutu Station



Source: JICA Study Team

Figure 6.16: Hourly Rainfall during the Maximum Storm at Kinyasungwe Station



Source: JICA Study Team

Figure 6.17: Hourly Rainfall during the Maximum Storm at Ikombo Station

Further, the spatial scale of the rainfall area in the target area was verified by comparing the observed daily rainfall amounts at pairs of two nearby stations. Table 6.10 and Figure 6.18 show the comparison of daily rainfall observed at the pairs on the same days. Six sets of pairs were selected arbitrarily by considering their locations: (i) Cases 1 to 3 are from the Sikoko River basin; (ii) Case 4 to 6 are from the Mangweta River basin. Correlation coefficients were calculated using data from the period when both stations of the pair have records, whose reliability were reviewed by comparing with original records. The results are summarized as follows:

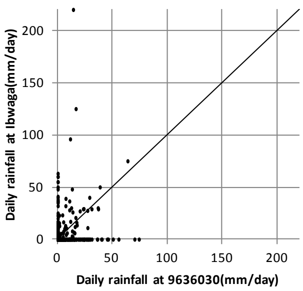
- Correlation coefficients are low in the all cases. The small spatial scale of rainfall areas are confirmed also from daily rainfall data.
- A closer horizontal distance between two stations does not necessarily represent a better correlation coefficient. The horizontal distance of Case 1 is 2.9 km (the closest among all cases), but its correlation coefficient is not high.

Table 6.10: Comparison of Daily Rainfall Observed at Nearby Stations on the Same Days

case	WMO code	Station Name	LAT	LONG	Elevation from WRBWO Database (m)	Elevation from SRTM (m)	Distance of two stations (km)	Correlation coefficient
1	9636030	SAGARA	-6.270	36.550	1,219	1,664		
	Ibwaga	Ibwaga Primary School	-6.295	36.557	N/A	1,669	2.9	0.24
2	9636030	SAGARA	-6.270	36.550	1,219	1,664		
	Ilolo	Ilolo MET	-6.353	36.477	N/A	968	12.3	0.18
3	Ibwaga	Ibwaga Primary School	-6.295	36.557	N/A	1,669		
	Ilolo	Ilolo MET	-6.353	36.477	N/A	968	11.0	0.18
4	9636031	MLALI VILLAGE	-6.300	36.770	1,524	1,310		
	9636032	MSETA VILLAGE	-6.380	36.720	1,524	1,134	10.5	0.19
5	9636031	MLALI VILLAGE	-6.300	36.770	1,524	1,310		
	9636034	CHAMKOROMA PR. SCHOOL	-6.330	36.670	N/A	1,019	11.6	0.22
6	9636032	MSETA VILLAGE	-6.380	36.720	1,524	1,134		
	9636034	CHAMKOROMA PR. SCHOOL	-6.330	36.670	N/A	1,019	7.9	0.19

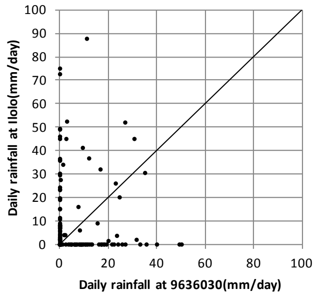
Source: JICA Study Team

(1) Sikoko River basin



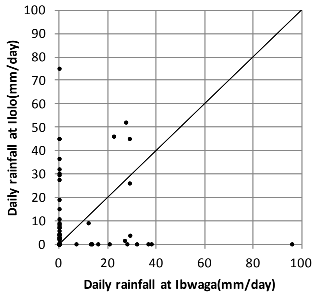
Correlation coefficient= 0.24

(2) Sikoko River basin



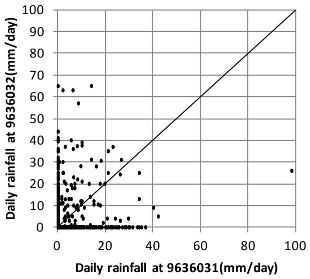
Correlation coefficient= 0.18

(3) Sikoko River basin



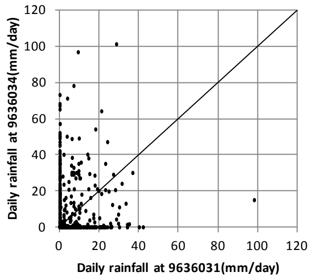
Correlation coefficient= 0.18

(4) Mangweta River basin



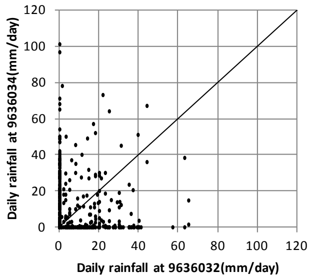
Correlation coefficient= 0.19

(5) Mangweta River basin



Correlation coefficient= 0.22

(6) Mangweta River basin



Correlation coefficient= 0.19

Source: JICA Study Team

Figure 6.18: Comparison of Daily Rainfall Observed at Near Stations in Same Days

(3) Storm Area Movement Assessed by Satellite-Based Data

Ground-observed rainfall data is temporally and spatially limited, and no meso-scale meteorological information, such as storm cloud movement or the spatial scale of rainfall area, is available at TMA in the target region. Therefore, the movement of storm areas was assessed by using a satellite-based rainfall dataset, although its accuracy is still very low, in particular for high-intensity, small-area, and short-duration storm rainfall events that generate flash floods.

The Global Rainfall Map in Near-Real-Time (GSMaP_NRT) using the Japan Aerospace Exploration Agency (JAXA) Global Rainfall Watch System was used to understand the characteristics of the spatial distribution of rainfall. GSMaP_NRT is a high-resolution global precipitation map generated from satellite data produced and distributed by the Earth Observation Research Center in JAXA. The temporal and spatial resolutions are one hour and 0.1 degree latitude/longitude (about 11 km), respectively. Data after 1 January 2010 is available on their website[4].

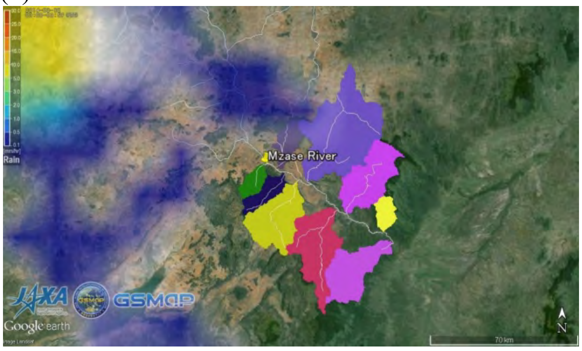
Figure 6.19 shows the spatial distribution of hourly rainfall for the storm event of 30 March 2014. This event was selected because of (i) the availability of the satellite data and (ii) the occurrence of resulting flood damages to the railway. On that day, the track was washed away at the Mzase Bridge (crossing the Mzase River) at Km 365.7 near Gulwe Station. The results are summarized as follows:

- A relatively intense rainfall area (depicted in yellow) moved from the northwest to the southeast.

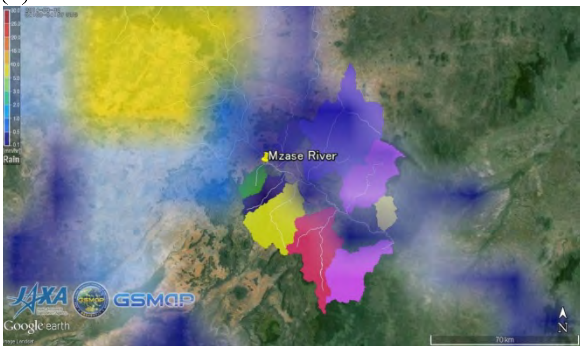
[4] http://sharaku.eorc.jaxa.jp/GSMaP/index.htm

- The storm supplied rainfall in the Mzase River basin for one to two hours before the flash flood occurred (Figure 6.19 (3) and (4)).
- The intense rainfall area had already moved to other tributaries in the next hour (Figure 6.19 (5))
- The storm area in the target region might move quickly and the duration of the storm event might be several hours long. However, storm area movements in the target region cannot be simply characterized, due to complex meteorological processes affected by macro-scale circulation, local topography, etc.

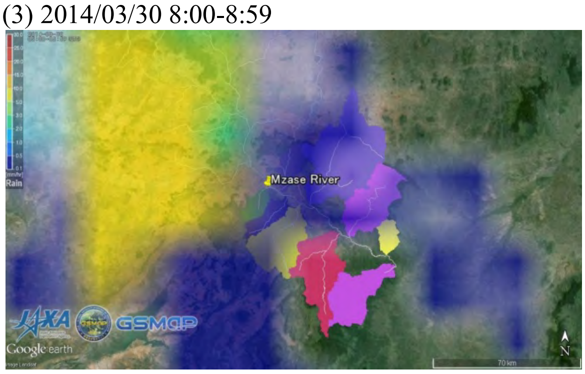
(1) 2014/03/30 6:00-6:59



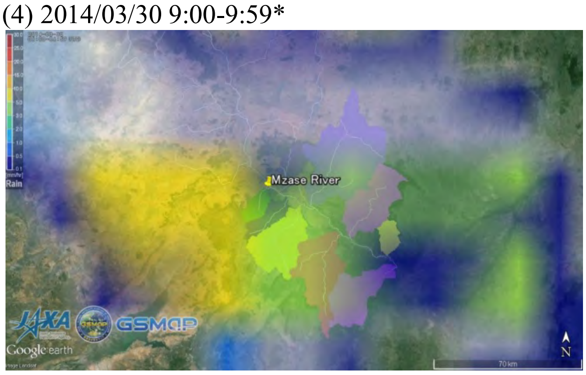
(2) 2014/03/30 7:00-7:59



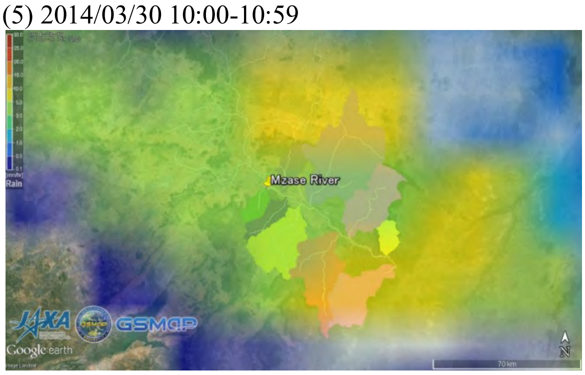
(3) 2014/03/30 8:00-8:59



(4) 2014/03/30 9:00-9:59*



(5) 2014/03/30 10:00-10:59



* Snapshot of the Video Taken at the Mzase Bridge at Km 365.7 around 9:30 on 30 March 2014

Source: JICA Study Team

Figure 6.19: Spatial Distribution of Hourly Rainfall for the Storm Event on 30 March 2014

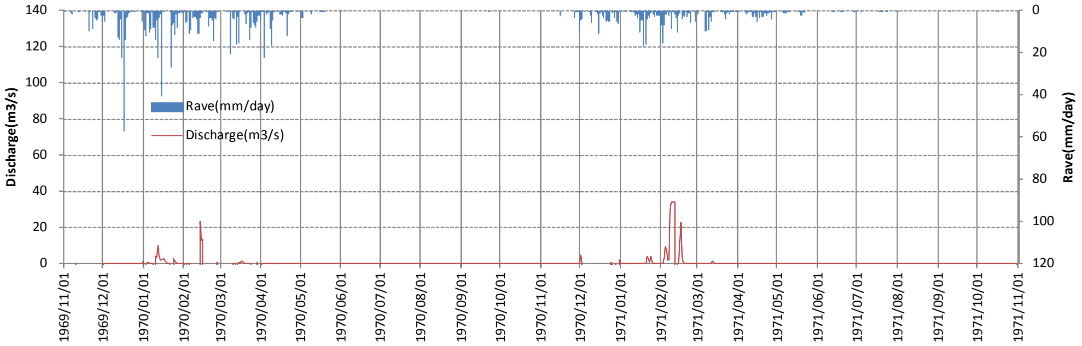
6.2.2 Runoff Characteristics

(1) Daily Discharge

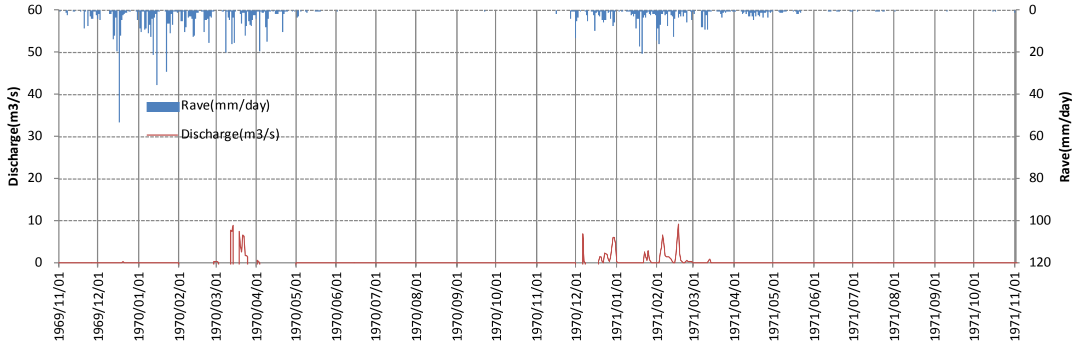
Runoff characteristics in the upstream areas of Kilosa were investigated from the collected daily discharge data. Figure 6.20 and Figure 6.21 show the daily discharge and rainfall in the hydrological years of 1969/1970 and 1970/1971 at gauging stations in the main stream and tributaries, respectively. These hydrological years were selected as examples because of the good availability of discharge data at all six gauging stations. Daily rainfall data shown in these figures are the catchment average rainfall amounts at each gauging station. The results are summarized as follows:

- In the main streams, as shown in Figure 6.20, at 1GD2 (Mkondoa at Kilosa) there is a year-long flow, whereas the flow at 1GD14 (Kinyasungwe at Gulwe) and 1GD16 (Kinyasungwe at Kongwa) are ephemeral, and do not flow year-long, only when rainfall occurs.
- In the tributaries as shown in Figure 6.21, the flow is year-long at all three stations: 1GD29 (Mkondoa at Mbarahwe), 1GD30 (Lumuma at Kilimalulu) and 1GD31 (Mdukwe at Mdukwe).
- Hydrographs of ephemeral stretches have steep rising limbs, with an almost instantaneous rise of peak flow, and steep recession limbs. These characteristics are known as “flash floods”, which happen very suddenly and continue for only a short time.

