Feasibility Study on Water Resources Development in
Rural Area in
the Kingdom of Morocco
Final Report
Volume III Supporting Report (1)
Basic Study

Supporting Report II Hydrology and Flood Mitigation

FEASIBILITY STUDY
ON
WATER RESOURCES DEVELOPMENT
IN
RURAL AREA
IN
THE KINGDOM OF MOROCCO

FINAL REPORT

VOLUME III
SUPPORTING REPORT (1)
BASIC STUDY

SUPPORTING REPORT II

HYDROLOGY AND FLOOD MITIGATION

Table of Contents

List of Tables

List Of Figures

SUPPORTING REPORT II

HYDROLOGY AND FLOOD MITIGATION

II1 Observatory

II1.1 Meteorological Observation

Principal agencies responsible for the meteorological observation and data compilation are General Direction of Hydrology (DGH: Direction Générale de l'hydraulique) and National Meteorology Service (SMN: Service Météorologie Nationale). In addition to these, other water related agencies of the Ministry of Equipment; Ministry of Agriculture, Rural Development and Maritime Fishery; Ministry of Interior; and National Office of Electricity (ONE: Office National d'Electricité) have their own observation networks for their specific needs.

Hydro-meteorological observation network of DGH consists of 106 meteorological stations and 310 rain gauge stations over the country. These stations are operated and managed by the central office of DGH in Rabat and its 9 regional offices in Tetouan, Oujda, Fes, Benslimane, Beni Mellal, Marrakech, Agadir, Er Rachidia and Laayoune. Rivers and their managing offices of DGH are listed in Table II1.1.1.

The meteorological stations, located at the flow gauging stations and major dams, are generally for observation of rainfall, evaporation, humidity, temperature and wind, and partly for sunshine, atmospheric pressure and ground temperatures as well. A caretaker resides permanently at each station for regular observation and maintenance of the station.

II1.2 Flow Gauging

Flow gauging stations managed by DGH are classified into principal and simplified stations depending on the equipped gauges and facilities. The principal station allows carrying out water level observation and discharge measurement equipped with staff-gauge, recording water level gauge and mostly cableway or winch for flood flow measurement. A permanent caretaker resides in the principal station and read staff-gauge to compliment recording gauge and guarantee the accuracy of water level gauging. The simplified stations have staff-gauge commonly and some of them also have recording water level gauge, but generally no equipment for flood flow gauging and no permanent residing caretaker.

The flow measurement was initiated as early as 1912 and the measurement with permanent station started from 1918.

The number of flow gauging stations increased notably after the launching of the dam construction program from 35 in 1956 to 250 principal stations to date. Besides, there are 710 river locations registered for flow gauging.

II1.3 Water Quality Monitoring

DGH started water quality monitoring in 1984 to characterize the surface and ground water quality. The first 6 years have been considered as a stage to accumulate basic knowledge of the water quality. In 1990 the monitoring network has been reexamined to study the pollution impact on the water resources. Since this date, the network has been increasing progressively to cope with the increasing demand to identify the water quality conditions. Currently, a total of 765 stations constitute the water-quality monitoring network for water sampling in rivers, ground water and reservoirs of the existing dams. More than 30,000 analyses on physical, chemical and bacteriological items are achieved every year with this network.

II1.4 Groundwater Observation

The groundwater observation network consists of 1,700 sites distributing on about 80 groundwater basins (nappe). DGH achieves an important program of survey and drilling works for recognition, assessment and mobilization of the country's groundwater resources. DGH carries out annually about 500 drilling works with depth varying from 100 to more than 1,000 m.

II2 Climate of Study Area

II2.1 River Basins in Study Area

The Kingdom of Morocco has surface territory of 710,850 km^2 consisting of the following major 13 river basins grouped in 5 regions as shown in the next page:

