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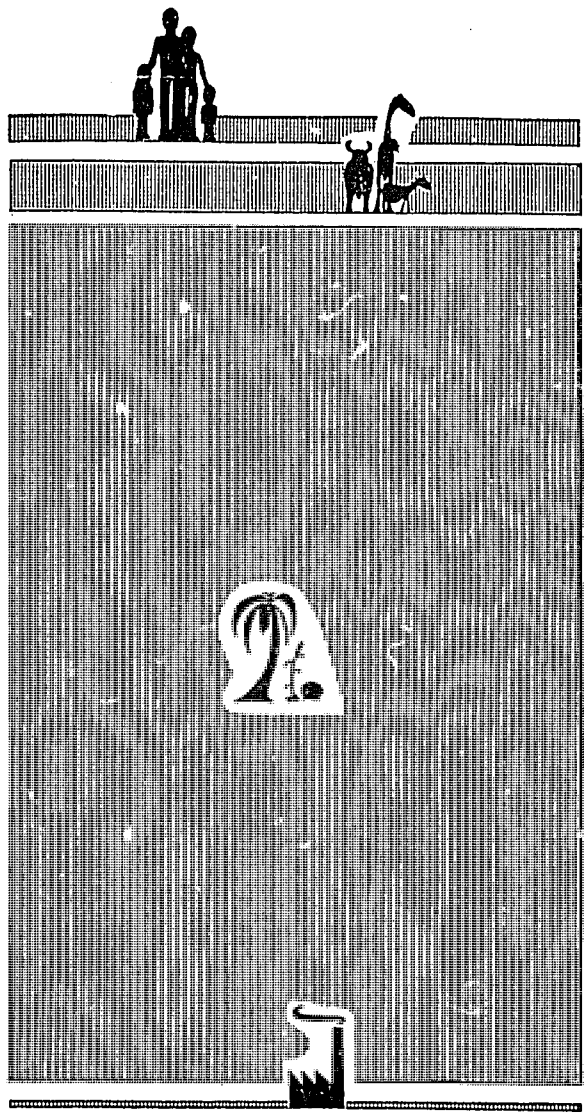
APPENDIX I

STRUCTURE AND APPLICATIONS OF A WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA

- 1984 Estimates
- 1990 Forecasts
- Constraint Analysis of National Water Supply Objectives
- 1995 Supply Side Analysis of Consultants' Recommended Program



COMPREHENSIVE GROUNDWATER DEVELOPMENT PROJECT

March, 1986

Louis Berger International, Inc.

LOUIS BERGER INTERNATIONAL, INC.

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March 18, 1986

Engineer Yussef Mohamed Elmi
Water Development Agency
Mogadishu, Somalia

RE: Revised Water Industry Systems Model for Somalia

Dear Engineer Yussef:

I am pleased to submit herewith four copies of our revised "Structure and Applications of a Water Industry Systems Model for Somalia (WISyMS)", which becomes Appendix I of the Draft Final Report, "Study of Private Sector Participation in Somalia's Water Resource Development Industries," which we submitted in February. You will note that it has been expanded from the version of the model which we submitted as a staff working paper in September of 1985. The changes include the following:

1) The category of "Drilled wells" has been disaggregated into four new subcategories: urban wells (including municipal and private wells), rural diesel pumped wells, rural hand pumped wells, and irrigation wells.

2) The Level III Submodel (analyzing inputs to the water industry) now treats drilling/construction, maintenance, well rehabilitation, and well operation separately.

3) The Level III Submodel now includes cost data for all inputs to drilled wells.

4) 1995 forecasts have been made, including the MMWR's water consumption goals (as set out in the MMWR's document, "Planning for the Drinking Water Supply and Sanitation Decade"), moved forward to serve as targets for 1995. These are compared with the supply side analysis described below.

5) A 1995 supply side analysis of the Consultants' Recommended program (as set forth in Section Two of the main body of the Draft Final Report) has been made, which demonstrates how the program meets the MMWR's water consumption goals for the Drinking Water Supply and Sanitation Decade by 1995.

We look forward to your comments on this appendix, as well as your comments on the rest of the Draft Final Report.

Sincerely,

LOUIS BERGER INTERNATIONAL, INC.

Harvey A. Lerner
Study Director

HAL/dms

Enclosures

cc: Kalif Hagi Farah (WDA)
William Darkins (USAID)

COMPREHENSIVE GROUNDWATER DEVELOPMENT PROJECT

STUDY OF WATER RESOURCE DEVELOPMENT INDUSTRIES IN SOMALIA

APPENDIX I

STRUCTURE AND APPLICATIONS OF A WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA

- 1984 Estimates
- 1990 Projections/Forecasts
- 1990 Constraint Analysis of National Water Consumption Objectives
- 1995 Supply Side Analysis of Consultants' Recommended Program

Prepared for: The Water Development Agency
Somali Democratic Republic

Prepared by: Louis Berger International, Inc.
March, 1986

Funded by: United States Agency for
International Development

WATER RESOURCE DEVELOPMENT INDUSTRIES IN SOMALIA

APPENDIX I

STRUCTURE AND APPLICATIONS OF A

WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA (WISyMS)

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APPENDIX I

STRUCTURE AND APPLICATIONS OF A WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA (WISyMS)

I-1. INTRODUCTION

I-1.1 Scope and Organization of Working Paper

This appendix sets forth the comprehensive data base used by Louis Berger International, Inc. (LBII) in its study of water resource development industries in Somalia. It also provides an explanation of and documentation for LBII's Water Industry Systems Model for Somalia (WISyMS) which was used to integrate available data, to make projections, and to perform other types of analysis.