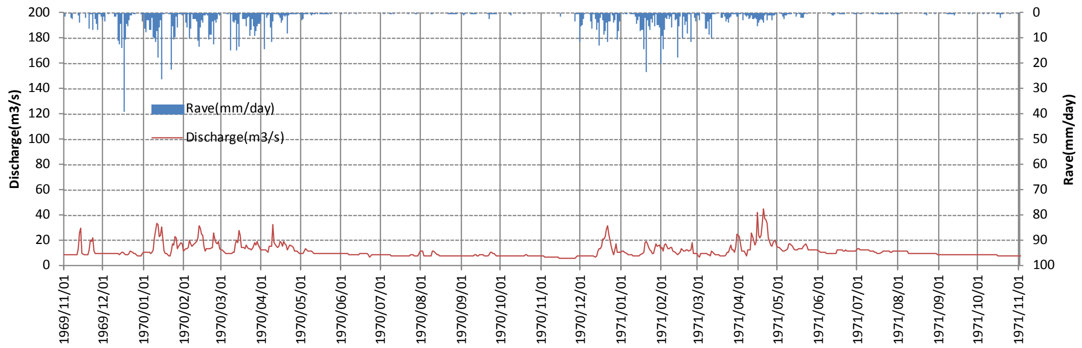
1GD16 Kinyasungwe at Kongwa



1GD14 Kinyasungwe at Gulwe



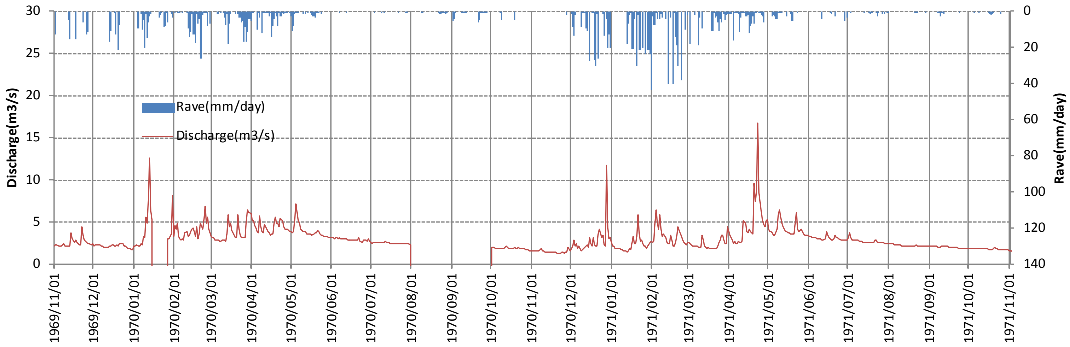
1GD2 Mkondoa at Kilosa



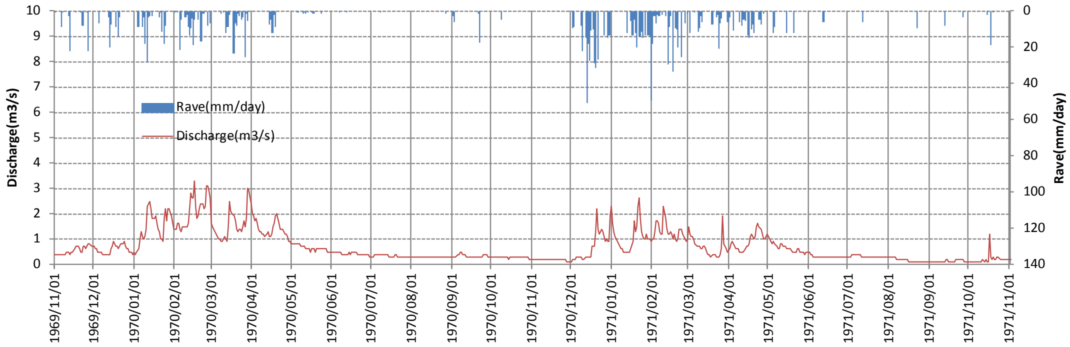
Note: “Rave” means catchment average rainfall
Source: JICA Study Team

Figure 6.20: Daily Discharge and Rainfall at Three Gauging Stations in the Main Streams (Mkondoa River and Kinyasungwe River)

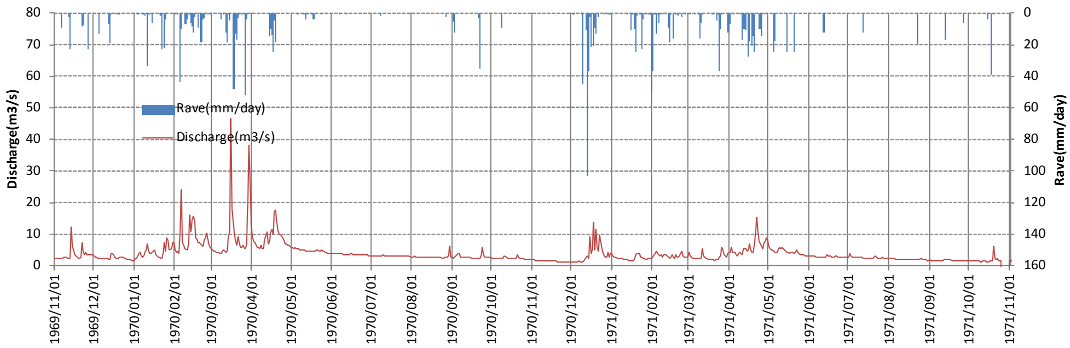
1GD29 Mkondoa at Mbarahwe



1GD30 Lumuma at Kilimalulu



1GD31 Mdukwe at Mdukwe



Note: "Rave" means catchment average rainfall
Source: JICA Study Team

Figure 6.21: Daily Discharge and Rainfall at Three Gauging Stations in the Tributaries (Mkondoa River, Lumuma River and Mdukwe River)

(2) Hourly Water Level

Since hourly discharge data is not available in the target area, runoff characteristics at hourly time-steps were investigated from hourly water level data observed at 1GD2 (Mkondoa at Kilosa). Table 6.11 shows the peak water level of floods at 1GD2 during the rainy seasons in hydrological years of 2011/2012 and 2012/2013, and the corresponding flood damages to the Central Railway Line at these floods. Figure 6.22 shows the hourly water level of these floods.

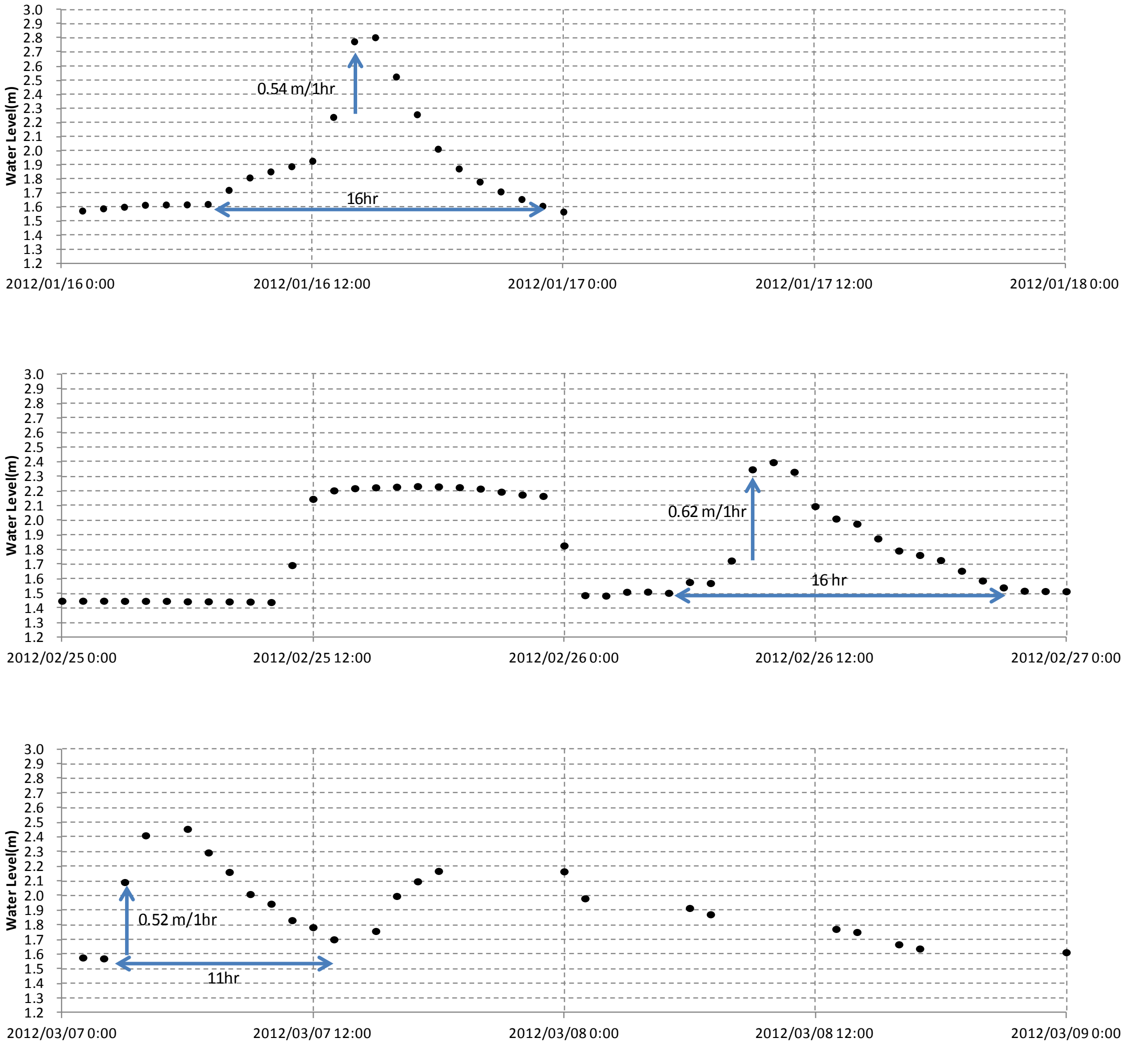
Here, a water level of 2.3 m was applied as a threshold to extract flood events. The threshold water level was set by considering number of extracted floods during the limited period of the available hourly water level data. The results are summarized as follows:

- The highest water level at 1GD2 was 2.81 m at 2012/1/16 at 15:00, during the period of available data. On the same day, flood damages for the Central Railway Line occurred at Km 349, where the Maswala River crosses the railway line.
- On 2012/1/16, the water level increased by 0.54 m in one hour. That huge increase in the water level may have been caused by substantial rainfall in the Maswala River basin. However, that is not certain, since there are five big tributaries between the confluence of the Maswala River to Kilosa, and the rainfall in these tributaries likely also contributed to the increase in water level at Kilosa.
- Two other floods were also observed but no damages were recorded. That means that a high water level at 1GD2 does not necessarily indicate the possibility of flood damages to the Central Railway Line in the upstream areas of Kilosa.
- The duration of the three flood event at 1GD2 was less than 24 hours. Although data of the spatial and temporal distribution of rainfall in the upstream areas during these flood events is not available, these data indicate that a flood event might not last for more than one day at this site.

Table 6.11: Flood Water Level at 1GD2 and Flood Damages to the Central Railway Line

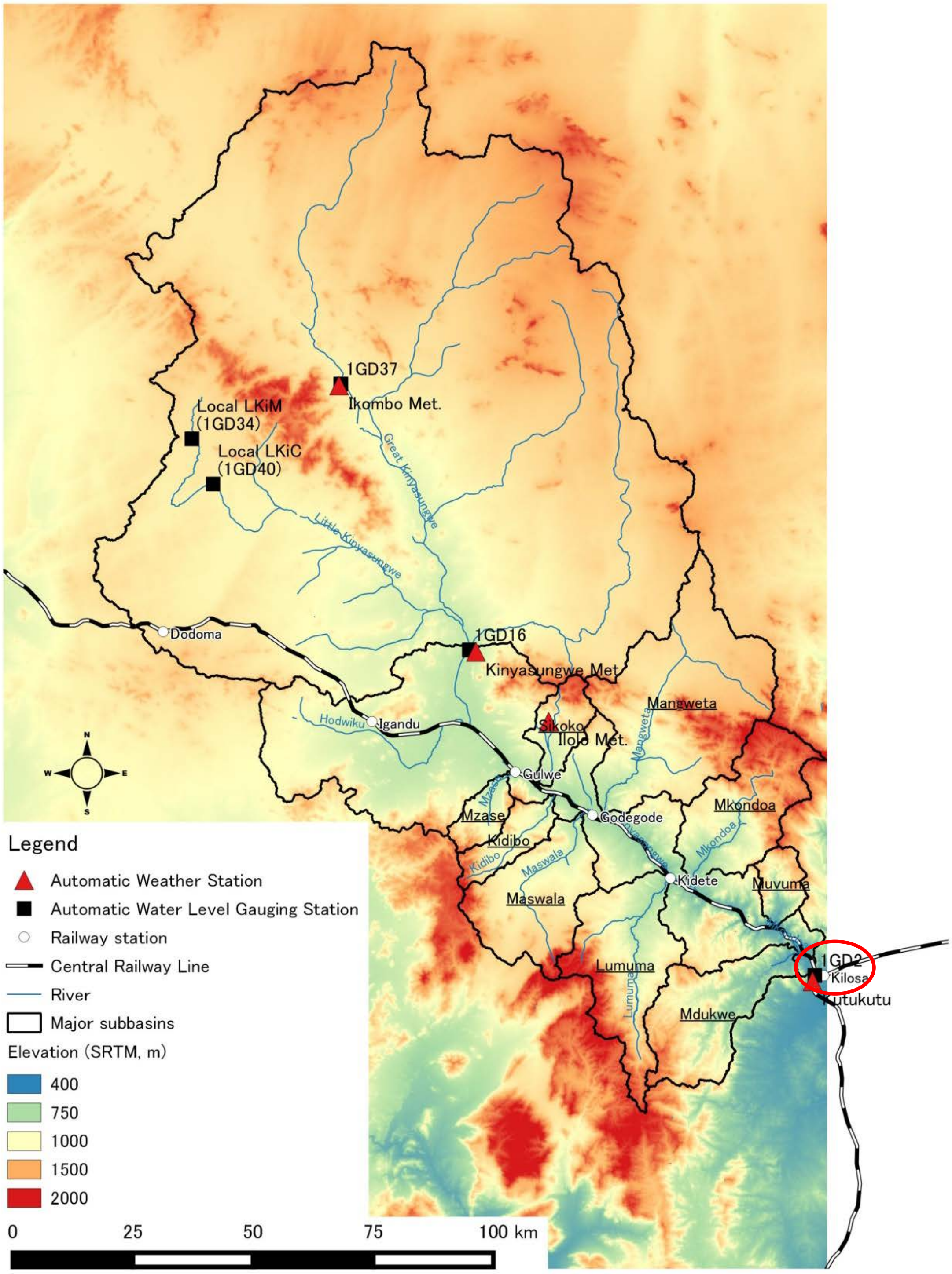
No.	Date and Time of Peak Water Level at 1GD2 (Mkondoa at Kilosa)	Peak Water Level (m)	Duration of Flood Event (hr)	Flood Damage of Central Railway Line Recorded by TRL
1	2012/1/16 15:00	2.81	16	Culvert ballast wall broken down at Km 349/4B, Km 349/7B, Km 349/5B No passage of train for 168 hours from 2012/1/16
2	2012/2/26 10:00	2.40	16	No damage was recorded
3	2012/3/7 6:00	2.46	11	No damage was recorded