Major River Basins in Morocco

Region/River Basin	Basin Area (km^2)	Ratio (%)
Northern Rif Region	(20,600)	(2.90)
- Tangérois	2,400	0.34
- Coastal Mediterranean	12,600	1.77
- Loukkos	5,600	0.79
North-Central Atlantic Region	(132,500)	(18.64)
- Sebou	40,000	5.63
- Bou Regreg and Coastal Atlantic of Casablanca	20,000	2.81
- Coastal Atlantic of Safi-Essaouira and Tensift	37,500	5.28
- Oum Er Rbia	35,000	4.92
Eastern Region	(57,500)	(8.09)
- Moulouya	57,500	8.09
West-South Atlantic Region	(35,400)	(4.98)
- Souss-Massa and Coastal Atlantic of Agadir	35,400	4.98
South Atlantic and Sahara Region	(464,850)	(65.39)
- Guir, Bouanane and Tamlaht	29,900	4.21
- Ziz, Rheris and Maider	39,290	5.53
- Drâa	95,000	13.36
- Sahara Basins	300,660	42.30
Total	710,850	100 %

The 25 dam sites selected for the present study distribute over the 9 river basins excluding those of Tangerois, Lukkos, Moulouya and Sahara.

II2.2 Overview of Climate

General climatic features are described in the following paragraphs respectively for the regions discussed in the previous section.

II2.2.1 Northern Rif Region

The climate of Mediterranean sub-humid type prevails in the west, becoming semi-arid toward the east near Al Hoceima City. Climate of this region is characterized by the wet season from September to April and the dry season in the rest of the year.

This region receives large rainfall amount with annual mean of 700 to 800 mm, though the rainfall reduces to about 350 to 400 mm in the East of the Lao river. Due to the availability of high rainfall, the region enjoys one of the most productive surface water of the country. The region having only 2.9% of the national territory has about 20% of country’s water resources potential.

II2.2.2 North-Central Atlantic Region

The climate is influenced by both Mediterranean and Oceanic types. The mean annual rainfall is about 500 mm varying significantly by locations from 2,000 mm in the Rif mountains to 250 mm in Haouz.

The region is the biggest recipients of water resources produced in the mountainous ranges of the Rif and the Atlas. The region with 19% of the national teritory has 56% of water resources potential of the country.

II2.2.3 Eastern Region

This region, represented by a single river basin of the Moulouya, is located in the east of the Rif and the Atlas mountains. The climate is arid with Mediterranean type in the northeast, continental type in the middle Moulouya and mountain type in the upper Moulouya. The annual rainfall is about 250 mm. However, it varies from 400 mm in Mediterranean and high Atlas areas to 200 mm in the middle Moulouya. The seasonal flow distribution is significantly irregular.

II2.2.4 West-South Atlantic Region

The climate is arid type attenuated by the influences of the Atlantic Ocean as well as the relief altitude. The annual rainfall is about 230 mm on average with significant variation toward the east and south. The eastern region situated in the High Atlas has more rainfall of about 400 mm.

II2.2.5 South-Atlantic and Sahara Region

The climate is classified generally as arid type with some moderate arid areas in higher places. Rainfall is the lowest in the country with annual amount of 85 mm on average, which occures irregularly concentrating in some days of the year. However, the annual rainfall is relatively high in the Draa basin (400 mm) and in the Guir basin (200 mm).

II2.3 Monthly Meteorological Features

Monthly meteorological records were collected for the latest 20 years (1980-1999) at the representative stations over the country, namely at Fes-Sais in the Sebou river basin, Marrakech in the Tensift river basin, Ouarzazate in the Draa river basin and Rachidia in the Ziz river basin. The collected data include monthly records of temperature (average, maximum and minimum), rainfall, relative humidity (observed at 6:00, 12:00 and 18:00), pan-evaporation, sunshine duration, and wind speed (absolute maximum speed and its direction).

These data were processed and are shown in Table II2.3.1. They are also shown comparatively in Figure II2.3.1 and Table II2.3.2. As to wind, monthly maximum wind speed and frequency by directions were studied. The results of study are shown in Table II2.3.3 and Figure II2.3.2. Principal meteorological features of these stations are summarized in the table on the following page.

Principal Meteorological Features

Description		Fes-Sais	Marrakech	Ouarzazate	Rachidia
Temperature (°C)	Average	16.8	20.0	19.2	19.4
	Range	9.0~25.8	12.1~28.7	9.1~29.8	8.3~30.6
Rainfall (mm)	Monthly	0.8~57.8	1.2~46.9	2.4~21.1	2.4~17.6
	Annual	436.1	230.4	130.5	117.3
Humidity (%)	Average	61.4	55.2	35.4	41.0
	Range	46.3~70.8	45.5~63.2	20.2~50.0	23.2~58.2
Evaporation (mm)	Monthly	70.9~356.5	127.8~397.0	110.5~435.8	101.9~544.9
	Annual	2109.0	2850.2	3036.6	3480.7
Sunshine (hr)	Monthly	197.1~337.4	214.1~330.1	250.6~343.4	239.5~316.4
	Annual	3049.5	3197.5	3476.7	3305.1
Wind speed	Max (m/s)	36	37	52	50
	Direction*	28(W/WNW)	28(W/WNW)	34(NNW)	28(N)

(Remark) *: Wind direction in 36-wind rose.

These data show distinct contrast of meteorological parameters between stations located in the western side of the Atlas Mountains (the Atlantic ocean side: Fes-Sais and Marrakech) and those located in the eastern side (Sahara side: Ouarzazate and Rachidia). It is distinctive that most of the strong winds come from west or northwest direction, in other word, from the Atlantic Ocean side.

II3 Water Resources

II3.1 Water Resources Problems

II3.1.1 Water Cycle in Morocco

Water resources problems in Morocco are looked over in this section mainly based on "Water, the On-going Challenge, Chaouki BENAZZOU, 1994". From the nationwide viewpoint, water cycle in Morocco is shown in Figure II3.1.1. Average annual precipitation is 150 billion m^3. Out of the annual precipitation, only 30 billion m^3 are considered useful deducting the evapo-transpiration. If the loss of water due to infiltration and its return flow are taken into account, surface water potential is worked out at about 22.5 billion m^3.

As seen in the water cycle, about 11.7 billion m^3 were finally mobilized (as of end 1993). This volume allows, in a standard year, the irrigation of 885,000 ha, production of 1.4 billion m^3 of drinking and industrial water, and power generation of 1,100 GWh.

II3.1.2 Problems

The water resources distribute unequally over the country and vary significantly between the years. Major water resources problems of the country are:

- Unequal spatial distribution,
- Irregularity of surface flows, and
- Increasing water demand.

(1) Unequal Spatial Distribution

Due to the significant difference of annual precipitation between the regions, distribution of surface water potential varies depending on the region as follows:

- Atlantic zone: 73.6 % (of the national total: 22.5 billion m^3) including the Sebou, Oum Er Rbia, Lukkos, Bou Regreg, Tensift and other river basins
- Oriental zone: 10.4 % including the Moulouya, Kerd, Kiss, Isly and other river basins
- Mediterranean zone: 6.8 % including the Laou, Marti, Neckor, Rhis and other river basins
- Oriental South Atlas zone: 6.7 % including the Guir, Ziz, Rheris, Draa and other river basins
- Occidental South Atlas zone: 2.5 % including the Souss, Massa and other river basins
- Saharan zone: No water potential

Among these, river basins of the Sebou (6,610 million m3/yr) and the Oum Er Rbia (4,500 million m^3/yr) in the Atlantic zone are the dominant areas in Morocco with high surface water potential and its utilization. On the contrary the surface water potential is low in other zones especially in the Saharan zone.

(2) Irregularity of Surface Flows

In addition to the unequal spatial distribution, the surface flow also varies significantly from 50 billion to 400 billion m^3 between the years. This irregularity of flow between the years makes the strategic water resources development difficult. The surface flows also subject to seasonal changes. It was common in Morocco that the dried or little-flow river in summer caused calamity of flood disasters in winter, which has been alleviated fairly due to the construction of dams on the major rivers.

(3) Increasing Water Demand

Demand of water for irrigation, drinking and industry, and power generation are increasing to meet the requirements due to population growth, urbanization and economic development of the country.

Morocco had a surplus water of about 188 million m^3 in 1990 including ground water. Thirty years later in 2020, the demand will exceed the available resources yielding a deficit of 360 million m^3.

II3.1.3 Needs for Small and Medium Dams

In order to cope with the water resources problems described above, various measures can be considered. Trans-basin canal scheme will serve for alleviation of the unequal spatial distribution of surface water. This scheme, however, can be applicable only at the topographic conditions allow and is costly in general. The dam scheme would cope well with the seasonal and yearly irregularity of surface flows regulating the natural flows. The Government has put this measure into practice. According to the long-term program, dam constructions are scheduled as follows:

- One dam per year: up to the year 2000
- Two dams per year: from 2000 to 2010
- Three dams per year: after 2010

This program has been serving for water resources development and is expected to adjust the imbalance between the demand and supply of water in future as well. However, this program is not enough to answer the requests raised in the various places of the country currently suffering from water resources problems. Small and medium dams are therefore necessary to complement roles of the programmed dams. The small and medium dams shall meet the local specific needs and conditions.