Source: JICA Study Team



Source: JICA Study Team

Figure 6.22: Hourly Water Levels during Flood Events at 1GD2 (Mkondoa at Kilosa)



Source: JICA Study Team

Figure 6.23: Location of 1GD2 Water Level Gauging Station (Mkondoa at Kilosa)

6.3 Hydrological and Hydraulic Analyses for Setting of Hydraulic Conditions for Flood Protection Measures

Considering the low availability of hydrological data, and complex rainfall and runoff characteristics in the upstream areas of Kilosa (as previously described), this study conducted hydrological and hydraulic analyses for the purpose of setting the hydraulic conditions for flood protection measures, as follows:

- A frequency analysis for annual maximum hydrological series, such as point rainfall, catchment average rainfall, and daily average discharge, was conducted to determine probable hydrological values.
- A hydraulic analysis for floods in the main streams between Kilosa and Gulwe was conducted to estimate flood discharges that would reproduce the measured water level of the flood marks.
- A hydrological analysis was conducted to estimate flood peak discharges in return periods in the catchment areas between Kilosa and Gulwe.

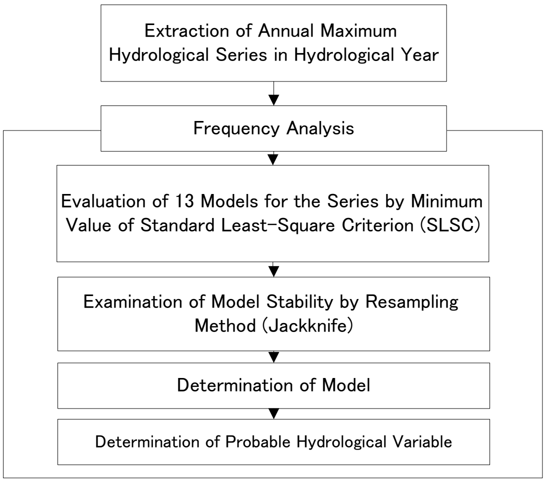
6.3.1 Estimation of Probable Hydrological Variables

(1) Frequency Analysis

The frequency analysis for the annual maximum series of hydrological variables in a given hydrological year, from November to October, was conducted to determine probable variables. Figure 6.24 shows the flowchart of the frequency analysis. The software “Hydrological Statistics Utility” (version 1.5), which was developed by the Japan Institute of Construction Engineering, was employed for the analysis. Table 6.12 shows 13 models for frequency analysis in the Hydrological Statistics Utility. Standardized least squares criterion (SLSC), proposed by Takara[5], was employed for examining the goodness of fit of each model. Model stability was examined by applying the jackknife method (one of re-sampling methods). The model with the smallest SLSC and the least estimated error was selected. An unbiased estimator by the Jackknife method was employed for probable hydrological variables.

According to the World Meteorological Organization (WMO)[6], a record of 40 to 50 years is, in general, satisfactory for extreme precipitation frequency analysis. However, most stations in the Study Area do not satisfy this requirement. Therefore, the stations that have more than or equal to 15 samples of annual maximum series were selected for frequency analysis. It should be noted that the frequency analysis in this study might contain the results that are not reasonably accurate or robust due to the small sample size.

[5] Takara, K. and Takasao, T. (1988) Evaluation Criteria for Probability Distribution Models in Hydrologic Frequency Analysis. Preprint, Fifth IAHR International Symposium on Stochastic Hydraulics, University of Birmingham, UK, August 1988, Paper A5, 10 pp.
[6] World Meteorological Organization (WMO), 1981: Selection of Distribution Types for Extremes of Precipitation (B. Sevruk and H. Geiger). Operational Hydrology Report No. 15, WMO-No. 560, Geneva.



Source: JICA Study Team

Figure 6.24: Flowchart of Frequency Analysis

Table 6.12: Models for Frequency Analysis in Hydrological Statistics Utility

No.	Name of Model	Abbreviation
1	Exponential Distribution	Exp
2	Gumbel Distribution	Gumbel
3	Generalized Extreme Value Distribution	GEV
4	Square-Root Exponential Type Distribution	Sqrt-Et
5	Log Pearson type III Distribution (Real Number Calculations)	LP3Rs
6	Log Pearson type III Distribution (Logarithmic Calculations)	LogP3
7	Iwai Method	Iwai
8	Ishihara-Takase Method	IshiTaka
9	Log normal Distribution 3 Population Quantile Method	LN3Q
10	Log normal Distribution 3 Population (Slade II)	LN3PM
11	Log normal Distribution 2 Population (Slade I, L Moment)	LN2LM
12	Log normal Distribution 2 Population (Slade I, Product Moment)	LN2PM
13	Log normal Distribution 4 Population (Slade IV, Product Moment)	LN4PM

Source: Japan Institute of Construction Engineering

Table 6.13 summarizes the result of frequency analysis. Additional tables and figures of annual maximum daily rainfall series, and these results are shown in Appendix K. The results are summarized as follows:

Point Daily Rainfall

- 14 rainfall stations among the 35 total were selected for frequency analysis and daily rainfall at the 30-year return period level is in the range of 80.0 – 128.3 mm/day.
- Among the 14 stations, only three stations are located in the catchment area between Kilosa and Gulwe. These stations are 9636000 in the Sikoko River basin, 9636006 in the Mangweta River basin, and 9636008 in the Mkondoa River basin, and their 30-year daily rainfall values are 88.5, 128.3, and 106.7 mm/day, respectively.
- Among the three stations, the 9636008 station located in the Mkondoa River basin has the largest amount of annual maximum daily rainfall series (44).

Catchment Average Daily Rainfall at 1GD2 (Mkondoa at Kilosa)

- The annual maximum series of catchment average rainfall at 1GD2, estimated by the Thiessen method using point rainfall data of more than two stations, were selected as samples for frequency analysis.
- The 30-year catchment average daily rainfall is 46.2 mm/day.

Daily Average Discharge at 1GD2 (Mkondoa at Kilosa)

- The 30-year return period of daily average discharge at 1GD2 is 184 m^3/s. However, the results of the frequency analysis, as well as the discharge data, that was obtained from the WRBWO are not reliable because of the small recorded discharge levels compared with the actual measurement conducted by the discharge measurement and suspended load sampling surveys in this Study. For example, 97 m^3/s as a 5-year flood discharge almost equals to the small scale flood of 94 m^3/s with a 1.91 m water level measured on 27/03/2015 at 1GD2. According to the recent year's record at 1GD2, a water level of about 1.91 m was frequently observed, more frequent than a 5-year return period.

Table 6.13: Results of Frequency Analysis

Hydrological Variable		**Point Daily Rainfall (mm/day)**														**Catchment Average Daily Rainfall (mm/day)**	**Daily Discharge (m^3/s)**
Site		9536000	9536004	9536017	9635001	9635012	9635014	9636000	9636006	9636008	9636013	9636018	9636020	9636029	9736007	1GD2 (Mkondoa at Kilosa)	1GD2 (Mkondoa at Kilosa)
No. of Sample		37	34	38	76	24	24	32	28	44	34	30	50	15	23	76	20
Model		LN3PM	Gumbel	Gev	Gev	LogP3	Gev	LogP3	LogP3	Gev	Gev	Gev	LogP3	Gev	LN2LM	Iwai	Iwai
SLSC		0.019	0.026	0.032	0.02	0.028	0.045	0.037	0.036	0.032	0.037	0.043	0.025	0.036	0.034	0.018	0.038
Probable Value in Return Period	2	60.9	57.3	55.7	68.3	61.5	59.7	53.7	67.4	55.2	56.5	67.8	54.3	59.1	73.3	27.4	54
	3	71.0	67.2	62.3	76.8	69.3	70.6	60.9	79.5	63.2	64.7	79.4	61.4	65.6	82.8	31.0	74
	5	80.4	78.3	68.3	85.7	77.2	83.3	68.4	92.3	72.7	73.5	91.1	68.9	71.0	92.9	34.9	97
	10	90.2	92.2	74.4	96.0	86.0	99.7	77.1	107.5	85.6	84.3	103.7	77.5	75.8	105.2	39.5	130
	20	98.0	105.5	78.9	105.0	93.6	115.5	84.6	121.0	98.7	94.0	114.0	85.1	78.8	116.5	43.8	164
	30	101.9	113.2	81.0	109.7	97.5	124.5	88.5	128.3	106.7	99.4	119.1	89.3	80.0	122.8	46.2	184
	50	106.5	122.8	83.0	115.3	102.1	135.5	93.2	137.1	117.0	105.8	124.8	94.3	81.1	130.6	49.1	211
	80	110.2	131.6	84.6	120.1	106.0	145.2	97.1	144.7	126.8	111.4	129.3	98.7	81.9	137.7	51.7	237
	100	111.9	135.7	85.2	122.3	107.7	149.6	98.8	148.2	131.6	113.9	131.3	100.7	82.1	141.0	52.9	249
	150	114.8	143.3	86.1	126.0	110.8	157.2	101.8	154.3	140.4	118.4	134.5	104.3	82.5	146.9	55.1	272
	200	116.7	148.6	86.6	128.5	112.8	162.3	103.8	158.5	146.8	121.4	136.5	106.7	82.7	151.2	56.7	289
	400	121.0	161.5	87.6	134.1	117.3	173.1	108.3	168.1	162.7	128.1	140.6	112.5	83.0	161.3	60.4	332

Source: JICA Study Team

(2) Fuller's Formula

In the report of hydrological assessment for the Msagali earth dam project by the Mpwapwa District Council[7], Fuller's Formula is employed to estimate the flood peak discharge corresponding to a specified return period, as follows:

$$Q_T = CA^{0.8}(1 + 0.8 \ln T)(1 + 2.67A^{-0.3})$$

where
Q_T: Flood magnitude corresponding to a specified return period (m^3/s)
A: Catchment area (km^2)
T: Return period (year)
C: Constant value (0.1815 for Kinyasungwe River)

Fuller's Formula is an empirical flood formula that has been applied widely in different regions of the world, such as United States of America, Canada, India, Iran, etc. The estimate of peak discharge depends upon the constant value that varies from basin to basin due to basin physical characteristics, rainfall characteristics, etc. According to WMO[8], it should be noted that empirical formulae provide a rough estimate providing only the order of magnitude of large flood flows. Therefore, this study employed the Fuller's Formula to estimate peak discharge as reference values using the same constant values applied the Msagali earth dam project.

Table 6.14 shows the results of the flood peak discharge at 1GD2 as estimated by Fuller's Formula.

Table 6.14: Flood Peak Discharge at 1GD2 (Mkondoa at Kilosa) Estimated by Fuller's Formula

Return Period (year)	Flood Peak Discharge at 1GD2 (m^3/s)
2	801
3	969
5	1,179
10	1,465
20	1,751
30	1,918
50	2,129
80	2,323
100	2,415
150	2,582
200	2,701
400	2,987

Source: JICA Study Team

6.3.2 Hydraulic Analysis for the Main Streams between Kilosa and Gulwe

A hydraulic analysis for the main streams between Kilosa and Gulwe was conducted to estimate the flood discharge of historical flood events.

7 Mpwapwa District Council, 2011. Hydrological assessment and water demand study on Msagali earth dam project, Mpwapwa District. Ministry of Local Government and Regional Administration, the United Republic of Tanzania.
8 World Meteorological Organization (WMO), 1981: Selection of Distribution Types for Extremes of Precipitation (B. Sevruk and H. Geiger). Operational Hydorology Report No.15, WMO-No.560, Geneva.

(1) Model Set-up

A hydraulic analysis was conducted by using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1, developed by HEC, the U.S. Army Corps of Engineers. Table 6.15 shows the details of the hydraulic analysis model set-up.

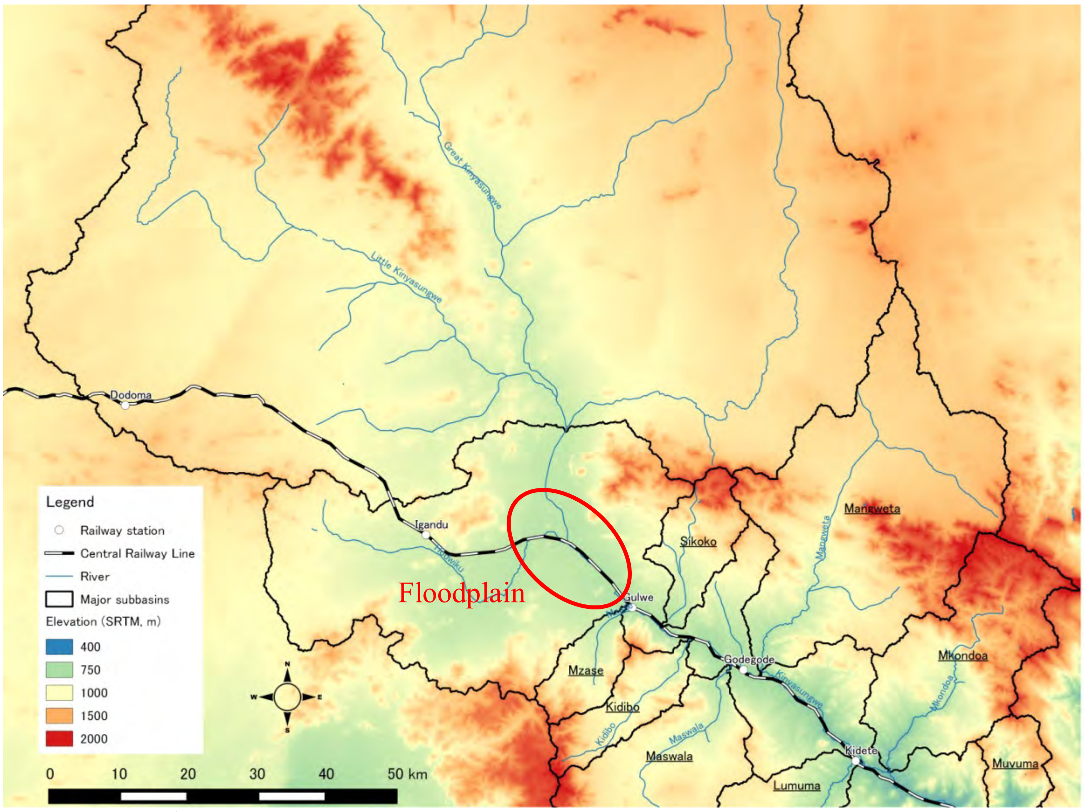
Flood water from upstream of Gulwe might be stored in the floodplain and seasonal swamp located at upstream of Gulwe. Figure 6.25 and Figure 6.26 show the location of the floodplain with topography in the background, and the current condition of the seasonal swamp, respectively. If the floodwater from the upstream areas of Gulwe are indeed stored at the seasonal swamp, then most of this water might not be propagated to the downstream areas. Therefore, this Study assumed a discontinuity of floodwater propagation at the floodplain and seasonal swamp, and no inflow from the upstream of the Kinyasungwe River at Gulwe.

Floodwater from the Mkondoa River might inundate Kilosa (the town) and the velocity of the inundated water might be decreased due to friction caused by buildings and trees. However, detail data on actual situation of flood inundation near Kilosa is not available. Therefore, this study conducted hydraulic analysis in two cases: case1 with the ineffective areas near Kilosa (Figure 6.27); and case2 without ineffective areas.

Table 6.15: Hydraulic Analysis Model Set-up

Item	**Model Set-up**
Dimension	One dimension
Flow condition	Non-uniform flow
Flood flow	Steady flow
Target reach	Main streams from Kilosa to Gulwe (Km 282 - Km 365), assuming discontinuity of floodwater propagation due to the floodplain and seasonal swamp located upstream of Gulwe (Figure 6.25 andFigure 6.26).
River cross-section	· Current river cross-sections measured by the river cross-section and longitudinal profile survey in this Study · Approximately 1 km interval in main streams · Including three bridges of Kilosa, Kilosa (old), and New bridge. · Ineffective flow areas near Kilosa (Figure 6.27) ➢ Case1: With ineffective areas ➢ Case2: Without ineffective areas
Parameter	Manning's roughness coefficient of 0.03 in main channels and 0.05 in floodplains, by considering site conditions and references (Table 6.16, and Figure 6.28).

Source: JICA Study Team



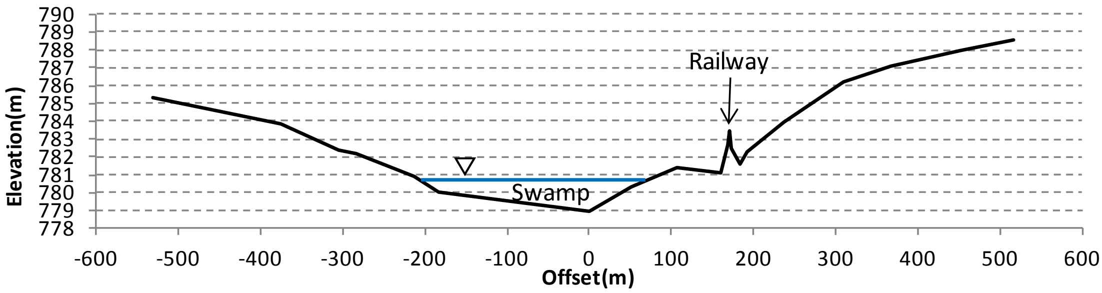
Source: JICA Study Team

Figure 6.25: Location of Floodplain Upstream of Gulwe

Plain view

Photo

Cross-section (Km 366.5)



Source: JICA Study Team

Figure 6.26: Seasonal Swamp Upstream of Gulwe

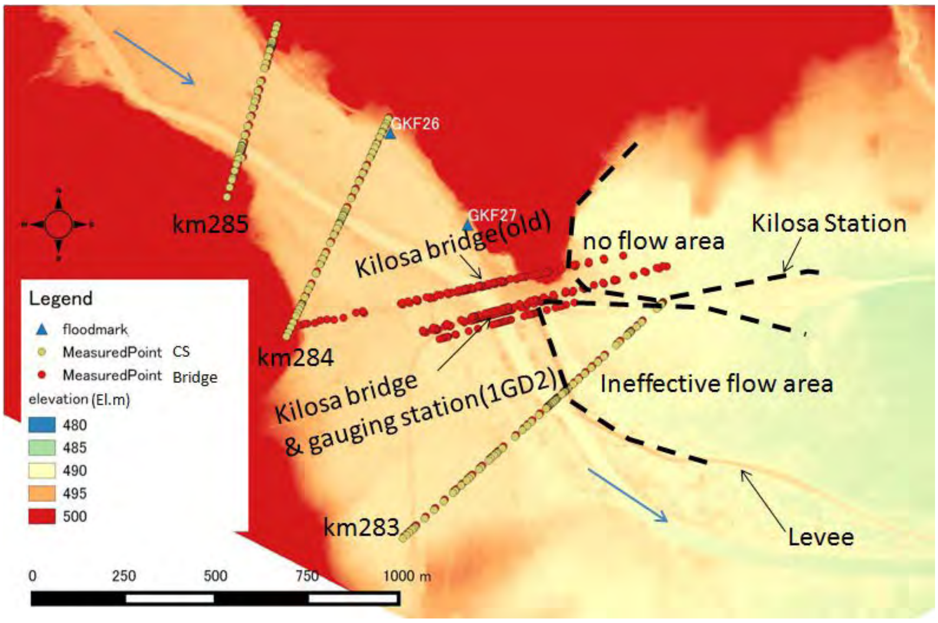


Figure 6.27: Ineffective Flow Areas near Kilosa

Table 6.16: Manning's Roughness Coefficients

Type of Channel and Description	Minimum	Normal	Maximum
A. *Natural Streams*			
1. **Main Channels**			
a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. **Flood Plains**			
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above, but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above, but with flow into branches	0.100	0.120	0.160
5. Dense willows, summer, straight	0.110	0.150	0.200

Source: Hydrologic Engineering Center, US Army Corps of Engineers, 2010. HEC-RAS River Analysis System, Hydraulic Reference Manual Version 4.1.

Km 283(1GD2 Gauging Station, Mkondoa at Kilosa)

Km 293 (New Bridge)

Km 312

Km 313

Km 327

Km 337

Km 355

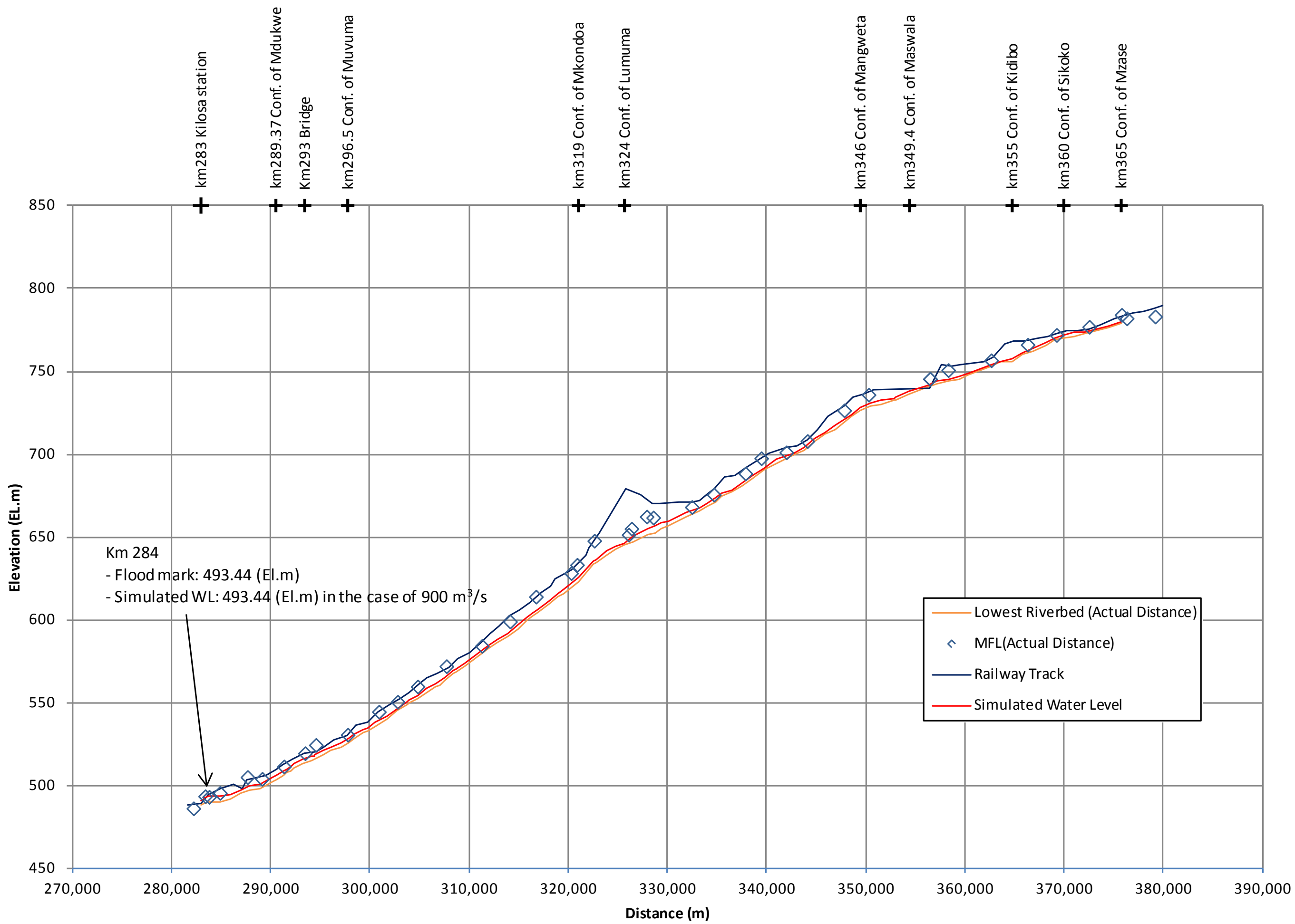
Source: JICA Study Team

Figure 6.28: Condition of River Cross Sections

(2) Estimation of Flood Discharge in Historical Flood Events

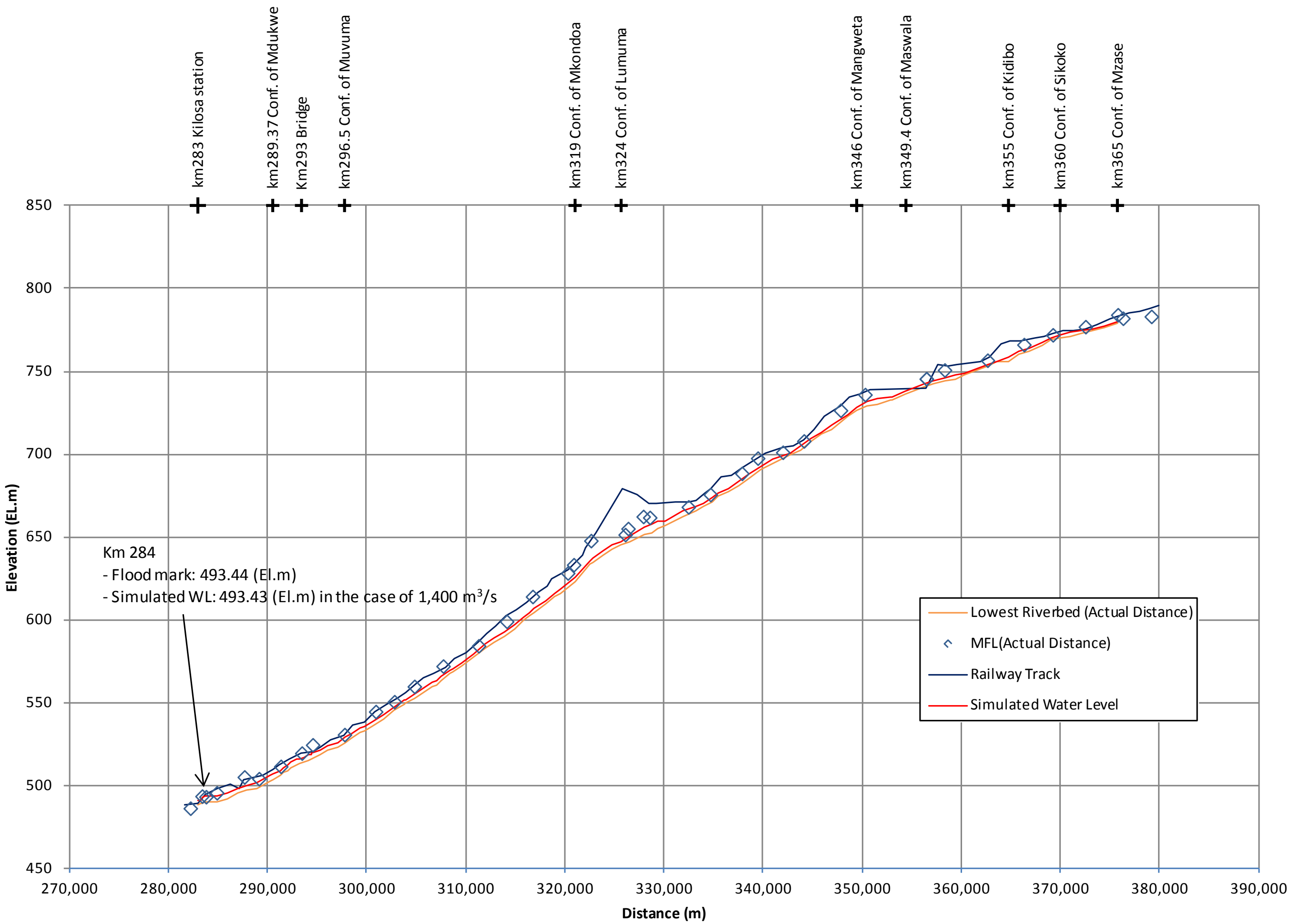
Flood discharge in historical flood events in the main stream was estimated through trial and error by reproducing water levels of flood marks measured by the flood mark survey in this Study. The distribution of flood discharge, the boundary condition for the hydraulic analysis, was set by assuming that the discharge at Kilosa was distributed to nine major tributaries according to sub-catchment size since the discharge data in the target area is not enough spatially available. The flood mark near Km 284 in Kilosa was selected as the target for the estimation because the mark was considered highly reliable (Appendix Q).