II3.2 General Features of Annual Flow

For most of rivers in Morocco, source of flow is rainfall. Some of the central-western basins such as the Sebou and Oum Er Rbia rivers receive snowmelt water. The following table shows general characteristics of annual flows by regions.

General Features of Annual Flow by Regions

Region	Basin area	Ann. rainfall	Annual flow	
	(km^2)	(mm/yr)	(Mm^3/yr)	(mm/yr)
Northern Rif Region	20,600	700 - 800	4,200	204
North-Central Atlantic Region	132,500	500 - 2,000	11,500	87
Eastern Region	57,500	250 - 400	1,650	29
West-South Atlantic Region	35,400	200 - 400	780	22
South-Atlantic - Sahara Region	464,850	85 - 200	2,400	5.2

II3.3 River Flows at Candidate Dam Sites

II3.3.1 Availability of Flow Records

A total of 23 flow stations were selected as reference stations for 25 candidate dam sites as shown in Table II3.3.1. Characteristics of river flows at the candidate sites were studied based on these stations. For the convenience of descriptions below, the hydraulic regions are simply called as Regions-I through VII as shown in the table.

These stations are mostly located at the nearest sites to the candidate dams of the same river courses. For Boukarkour (No.18) and Side Abdellah (No.25) dams, no station was available in the same river system. Besides, stations for Tazarane (No.6), N'ouants (No.22) and Tiuzaguine (No.12) are located far away downstream from the dam sites.

Figure II3.3.1 shows the periods of available flow records at the selected stations. Among these stations, Rhafsai for Aoulai dam (No.19) has the longest data of 45 years. Stations in the Guir, Ziz and Rheris river basins located in the arid region have relatively longer period of record ranging from 20 to 38 years. On the contrary, the period of available data are less than 10 years at Takenfoust for Neckor dam (No.1), Tamchachete for Tizimellal dam (No.2), and Sidi Hssain for Amezmiz dam (No.7).

II3.3.2 Characteristics of Flows at Dam Sites

Flow characteristics were studied based on the latest 20-year data as far as the data are available. Daily and monthly discharges at each dam site were estimated from the flow records at reference station with the same specific discharge. Study results of flow characteristics are summarized in Table II3.3.2 and Figure II3.3.2 Major findings through the study are described in the next page.

(1) Mean Annual Flow

Mean annual flow in term of "mm/yr" is relatively high in Region-II. The flows are especially high in the southern slope of the Rif Mountains (Tabouda, Rhafsai and Galez stations). Annual flow is low in Regions I (Takenfoust), III and VII.

(2) Monthly Flow Patterns

Wet and dry seasons are rather distinctive in Regions-II and III with single-peak flow patterns, and in Region-VI with double-peak ones. The flood flows also concentrate around the peak-flow month. On the other hand flow is even throughout a year in Regions-I and VII.

In these regions, flood flow could take place in any month of the year. Flows in Regions-IV and V have a transitional nature between the flow patterns mentioned above.

(3) Mean Daily Discharge

Daily flow pattern is significantly variable between places. Number of days which accumulate 50% of annual flow (50%-flow day) was studied as an index to represent the flow-duration patterns. The 50%-flow day is generally short (less than 60 days) except for four stations at Takenfoust in Region-I, Sidi Mokhfi in Region-II, Sidi Hssain in Region V and Ait Bouijane in Region-VII. The 50%-flow day is extremely short (less than 10 days) at the stations in Regions III and VII excluding Ait Bouijane and Tamdrouste stations. In such stations, the flood flows that would be regulated by dam concentrate within only 10 days (but not consecutive) in a year.

(4) Maximum Daily Discharge

The maximum specific daily discharge is relatively high at Tabouda, Rhafsai and Galez in Region-II, and Ait Segmine and Tizi N'isly in Region-IV, showing specific discharge more than 0.5 $m^3/s/km^2$. The specific daily discharges happen to be very low at Takenfoust and Sidi Mokhfi stations probably due to the shortage of data period.