Figure 6.29 and show the longitudinal profiles of hydraulic analysis for reproducing the water level of flood mark at Km 284 in Case 1 (with ineffective areas near Kilosa) and Case 2 (without ineffective areas near Kilosa), respectively. The simulated water level at Km 284 with 900 m^3/s in Case 1 and 1,400 m^3/s in Case 2 almost coincides the flood mark. Discharges from historical flood events that caused damage to the railway might be in the range from 900 to 1,400 m^3/s at Kilosa. However, the simulation result underestimates flood water levels compared with flood marks in the upstream areas. Further investigation is required.



Source: JICA Study Team

Figure 6.29: Longitudinal Profile of Hydraulic Analysis for Reproducing the Water Level of Flood Mark at Km 284, Case 1 (With Ineffective Areas Near Kilosa)



Source: JICA Study Team

Figure 6.30: Longitudinal Profile of Hydraulic Analysis for Reproducing the Water Level of Flood Mark at Km 284, Case 2 (Without Ineffective Areas Near Kilosa)

6.3.3 Hydrological Analysis

Hydrological analysis in the catchment area between Kilosa and Gulwe was conducted to estimate flood peak discharge in return periods.

(1) Selection of Hydrological Model

Table 6.17 shows the list of hydrological models applied in this Study. Since hydrological data for model calibration are not available in terms of temporal and spatial scales, this Study selected models whose parameters can be estimated from pre-determined empirical/analytic equations or look-up tables, by considering the physical properties of the basin.

The Soil Conservation Service (SCS) Unit Hydrograph (UH) in the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) version 4.0 developed by HEC, the U.S. Army Corps of Engineers, was applied to estimate surface runoff generation, that is the most important hydrological process in the target area. The SCS UH method is one of the most widely-used models to estimate runoff generation in ungauged catchments[9]. In the TRL project[10], SCS UH method was applied to estimate flood peak discharge for flood prevention works along the Central Railway Line between Kilosa and Gulwe.

Transmission loss, which is the loss of floodwater in river channels, is a significant hydrological process in ephemeral rivers. However, local data required for modeling this process is not available in the target area. Therefore, transmission loss was not considered.

Other hydrological processes, such as subsurface runoff, base runoff, and evapotranspiration, were not considered in this Study because of (i) less importance for flood estimation in the target area, and (ii) no available data for model set-up.

Table 6.17: Hydrological Models Applied in the Study

Hydrological Processes		Model Applied
Rainfall	Excess Rainfall	SCS Curve Number Loss Model in HEC-HMS
	Evapotranspiration	-
Runoff Generation in a basin	Surface Runoff	SCS UH in HEC-HMS
	Subsurface Runoff	-
	Base Runoff	-
River Routing in a river channel	River Routing	Muskingum-Cunge method in HEC-HMS
	Transmission loss	-

Source: JICA Study Team

(2) Model Set-up

Table 6.18 shows the list of data used for the model set-up. Data for topography and soil type obtained from the WRBWO were applied. On the other hand, data of land cover is not available at the WRBWO. Therefore, publicly available data for land cover was selected. Before application, a check of the data was conducted to confirm that it was similar to the satellite data from the satellite image data used for other analyses in this Study.

Table 6.19 shows the parameter estimation of the models applied in this Study. An SCS Curve Number (CN) is an empirically-derived relationship between location, land cover, soil type,

[9] Blöschl, G., Sivapalan, M., Wagener, T., Viglione, A., and Savenije, H. (Eds.): Runoff Prediction in Ungauged Basins – Synthesis across Processes, Places and Scales, Cambridge University Press, Cambridge, United Kingdom, 2013.
[10] TRC. 1997. Flood Prevention Works on TRC Central Line, Contract No. 3806, Additional Works, Volume I Main Reports, Apr. 1997 by Mott MacDonald In association with Inter-Consult Ltd

antecedent soil moisture conditions, and runoff. An SCS CN is used in many event-based models to establish the initial soil moisture condition, and the infiltration characteristics. Lower numbers of SCS CN indicate low runoff potential while larger numbers are for increasing runoff potential.

Table 6.18: List of Data Used for Model Set-up

Item	Data Used	Data Sources	Horizontal resolution	Remark
Topography	Shuttle Radar Topography Mission（SRTM）	U.S. Geological Survey	90m	Obtained from WRBWO
Land Cover	Global Land Cover Characterization Version 1.2	U.S. Geological Survey	1km	
Soil	Soil Groups	National Land Use Framework Plan Volume III, 2009	-	Obtained from WRBWO

Source: JICA Study Team

Table 6.19: Parameter Estimation

Process	Model	Parameter	Parameter Estimation
Excess Rainfall	SCS Curve Number Loss Model in HEC-HMS	Initial abstraction: I_a(mm)	0.2S S:potential maximum retention S=25400/CN-254
		Curve Number: CN	Derived from, landcover, soil type, and look-up table
		Impervious area: (%)	0, because of no urban area
Surface Runoff	SCS UH in HEC-HMS	Lag time: t_{lag} (min)	60% of time of concentration
River Routing	Muskingum-Cunge method in HEC-HMS	River length, slope, width Manning's coefficient	Assumed from river cross section survey

Source: JICA Study Team

(3) Temporal and Spatial Distribution of Design Storm

Rainfall characteristics in the target area are high-intensity, small area, and short duration. Since rainfall data is spatially and temporally limited, the temporal and spatial distribution of design storm for hydrological analysis were set as follows:

1) Selection of representative probable daily rainfall
The 9636008 station located in the Mkondoa River basin was selected as the representative rainfall station since it has the largest number of annual maximum daily rainfall series among three stations located in the catchments between Kilosa and Gulwe.

2) Assumption of spatial distribution of daily rainfall in sub-basins
Since rainfall characteristics vary in depth from sub-basin to sub-basin, the spatial distribution of rainfall in sub-basins was assumed by the ratio of annual rainfall between sub-basin and the Mkondoa River basin where the 9636008 station is located. Table 6.20 shows the ratio in sub-basins applied for considering spatial distribution.

Table 6.20: Ratio in Sub-basins Applied for Considering Spatial Distribution

Sub-basin		Station name	Annual Rainfall (mm)	Ratio to 9636008 in Mkondoa	Ratio in sub-basins	Remark
Northern tributaries	Sikoko	9636000	667	0.95	1.00	
		Ilolo	748	1.06		
	Mangweta	9636006	775	1.10	0.92	
		9636030	540	0.77		
		9636031	480	0.68		
		9636032	727	1.03		
		9636034	727	1.03		
	Mkondoa	9636008	704	1.00	1.44	
		9636027	1320	1.88		
	Muvuma	-	-	-	1.00	assumes same as 9636008
Southern tributaries	Mzase	-	-	-	0.82	assumes same as Maswala
	Kidibo	-	-	-	0.82	assumes same as Maswala
	Maswala	9636004	577	0.82	0.82	
	Lumuma	9636049	366	0.52	0.52	
	Mdukwe	-	-	-	0.52	assumes same as Lumuma

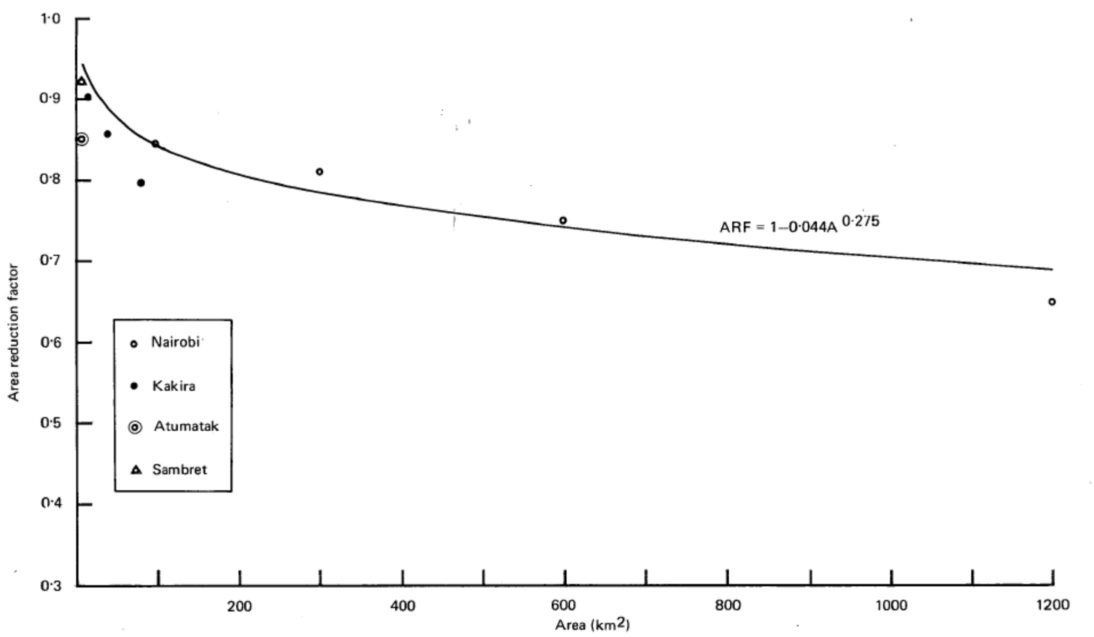
Source: JICA Study Team

3) Application of areal reduction factor

Point rainfall data obtained at rainfall stations were multiplied by an areal reduction factor (ARF) to obtain an areal rainfall estimate at each catchment. The ARF developed by TRRL (1974) using data from a number of East African catchments was applied in this Study. Figure 6.31 shows the ARF.

$$\mathrm{ARF} = 1 - 0.044\mathrm{A}^{0.275}$$

where A: catchment area in km^2

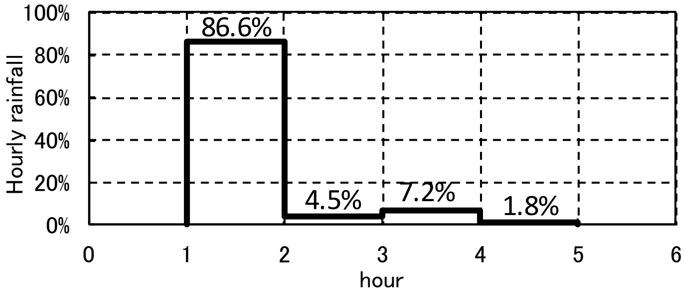


Appendix 1. Fig. 4. EAST AFRICAN AREAL REDUCTION FACTORS

Source: Transport and Road Research laboratory (TRRL), Department of the Environment, UK. 1974. The prediction of storm rainfall in East Africa, TRRL Laboratory Report 623

Figure 6.31: East African Areal Reduction Factors

4) Assumption of hourly distribution of daily rainfall
The temporal distribution was set from the highest hourly rainfall pattern observed at the Kutukutu rainfall station (Figure 6.32).



Source: JICA Study Team

Figure 6.32: Design Storm Profile

The design storm profile determined as above was supplied only in the catchments between Kilosa and Gulwe, since this Study assumed the discontinuity of floodwater propagation at the floodplain and seasonal swamp, as described in Subsection 0.

In addition, this Study assumed the storm occurs over the entire target area at the same time.

(4) Estimation of Flood Peak Discharge in Return Periods

Table 6.21 shows the flood peak discharge in return periods estimated by the hydrological model. The temporal and spatial distribution of rainfall was assumed using probable daily rainfall at the 9636008 station by following the assumptions described above. The results are summarized as follows:

- Estimated flood peak discharges are much higher than the historical flood discharge, which was estimated about 800 m^3/s by the hydraulic analysis in 0.
- However, the hydrological model cannot be calibrated because hydrological data required for calibration are not available in terms of temporal and spatial scales.
- In order to improve the accuracy of flood discharge prediction for the design of flood countermeasures in the target area, the accumulation of hydrological data, at least in an hourly time step, with a dense network of rainfall, water level, and discharge gauging stations is highly recommended.

Table 6.21: Flood Peak Discharge in Return Period Estimated by Hydrological Model

Unit: m^3/s

Site	Main streams	Tributary at the confluence of the main streams								
Return Period (year)	**Kilosa**	**Mdukwe**	**Muvuma**	**Mkondoa**	**Lumuma**	**Mangweta**	**Maswala**	**Kidibo**	**Sikoko**	**Mzase**
2	1,819	35	136	957	100	1,076	467	220	300	168
5	3,886	99	246	1,635	236	2,094	784	366	484	275
10	5,766	170	338	2,183	358	2,942	1,033	482	637	358
20	7,761	256	436	2,770	494	3,699	1,339	606	832	466
30	8,937	309	498	3,140	583	4,144	1,538	682	954	538
50	10,310	377	581	3,632	702	4,714	1,801	785	1,119	632

Source: JICA Study Team

6.4 Culvert and Bridge for Landside Water

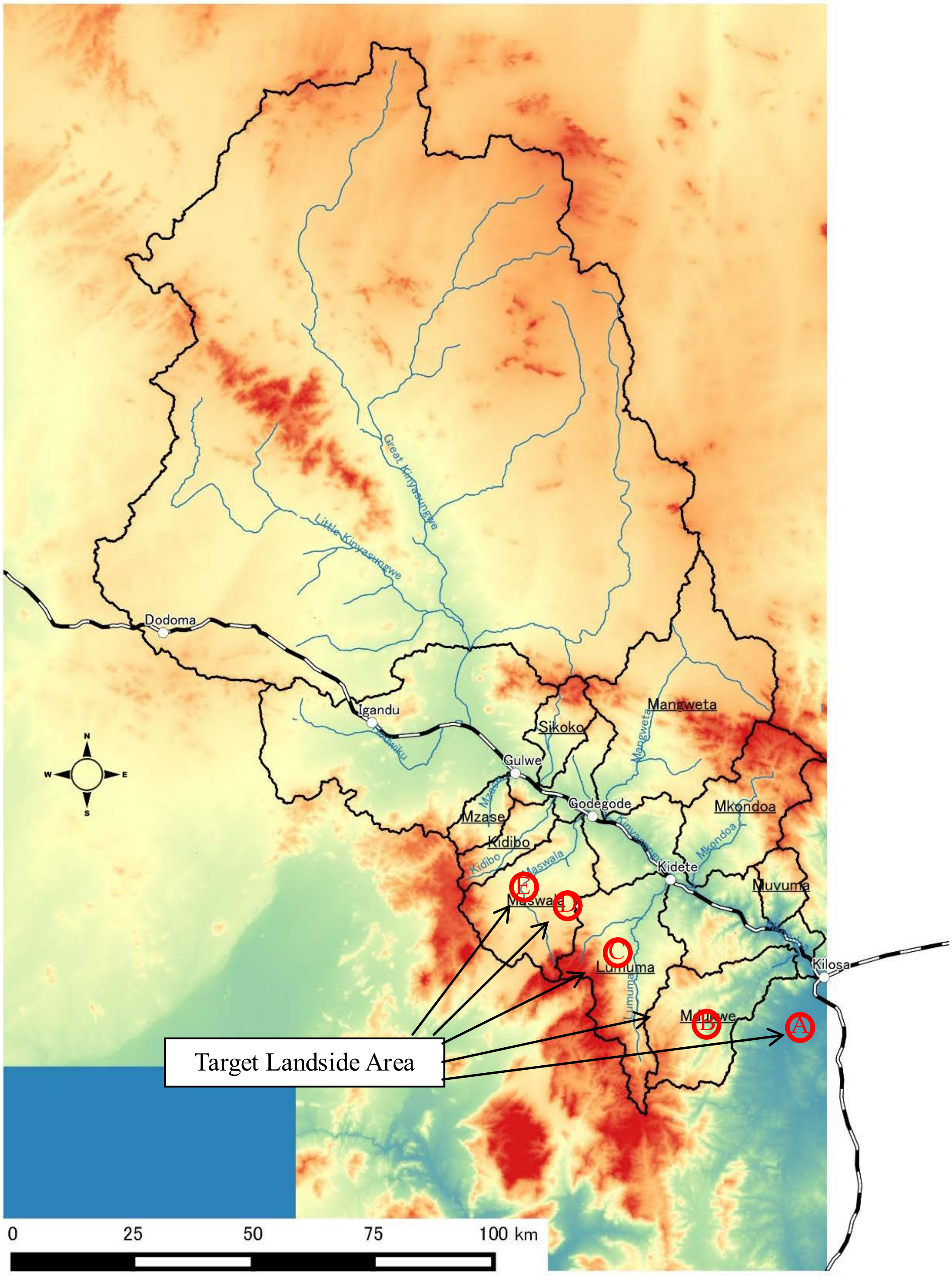
Because the Central Railway Line is laid alongside the mainstreams of the Kinyasungwe River and the Mkondoa River, the railway would be affected not only by floods from the mainstream and major tributaries, but also floods from the small streams in the remaining basin. For flood counter-measures in these small streams (hereinafter referred to as “Landside water”), waterway culverts were applied.

However, many of these existing culverts are encountering the influence of sedimentation downstream, and there is an urgent need for clearing of the clogged culverts. Further, serious erosion has occurred at the embankments of culverts and on their peripheries when large floods occur.

As a countermeasure for Landside water, it is most important to design the culverts to facilitate a smooth water flow during floods. In addition, there are agricultural and pastoral lands lying in adjacent to the areas of “Landside water”. Therefore, it is important to consider the inclusion of culverts crossing underneath the railway for livestock movements.

Figure 6.33 shows target Landside Areas which are described in following section. The target areas consist of five sub areas, named A to E.

This section covers the study of culverts with appropriate dimensions to allow water to discharge safely passing the railway to river side.

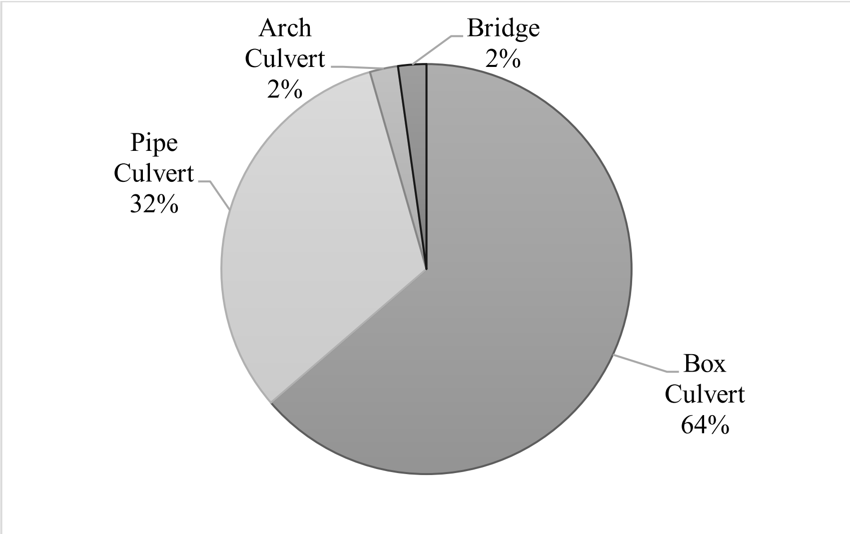


Source: JICA Study Team

Figure 6.33: Target Major Tributaries and Landside Areas

As previously mentioned, surface flows in streams in the area sandwiched between the railway and the basin boundary normally only appear during the rainy season (December to March), and sometimes damage the railway and other properties in the Study Area. In order to avoid such flood damages, drainage structures have been placed along the railway. Figure 6.34 shows the proportion of the type of culverts and bridges along the railway, based on the data collected by the field measurements conducted by JICA Study Team with staff from RAHCO/TRL from 1-5

December 2014. Through the survey, the JICA Study Team researched a total of 135 drainage structures. From the pie chart, it is recognized that the share of box and pipe culverts is over 95%, while bridges and arch culverts are limited.



Source: JICA Study Team

Figure 6.34: Type of Drainage Structures along the Central Railway in the Study Area (135 Structures)

Box Culvert (Km 349.8B)

Pipe Culvert (Km 283.6)

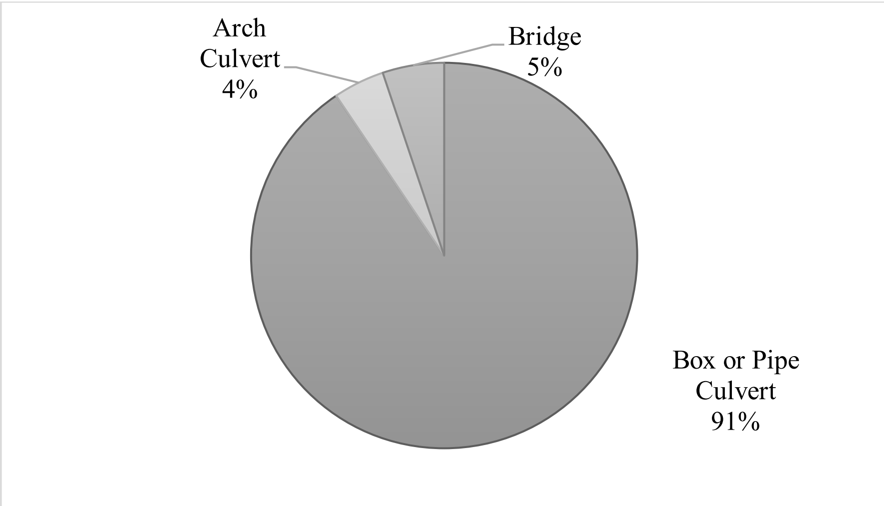
Arch Culvert (Km 328.8)

Bridge (Km 311.2)

Source: JICA Study Team

Figure 6.35: Examples of Drainage Structures

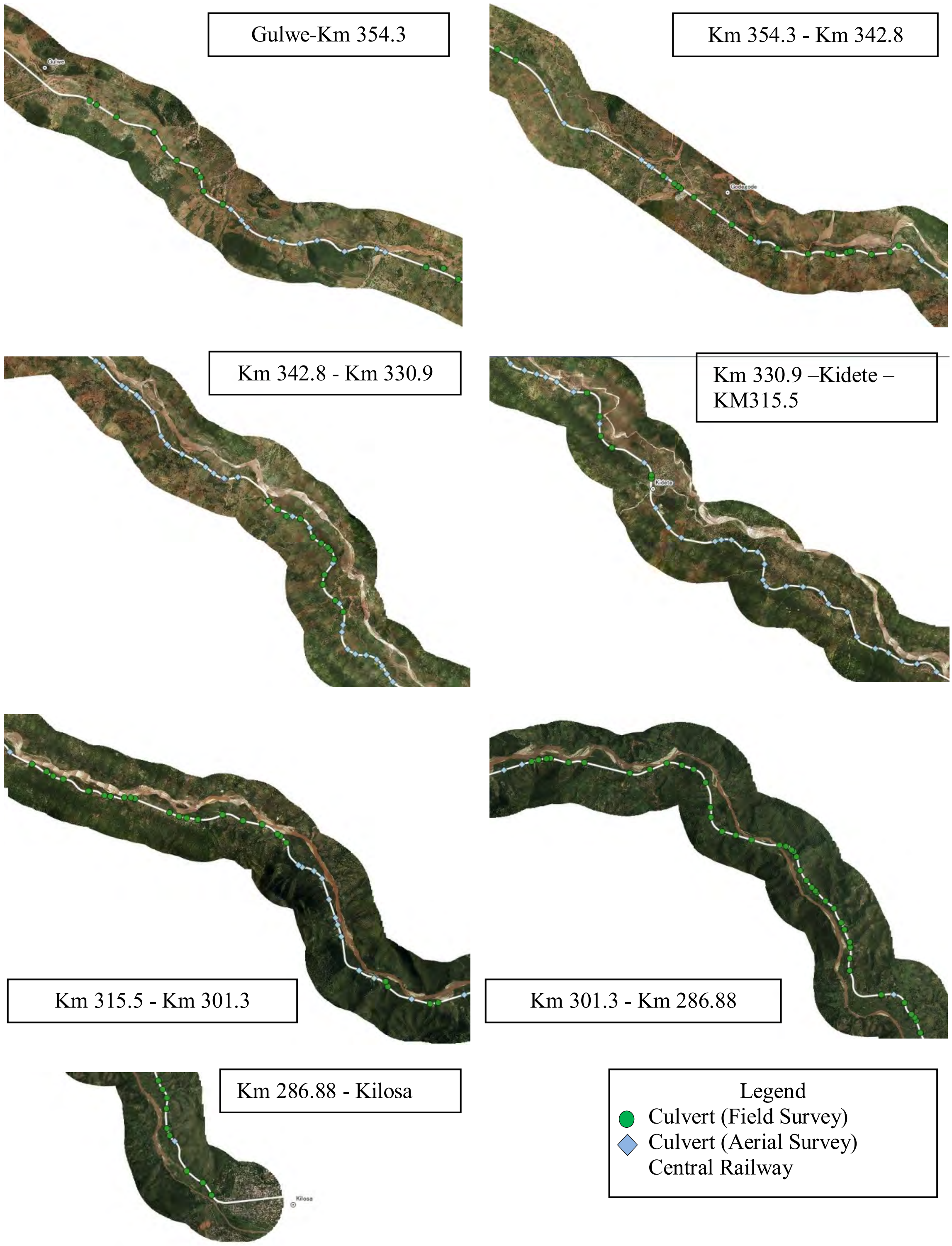
Field measurements have been completed at all 135 drainage structures through the Flood Risk Assessment conducted by the JICA Study Team in December 2014. However, because of the limited time available for field reconnaissance, some structures remained unmeasured. To compensate for the lack of information, the Study Team utilized the aerial survey data commissioned under this Study. Through examination with GIS, another 87 structures were identified between Kilosa and Gulwe. Through these data, the protection of each type of structure was recalculated for Figure 6.36.



Source: JICA Study Team

Figure 6.36: Type of Drainage Structures between Kilosa and Gulwe (223 Structures)

It is difficult to distinguish the difference between box culverts and pipe culverts from aerial images. Therefore, in Figure 6.36 above, the total of both types are combined, constituting a 90% share of structures. The locations of the structures are shown in Figure 6.37, and the average interval between culverts and bridges are shown in Table 6.22.



Note: Kilometer rage of existing railway

Source: JICA Study Team

Figure 6.37: Locations of Culverts

Table 6.22: Statistics of the Interval between Culverts and Bridges

Average (km)	0.386
Max (km)	1.7
Min (km)	0.05
Median (km)	0.3

Source: JICA Study Team

During the site reconnaissance in December 2014, the JICA Study Team found frequent clogging of culverts. Figure 6.38 shows typical examples of a "Clogged Culvert". To assess the flood risk caused to culverts, the criteria was prepared as shown Table 6.23:

Km 333.1 Km 311.0

Source: JICA Study Team

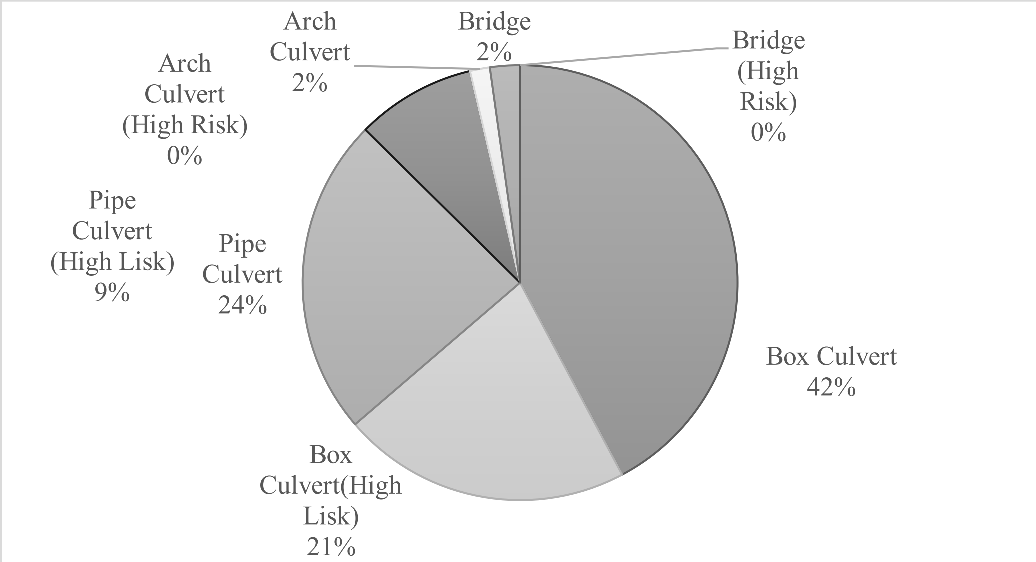
Figure 6.38: Example of clogged culverts

Table 6.23: Criteria for Treatment of Culverts and Bridges

Case	Sediment Deposition in Barrel	Possibility of Inundation due to Clogging	Existence of Protection (beside railway track)	Risk Rank
1	> 50% of height	Yes	None	High
2	> 50%	Yes	Exists	High
3	> 50%	No	None	High
4	> 50%	No	Exists	Medium
5	< 50%	Yes	None	Medium
6	< 50%	Yes	Exists	Medium
7	< 50%	No	None	Low
8	< 50%	No	Exists	Low

Source: JICA Study Team

According to these criteria, the percentage of "high risk" culverts was calculated to be 30% (Figure 6.39).