(5) Correlation Between Stations

Based on the average monthly flow records of respective dam sites, correlation diagrams were prepared for specific monthly discharges as shown in Figure II3.3.3. As a result, relatively strong correlation was found between Rhafsai and Tabouda stations, Rhafsai and Garez stations, and Dar Hamra and Tissa stations all located in Region-II. In other regions, correlations between the selected stations were weak, which represents the variety of river flow patterns in the Study Area.

II3.3.3 Estimation of Inflows

Mean monthly inflows were estimated at the candidate dam sites for preliminary water balance study. Considering the availability of flow data, periods of data were limited to the latest 10 to 20 years so as to compare the candidate dams on the same basis as far as possible.

(1) For No.4, 5, 10, 11, 12, 13, 16, 18, 19, 22 and 25 dams: Inflows at dam sites were estimated based on the specific discharges of the reference flow stations. Though the reference stations have records more than 20 years, data of the latest 20 years are used for the water balance study.

(2) For No.6, 8, 9, 15, 17, 20, 21, 23 and 24 dams: Inflows were estimated based on the specific discharges of the reference stations. Since the reference station have records more than 10 years but less than 20 years, data as much as available are used for the balance study.

(3) For No.7 and 14 dams: Inflows were estimated based on the specific discharges of the reference stations. However, since the available records at the reference stations are less than 10 years, data periods were extended up to 10 years as follows:

- No.7 dam: Based on specific discharge at Illoudjane station.
- No.14 dam: Based on correlation with Dar Hamra station.

(4) For No.1, 2, and 3 dams: Inflows were estimated, only for reference, based on the specific discharges as far as the records are available. Since these dams were proposed for sediment control, the water balance studies are not made for them.

The average monthly river flows estimated at respective dam sites are shown in Table II3.3.3.

II3.3.4 Verification of Inflows

DGH already has estimates of annual inflows for the dams under the present study, but monthly inflows are not available for all. The annual inflows to dam estimated by the Study Team and DGH were compared with each other as shown in Table II3.3.4. According to the table, estimates by the Study Team for No.1 and No.20 dams seem too low judging from inflows height (mm/yr), probably due to short data periods (only 6 years for No.1 dam and 10 years for No.20 dam). On the contrary, the estimates by DGH for No.3 dam seem too high, though the reason is not known. Water balance studies are not made for No.1 and No.3 dams because they are proposed as sediment control dams.

As to Timkit dam (No.10), annual inflow height of the both estimates differs much. In order to verify the inflow at Timkit dam, the inflows at dam site were compared with rainfall data. Correlation diagrams of monthly rainfalls and inflows are shown in Figure II3.3.4. According to the correlation studies among flow stations (Figure II3.3.3) and among flow and rainfall stations (Figure II3.3.4), irrational features of Timkit inflow were not found, though the correlations are not definite.

II4 Flood Mitigation

II4.1 Flood and Sediment Problems

Nationwide investigation on the flood and sediment disasters has not been made yet. Data and information available on this subject are very limited. Study Team gathered data and information on flood and sediment disasters for all candidate dams in the course of site reconnaissance. These data and information include initial information on the sites, type and conditions of flood and sediment disasters in the catchment and command area of the projects, etc. Major findings through the reconnaissance are summarized in the following paragraphs.

II4.1.1 Cause of Disasters

Disasters in the Study Area are mainly caused by flooding and bank erosion. Damages due to debris/mud flows like the Ourika River were not informed at any candidate dam sites. In addition to the above, characteristics of flood runoff and inappropriate land use are also important factors to aggravate the flood and sediment disasters. Since river has little flow most of the time, people are apt to live near the river and even on the riverbed, cultivating lands and constructing irrigation facilities in traditional manners. The flush flood that occurs once in a long while brings about serious damages to these defenseless settlements, facilities and farmlands, and occasionally causing loss of lives.

II4.1.2 Flood Mitigation Facilities

River improvement works by such as channel normalization, dike and bank protection are few. Since the flood is a rare event, facilities exclusively for flood and sediment control would not be economically feasible, which makes the implementation of measures more difficult. Around 90 large dams including medium scale ones have been constructed to secure the water resources of the country. These dams also contribute well for flood mitigation. As a matter of fact, these dams have already protected most of the country’s major flood plains. But local flood disasters upstream of these dams are still left. Proposed dams under the present study are expected to alleviate this type of flood disasters.