Source: JICA Study Team

Figure 6.39: Risk Level of Culverts (135 Structures)

6.4.1 Suitable Dimensions of Culverts

In this sub-section, discussion focuses on culverts designed for water flows. However, as there is a requirement for livestock crossings at certain culverts, the size of the minimum cross-section and the current conditions for their locations were also studied.

Mesh DEM (Distal Elevation Model) data with 5 m resolution was used for analysis. With GIS software (QGIS), the watersheds and streams in the remaining watersheds were delineated, and a runoff analysis was conducted to determine the size and locations of the culverts.

In order to prevent the culverts from clogging, periodical maintenance is required. From the point of view of the design of culverts, it is important to consider the capacity for the design discharge and maintenance. The following works were conducted to meet this requirement:

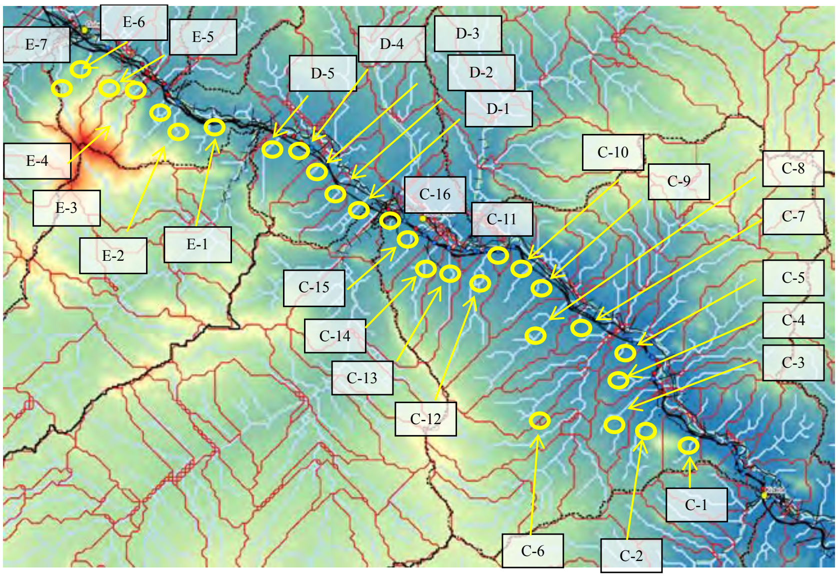
(1) Delineation of watershed and stream of the target landside area
(2) Calculation of design flood discharge by the East African Flood Model
(3) Estimation of suitable dimensions and quantity of waterway culverts

(1) Delineation of Watershed and Stream of the Target Landside Area

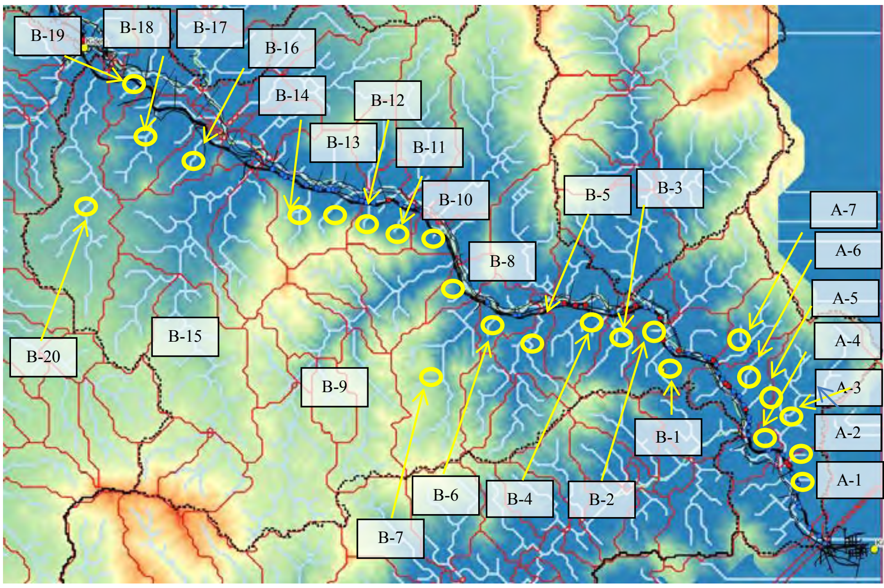
Through the DEM analysis, 55 watersheds were identified between Kilosa (Km 283) to Gulwe (Km 366) and Igandu (Km 402) (Figure 6.40). The Land-water areas were divided into five sub areas (named A to E). These areas are separated by major tributaries.

Figure 6.40 and Table 6.24 show the results of the hydrological analysis of Land-water area.

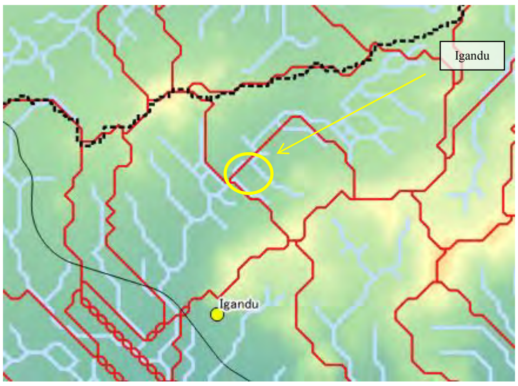
(C1 to D7)



(A1 to B20)



(Igandu)



Source: JICA Study Team

Figure 6.40: Watersheds and Streams of Target Landside Areas

Table 6.24: Physical Properties of Watersheds and Streams

	Area (km^2)	Length (km)	Stream Slope Angle (%)		Area (km^2)	Length (km)	Stream Slope Angle (%)
A1	1.9	0.6	5.9	C1	6.0	2	8.5
A2	0.7	1	6.3	C2	8.4	4.3	4.1
A3	16.1	7.4	3.5	C3	6.1	4.8	3.1
A4	0.8	0.3	0.6	C4	4.0	1.9	2.9
A5	1.0	1.4	7.4	C5	2.4	1	2.0
A6	2.5	2.5	6.5	C6	59.2	15.5	2.8
A7	7.3	4.1	9.7	C7	1.5	1.9	2.2
B1	5.2	2.2	1.1	C8	1.4	0.9	2.4
B2	0.6	0.4	4.9	C9	13.3	6.5	3.5
B3	5.1	3.3	7.8	C10	4.3	2.2	3.4
B4	6.2	1.1	17.5	C11	2.8	2.5	2.5
B5	11.2	3.3	11.6	C12	12.3	6.5	3.9
B6	3.1	7.9	1.5	C13	5.9	4.6	4.2
B7	18.0	8.7	6.1	C14	7.0	4.7	4.1
B8	2.6	1.3	15.2	C15	2.5	2.4	3.0
B9	68.5	17.6	3.7	C16	1.3	0.8	2.1
B10	2.1	0.2	24.4	D1	6.8	4.7	3.9
B11	1.2	1.3	9.2	D2	4.6	3.7	4.0
B12	2.2	1	20.1	D3	3.1	1.1	3.0
B13	2.3	2.4	14.9	D4	1.8	1	1.8
B14	6.0	2.8	13.8	D5	6.1	4.2	4.3
B15	65.1	19.9	3.5	E1	3.7	1.8	6.2
B16	4.2	2.9	4.6	E2	2.4	2.2	9.2
B17	1.1	1.3	3.6	E3	6.7	3.6	21.8
B18	8.5	3.7	4.0	E4	5.0	4.9	11.5
B19	1.8	1.2	4.0	E5	4.3	3.7	11.3
B20	24.2	11.8	2.4	E6	3.1	2.1	6.2
				E7	3.9	5.5	11.0
				Igandu	32.4	10.2	1.0

Source: JICA Study Team

(2) Calculation of Design Flood Discharge by the East African Flood Model

As for the runoff analysis, the TRRL East African Flood Model method was applied. This method was developed by the Transport and Road Research Laboratory (TRRL) of the UK to estimate floods, especially in the un-gauged catchments of East Africa. It is commonly applied to determine the design discharge for structures placed in areas where there are few to no existing rainfall stations.

1) The TRRL EAST Africa Flood Model

The application procedure of the TRRL East African Flood Model is shown in Table 6.25.

Table 6.25: Procedure of TRRL East African Flood Model

(a)	To calculate catchment area, land and channel slopes. The channel slope is estimated for the average slope from the drainage structure to the uppermost part of the stream.
(b)	Based on the site inspection report, establish catchment type in Table 7*1) and hence the lag time K
(c)	Based on the site inspection and using Fig. 15 *1)(Soil Zones), establish soil type and with land slope estimate the standard contributing area coefficient (CS) from Table 4*1); (In this case, because the stream of remaining basin is narrow and stream is impeded, land slope is assumed same as channel slope)
(d)	Using Fig. 14*1), determine antecedent rainfall zone. Refer to Table 3 *1)to determine if the zone is wet, dry or semi-arid
(e)	Estimate catchment wetness factor (CW) from Table 5*1)
(f)	Calculate the Contributing area coefficient (CA) using $CA = CS \times CW \times CL$ where, CS=standard value of contributing area coefficient CW=catchment wetness factor and CL= Land use factor
(g)	If antecedent rainfall zone so calculated as in above is semi-arid, initial retention Y is 5mm. For all other zones, Y is taken as zero
(h)	Work out the design storm rainfall to be allowed for during time interval TB hours i.e. P (mm)
(i)	Calculate the volume of runoff RO (m^3) using: $RO = CA \times (P-Y) \times A \times \mathbf{10^3}$
(j)	Calculate the average flow $\bar{\mathbf{Q}}$ using: $\bar{\mathbf{Q}} = 0.93 \times RO/3600 \times \frac{\mathbf{RO}}{\mathbf{3600}} TB$
(k)	Recalculate base time TB using $TB = TP + 2.3 \times K + TA$ where, $TA = \frac{\mathbf{0.28 \times L}}{\bar{\mathbf{Q}}^{1/4} \times \mathbf{S}^{1/2}}$
(l)	Repeat steps (i) to (l) until average flow $\bar{\mathbf{Q}}$, is within 5% of the previous estimate;
(m)	Calculate the Design Peak flow Q (m3/s) ,using $Q = F \times \bar{\mathbf{Q}}$ Where, peak flow factor F is 2.8 for K<0.5 hours and is 2.3 if K > l hour.

Source:*1) D. Fiddes, The TRRL East African Flood Model, Department of the Environment, TRRL Laboratory Report 706.Crowthorne, 1975. (See Appendix L)

2) Estimation of the design flood

The design flood for the return period of more than 10 years is calculated using the formula:

$$\frac{\mathbf{P_N}}{\mathbf{P_{10}}} = \frac{\mathbf{Q_N}}{\mathbf{Q_{10}}}$$

Where,
N : Return Period in years
QN : N-year Design Flood
Q10 :10-year Design Flood
PN : N- year daily point rainfall
P10 :10- year probable daily point rainfall

The design values for the return period of 30 years were estimated using this equation as tabulated in Table 6.26.

Table 6.26: Design Flood Discharge for Streams

Calculation of Q30				Calculation of Q30			
Name	Catchment Area (km^2)	Stream Length (km)	Q30year (m^3/s)	Name	Catchment Area (km^2)	Stream Length (km)	Q30year (m^3/s)
A-1	1.94	0.61	9.37	C-1	6.00	2.02	27.21
A-2	0.66	0.98	3.17	C-2	8.35	0.01	39.09
A-3	16.07	7.41	59.07	C-3	6.07	4.77	24.14
A-4	0.77	0.32	3.70	C-4	3.95	1.92	17.55
A-5	1.03	1.43	4.88	C-5	2.42	1.01	11.16
A-6	2.54	2.53	11.43	C-6	59.24	15.46	168.61
A-7	7.28	4.08	31.52	C-7	1.47	1.87	6.49
B-1	5.19	2.21	21.45	C-8	1.36	0.93	6.37
B-2	0.57	0.45	2.79	C-9	13.25	6.48	50.13
B-3	5.13	3.32	22.58	C-10	4.30	2.19	18.99
B-4	6.23	1.06	29.05	C-11	2.81	2.51	12.07
B-5	11.16	3.34	48.58	C-12	12.27	6.47	46.97
B-6	3.08	7.86	9.40	C-13	5.94	4.62	24.30
B-7	18.05	8.67	67.59	C-14	7.00	4.67	28.53
B-8	2.57	1.26	12.23	C-15	2.50	2.42	10.89
B-9	68.54	17.64	192.71	C-16	1.30	0.85	6.11
B-10	2.14	0.21	10.48	D-1	6.80	4.68	27.61
B-11	1.22	1.33	5.82	D-2	4.56	3.69	19.20
B-12	2.19	1.00	10.54	D-3	3.08	1.15	14.23
B-13	2.35	2.43	10.92	D-4	1.83	0.98	8.46
B-14	6.02	2.76	27.22	D-5	6.10	4.22	25.30
B-15	65.12	19.93	176.17	E-1	3.71	1.78	17.00
B-16	4.23	2.93	18.42	E-2	2.43	2.24	11.16
B-17	1.11	1.26	5.17	E-3	6.74	3.55	29.88
B-18	8.50	3.66	35.55	E-4	5.04	4.87	21.81
B-19	1.77	1.20	8.25	E-5	4.31	3.71	19.16
B-20	24.16	11.77	75.64	E-6	3.13	2.07	14.24
				E-7	3.93	5.53	16.78
				Iagndu	32.43	10.22	66.47

Source: JICA Study Team

(3) Estimation of Suitable Dimensions and Quantity of Waterway Culverts

To estimate the quantity of culverts for the target area, the purposes of the culvert were divided into two categories: (i) strictly for drainage, and (ii) for the crossing of residents and livestock.