II4.1.3 Reservoir Sedimentation Problems

Many of the existing dams in Morocco are suffering from sedimentation problems. In the Study Area, the following dams are facing to severe sedimentation problems:

(1) El Kattabi dam constructed in 1981: One-third of the reservoir volume has already been silted up. The Neckor dam (No.1) is proposed for a relief of the sedimentation problem.

(2) Al Wahda dam constructed in 1996: The dam is located at the lower end of the Ouergha river basin. The basin is known for its high sediment yield due to the Rif Mountain and much rainfall. A study proposes construction of 15 dams on the tributaries to reduce the sediment inflow to the reservoir.

(3) El Kansera dam constructed in 1935: About two-thirds of the reservoir capacity has already been silted up.

(4) Sidi Driss dam constructed in 1984: The dam reservoir and the Rocade canal, to supply municipal and irrigation water to Marrakech city and surrounding areas, are also suffering from severe sedimentation.

II4.2 Previous Works and Study

II4.2.1 Responsible Agency and Works

General Direction of Hydrology (DGH: Direction Générale de l'hydraulique) is a main authority responsible for flood control and prevention of sediment disasters of the country. DGH conducts investigation, planning, design and construction for flood and sediment control. The undertaking of DGH covers various types of works such as channel normalization, cut-off channels, intercepting canals, riverbed consolidation, revetments, earth dikes, and flood control dams.

Most of these works are implemented in collaboration with the local communes and the Ministry of Equipment, mostly based on the request of the local communes. Therefore the works are local oriented and of small scale.

II4.2.2 IBRD Study

DGH has a program to conduct "Study on National Protection Plan against Floods" under the financial assistance of the IBRD (World Bank). Implementation of this program was basically agreed with the IBRD and the procedures to commence the study is now at the final stage. However, the time schedule for the implementation of the study is not known yet. The study is rather institutional judging from the objective and scope outlined below.

(1) Objective

The study of the National Protection Plan against Floods aims at defining flood types, preparing synthesized materials of the flood risk zones, analyzing the current situation of the institutional framework, and proposals for its improvement, as well as the formulation of an action plan against floods.

(2) Scope of Study

The study includes 3 missions as follows:

- Mission 1: Qualification of the problems caused by flood and control measures of land use in the flood prone areas.
- Mission 2: Diagnosis of existing institutional framework and proposal of improvements and modification to be introduced, as well as, the regulation related to the flood hazards.
- Mission 3: Elaboration of an action plan for the higher and moderate risk zones.

II4.3 Characteristics of Flood Runoff

II4.3.1 Annual Maximum Discharge

Annual maximum discharges at dam sites were extracted from the daily discharge records and shown in Table II4.3.1. Ranges of the annual maximum discharges are very wide for all the sites. Some of the annual maximum values are extremely small. Probably no major flood took place in those years.

II4.3.2 Frequency of Flood Events

Flood day was defined for the present study as the day whose daily discharge exceeds the average of annual maximum daily discharge of each station. Number of the flood days was counted for each site and shown in Table II4.3.2. According to the table, flood events took place over the country in 1978, 1986, 1989 and 1995. Frequency of floods is relatively high in Regions I and II, while it is relatively low in Regions III, V and VII.

II4.3.3 Flood Runoff Pattern

Consecutive flood days and their frequency were studied based on the daily flow data. Table II4.3.3 shows the results of study. Most of the floods end in one day (62%) followed by 2-day floods (21%) and 3-day floods (11%). Rate of 1-day flood is high in Regions I, VI and VII, while the rate is low in Region-II.

II4.4 Roles of Dams in Flood Mitigation

II4.4.1 Primary Functions

Dam reservoir generally functions to flood and sediment control facility for 1) reduction of flood peak, 2) stabilization of river channel, and 3) trapping sediment. These functions are naturally provided with any dams notwithstanding the project purposes, though the extent of effects may depend on the conditions.

(1) Reduction of Flood Peak

The reduction of flood peak is the primary function of the reservoir. Flood runoff is generally sharp at dam site, for there is no reservoir in the upstream and the topography is steep. In such a site, flood peak would reduce markedly by the dam reservoir.

(2) Stabilization of River Channel

Flood flow is the major factor to form river channel. Under the conditions without dam, flood flow that occurs on rare occasion erodes the riverbank severely and washes away the riverine vegetation. Once a dam is constructed, tractive force of the river flow is weakened significantly and the river channel shall be free from destructive forces of flows. Such conditions allow the vegetation on riverbanks, and the vegetation further stabilizes the river channel and its course.