As discussed in previous section, from the results of hydraulic analysis of DEM data, 55 streams were identified between Kilosa and Gulwe. In this sub-section, the quantity of culverts for these streams was calculated. After the estimation, the culverts for residents and livestock were calculated.

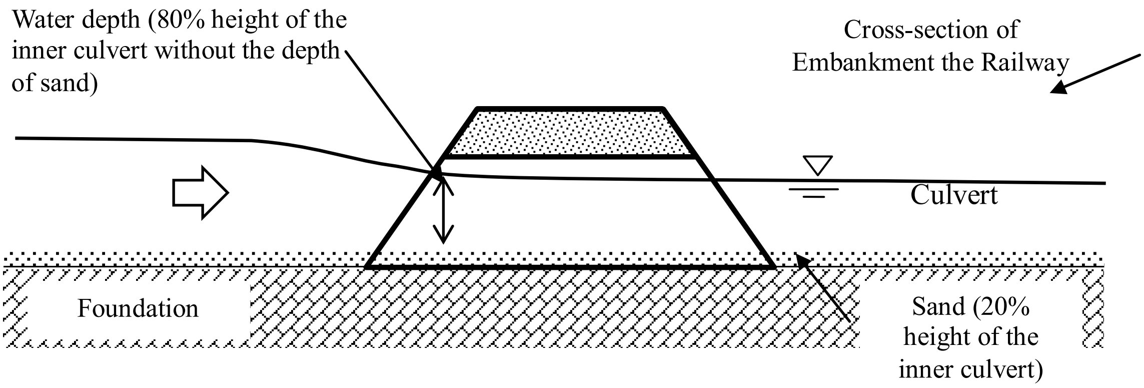
1) Culvert Drainage Capacity

From the point of view of maintenance, the cross-section of drainage culverts should be a rectangle, over 2.0 m per side. Two inner sizes of culverts, 2.0 m × 2.0 m and 3.0 m × 3.0 m, were selected by considering the following factors:

(1) As for maintenance inner barrel by manpower, minimum height of 1.8 m is required.
(2) The culverts of the above two sizes dominantly exist in the study area (for instance, at the crossing under railway in the Maswala River).

In order to avoid the risk of over-topping of the railway embankment, minus 20% as an allowance for the loss of cross-section to sand deposition, the design discharge was set as 80%

of the remaining cross-section area (80% of the remaining 80%, or 64% of the original). Therefore, the actual water flow depths for the two culvert sizes were 1.3 m and 2.0 m, respectively.



Source: JICA Study Team

Figure 6.41: The Shape of the Flow through the Culvert

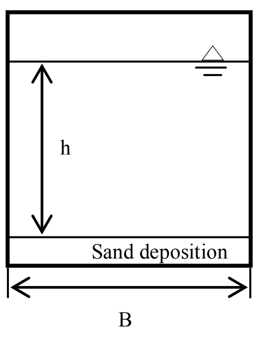
Culvert flow rate calculation is based on the following equation:

$$Q = A \times v = \frac{A}{n} \times R^{\frac{2}{3}} \times S_0^{\frac{1}{2}}$$

Where,

Q : Design discharge (m^3/sec)
A : Water flow section (m^2)
v : Velocity of water flow (m/sec)
n : Manning's coefficient of roughness
R : Hydraulic radius
S_0: Slope (%)

For Box Culverts with the cross-section of Figure 6.42.



Source: JICA Study Team

Figure 6.42: Cross-section of Culvert

$$R = \frac{A}{P} = \frac{B \times h}{(B + 2 \times h)}$$

Where:

B : Width of Culvert (m)
h : Water depth (m)

From above equation, following equation was derived

$$Q = \frac{1}{n} \times (B \times h) \times \frac{(B \times h)}{(B + 2 \times h)^{\frac{1}{3}} \times S_0^{\frac{1}{2}}}$$

From above equation, h (water depth) was derived by repeated calculation.

The result of calculation of capacity of the culvert was shown in Table 6.27. Since culverts extension was short, a slope of bed was assumed as of 0.1%, The Manning Coefficient was set at 0.013 for the concrete and the bed.

Table 6.27: Capacity of Drainage of Culvert

Size of Culvert (Inside)	Flow Capacity of Culvert(m3/s)	Reference
2.0 m×2.0 m	4.3	Water depth 1.3 m
3.0 m×3.0 m	13.1	Water depth 2.0 m
Slope 0.1%、Manning Coefficient n:0.013		

Source: JICA Study Team

2) Quantity of Culverts (for Waterways)

The quantity of the culverts for the waterway was calculated by dividing the design discharge levels for each stream (from Table 6.27) by the capacity of culverts (Table 6.28). As per these results, in many cases nearly three times as many 2.0 m × 2.0 m culverts are required to match the capacity of 3.0 m × 3.0 m culverts. In such cases, the culverts of larger size were adopted.

Table 6.28: Result of the Calculation of the Number of Culvert of Waterway

Number of Culvert			Number of Culvert			Number of Culvert		
Name	**B2.0m, H2.0m**	**B3.0m, H3.0m**	**Name**	**B2.0m, H2.0m**	**B3.0m, H3.0m**	**Name**	**B2.0m, H2.0m**	**B3.0m, H3.0m**
A-1	3	1	B-14	6	2	C-14	7	2
A-2	1	1	B-15	38	9	C-15	3	1
A-3	13	4	B-16	4	1	C-16	2	1
A-4	1	1	B-17	2	1	D-1	6	2
A-5	2	1	B-18	8	2	D-2	5	2
A-6	3	1	B-19	2	1	D-3	4	1
A-7	7	2	B-20	17	4	D-4	2	1
B-1	5	2	C-1	6	2	D-5	6	2
B-2	1	1	C-2	9	3	E-1	4	1
B-3	5	2	C-3	6	2	E-2	3	1
B-4	7	2	C-4	4	1	E-3	7	2
B-5	11	3	C-5	3	1	E-4	5	2
B-6	3	1	C-6	37	9	E-5	5	2
B-7	15	4	C-7	2	1	E-6	4	1
B-8	3	1	C-8	2	1	E-7	4	1
B-9	42	10	C-9	11	3	Igandu	16	4
B-10	3	1	C-10	5	2			
B-11	2	1	C-11	3	1			
B-12	3	1	C-12	11	3			
B-13	3	1	C-13	6	2			

Source: JICA Study Team

3) Total Quantity of Culverts

As per Table 6.22, the average interval of culverts was estimated at 0.386 km. This interval includes land cut area. Therefore, to calculate the required number of culverts, including the culverts for both waterway and residents (and livestock), the interval between culverts was assumed to be 300 m.

Therefore, in cases where the selected Alternative (see Chapter 8) includes a 9 km embankment, including A-1 to A-5 sub areas (Table 6.28), the total quantity of culverts was estimated as follows:

9,000(m) ÷ 300(m) = 30

30 – 5 (A-1 to A-5) = 25

2.0 m culverts: 25 + 3 (A-1) + 1(A-2) + 1(A-4) + 2 (A-5)

3.0 m culverts: 4 for A-3 sub areas

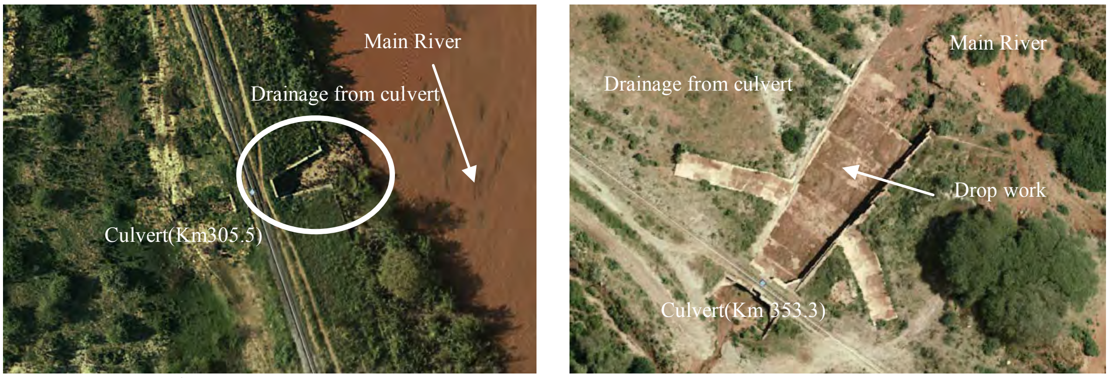
6.4.2 Outline of Structures of Intakes and Outlets of Culverts

(1) Drainage Area, Drainage Way, Drainage Position

In general, culverts require a drainage way in the downstream of the culvert, to reduce the possibility of bank erosion. Further, it is necessary to protect the surfaces of channels using revetment work. Figure 6.43 shows the example of the existing culverts with drainage ways. These culverts were commonly very close to rivers.

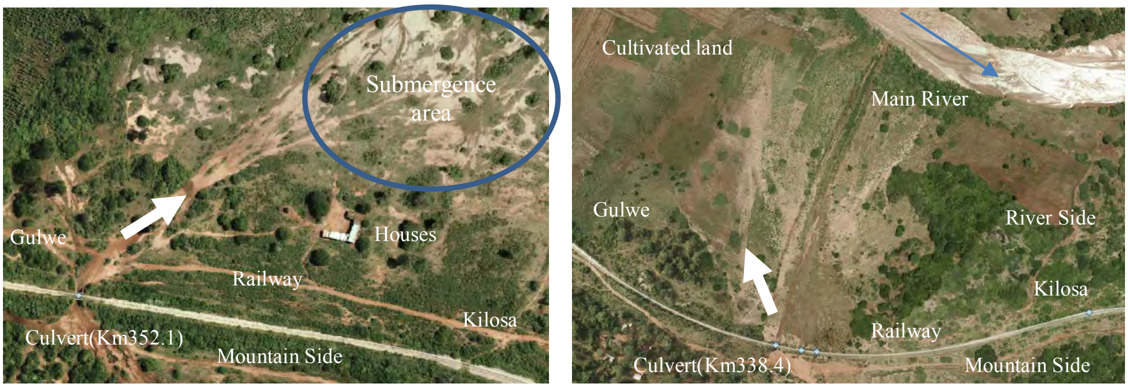
Figure 6.44 shows examples of culverts without drainage ways. These culverts are usually far from the river. Downstream of these culverts, an area of land is submerged during floods.

Therefore, in order to protect housing and cultivated lands from floods, if the location of the culvert is expected to result in a high discharge of flow from the mountain-side, it is recommended to orient the channel from the culvert toward the main river.



Source: JICA Study Team

Figure 6.43: Culvert with Drainage Way



Source: JICA Study Team

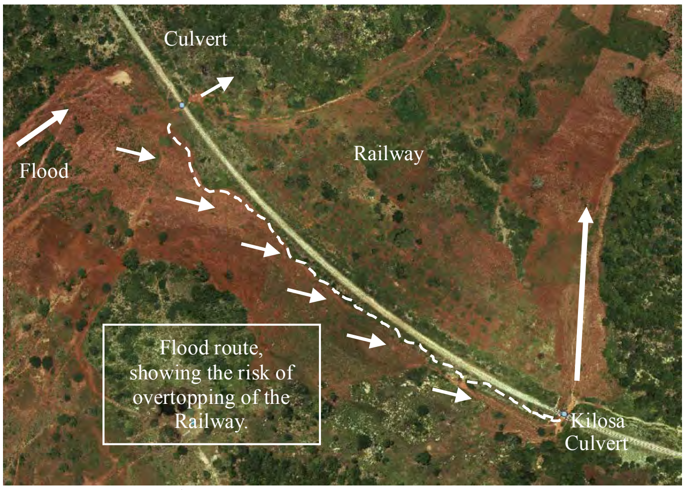
Figure 6.44: Culvert without Drainage Way

(2) Location of Waterway Culvert

The location of new waterway culverts should be placed in the center of streams, with sufficient capacity for discharge, with mandatory continuous maintenance. However, according to the survey of existing culverts, several culverts have been left without maintenance and are not suitable for drainage.

Figure 6.45 is an aerial photo showing the flood route along the railway. In this photo, two culverts were located (upstream and downstream). The flood from mountain-side first met the upstream culvert, but because the capacity of this culvert was not enough, the flood ran along the railway until reaching the downstream culvert. In this case, the floodwaters reached near the ballast of railway. To avoid the risk of such flood disaster, the upstream culvert should have sufficient capacity for drainage.

As demonstrated with this example, for new waterway culverts, topological considerations are very important.



Source: JICA Study Team

Figure 6.45: Flood Route around Existing Culverts

(3) Study of Required Structures at Culvert Intakes

Figure 6.46 shows an example of an intake wall for a waterway culvert, constructed of concrete and masonry. During the site survey, it was found that some culverts had serious damages around the intake. Therefore, it is necessary not only to increase the capacity of culverts, but also to place backfill materials behind the walls of the intakes of culverts.

Figure 6.46: Example of Culvert Intake

(4) Installation of Water Channel Upstream of Culverts

As previously mentioned, intermittent rivers in Africa are quite common, and riverbed slopes are very flat. These conditions cause rivers to meander, and it is very difficult to place a water channel upstream of a culvert to smoothly lead floodwaters to the intake. Ideally, this channel should be extended from the intake of the culvert to a point of steady river flow. However, the construction cost should be examined within the available budget to determine to what extent these works can be conducted.

Additionally, environmental and social requirements are also important in the design of culverts. For example, in Igandu, local residents expressed their opinions to the JICA Study Team that the enhancement of the capacity of culvert in some ways shifts the flood impacts to downstream communities. This concern is not limited to Igandu, but is relevant throughout the entire study area. In consideration of this, toward the detailed design stage, it is essential to consider the total impacts of floods into culvert design.

Further examination of new culverts along the re-routing section of track was conducted at preliminary design stage in December 2015 and compiled the results in Subsection 10.1.5 of this Report.