(3) Trapping Sediment

Any dam reservoir should provide sedimentation capacity, and the trapping sediment by the reservoir will alleviate the sedimentation of the downstream reservoir and elongate its operational life.

II4.4.2 Extent of Effects

In general the flood and sediment control effect is large and definite at just downstream of the dam and it gradually decreases toward downstream. The effect diminishes generally at the confluence of large tributary, since the tributary flows would prevail in the reaches downstream of the confluence and the flood peak and sediment transport capacity depends on conditions of the tributary flow.

Therefore, dams with flood and sediment control function should be located as close as possible to the objects to be protected. Taking an example of sediment control dams for Al Wahda dam, sediment reduction effect is not expected from the small catchment dams located far away from Al Wahda reservoir.

Notwithstanding the sediment volume trapped by the upstream dam, the river flows will carry the sediment into Al Wahda reservoir corresponding to their sediment transport capacities.

Based on the topographic maps (1/50,000 and 1/100,000), flood and sediment control effects and influenced stretches were studied, considering the river system, topography, land use, settlements and other properties. Results of study are shown in Table II4.4.1. The expected effects of respective dams are summarized below.

Flood and Sediment Control Effects of Dams

No	Dam	FR	CS	SR	No	Dam	FR	CS	SR
1	Neckor	×	×	×	13	Keng Grou	○	×	×
2	Tizimellal	×	×	×	14	Adarouch	○	○	×
3	Ait Baddu	○	×	○	15	Sidi Omar	○	○	×
4	Ain Kwachiya	○	○	×	16	Tiouine	○	○	○
5L	Lower N'fifikh	×	×	×	17	Azghar	○	○	×
5U	Upper N'fifikh	○	○	×	18	Boukarkour	○	○	○
6	Tazarane	×	×	×	19	Aoulai	×	×	○
7	Amezmiz	○	○	○	20	Sidi Abbou	○	○	×
8	Boulaouane	○	○	×	21	Sidi El Mokhfi	○	○	○
9	Taskourt	○	○	×	22	N'ouantz	×	×	×
10	Timkit	○	×	×	23	Igui N'ouaqa	○	○	×
11	Tadighoust	○	×	×	24	Amont Abdel	○	○	○
12	Tiouzaguine	○	×	×	25	Sidi Abdellah	○	○	×

(Note) FR: Flood peak reduction, CS: Channel stabilization, SR: Sediment reduction
○: Effects are expected, ×: Effects are not expected or not clear.

From flood and sediment control viewpoint, little effect is expected from Neckor (No.1), Tizimellal (No.2), Lower N'fifikh (No.5L), Tazarane (No.6) and N'Ouantz dams (No.22). Other dams are expected to function for flood mitigation.

II4.4.3 Reservoir Sedimentation

Annual reservoir sedimentation volumes for the dams under study are shown in Table II4.4.2. These values have been estimated by DGH based on study results of past sedimentation data of existing reservoirs in Morocco. According to the specific annual sedimentation rates (Ds), following features are disclosed:

- The sedimentation rate is high in the Rif Mountains with the rate more than 2,500 $m^2/km^2/yr$.
- The sedimentation rates are also high at the sites of Sidi Omar (No.15), Ait Baddou (No.3), Tiuzaguine (No.12) and Tinouine (No.16) dams ranging from 550 to 1,200 $m^3/km^2/yr$.
- The sedimentation rates at other dam sites are relatively low ranging from 250 to 450 $m^3/km^2/yr$.

II4.4.4 Principles for Flood and Sediment Control

Taking the above discussions into consideration, the flood and sediment control study should be made in line with the following:

(1) Flood mitigation function should be incorporated in planning dams as much as possible, to make the project multipurpose and economical. Since the flood does not occur so often in the study area, facilities exclusive for flood mitigation would not be economically viable in general.

(2) In order to accomplish the flood mitigation, flood mitigation measures other than dam should also be discussed including such as bank protection works and flood plain management.

(3) As to reduction of the reservoir sedimentation, possible measures other than the dam should be first discussed. In case a dam is proposed exclusively for sediment control purpose, the effects should be examined carefully taking account the river system, distance form the object to be protected, etc.