In addition to presenting and providing documentation for a comprehensive data base, this working paper explains the methodology used to:

1) Provide forecasts for the water industry in Somalia;

2) Analyze national water supply objectives in light of existing resource and market constraints;

3) Demonstrate the effects on water supply of the Consultants' Recommend Program; and

4) Generate integrated estimates of the characteristics of the water industry system in Somalia as it currently exists.

Annex I presents quantitative details.

This appendix is composed of eight sections and a set of ten annexes in addition to this introduction. Section I-2 provides an overview of the Water Industry Systems Model for Somalia (WISyMS) and its uses. Section I-3 provides an explanation of each of the three submodels of WISyMS. Section I-4 discusses the use of the model for the Consultant's 1990 forecasts. Section I-5 discusses the use of the model for a constraint analysis of national water supply objectives and discusses LBII's supply side analysis of the Consultants' recommended program. Section I-6 discusses LBII's methodology by which the model was used to generate 1984 integrated estimates of system parameters.

Definitions used in the model are contained in Section I-7; Section I-8 presents the methodology and formulae employed by the model; and Section I-9 discusses the sources of data and estimates used in developing the model. Annex I contains the detailed data generated by running the model under various assumptions.

I-1.2 WISyMS as an Integrated Data Base for a Private Sector Project

WISyMS is a tool for comprehensive sectoral analysis for a private sector project. It is believed that the concept and methodology of WISyMS have general applicability for privatization or divestiture interventions throughout their respective project cycles. More specifically:

- WISyMS has been designed as a multi-purpose data base which can serve the needs of project identification, project monitoring, and project evaluation without requiring substantial structural modification.

- WISyMS can be presented in layman's terms, so it can be used by some of the primary beneficiaries of privatization projects: the local businessmen, to whom it presents an integrated analysis of an entire industry structure, including project complements and substitutes, as well as upstream and downstream markets;

- WISyMS can be presented in more detailed, technical terms, so it can be easily up-dated by local planning personnel, and kept available for reference by local government personnel, donors, and private individuals interested in or concerned with the market; and finally

- WISyMS can reduce the "market information risk", which businessmen in developing countries often face both by providing a tool for reconciling conflicting information, and by providing them with the results of sensitivity analyses on the points of conflict.

I-2 OVERVIEW OF THE STRUCTURE AND APPLICATIONS OF THE WATER INDUSTRY SYSTEMS MODEL FOR SMOALIA

The Water Industry Systems Model for Somalia, (WISyMS) has been designed to provide an integrated analysis of the relationships between water consumers, water supply structures, and inputs to the water industry. Exhibit I-1 presents the symbols that will be used to represent the principal categories of water consumers throughout this paper in graphical explanations of the model. Exhibit I-2 presents the symbols used to represent the water supply structures in Somalia considered in this report. Exhibit I-3 presents the symbols used to represent the principal categories of inputs to the water industry in Somalia.

Water needs begin at the level of the consumer. The need for water leads to a need for water supply structures to serve the consumers' water needs efficiently. New wells must be drilled and new water supply structures must be constructed each year, and this drilling and construction activity in turn gives rise to a

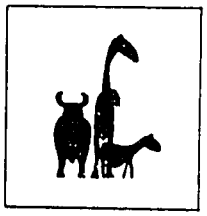
EXHIBIT I- 1

PRINCIPAL CATEGORIES OF CONSUMERS OF WATER

HUMANS

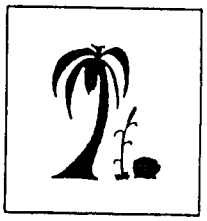
-URBAN
-RURAL SETTLED
-NOMADIC

ANIMALS



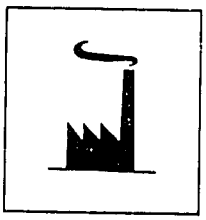
-CAMELS
-CATTLE
-SHEEP/GOATS
-OTHER

AGRICULTURE



-IRRIGATION FARMS
-RAIN FED FARMS
-FLOOD FED FARMS

GOVERNMENT/
INDUSTRY



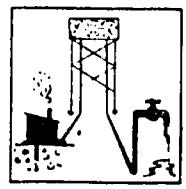
-GOVERNMENT
-INDUSTRY

3

EXHIBIT I- 2

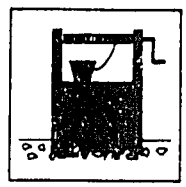
PRINCIPAL WATER SUPPLY STRUCTURES

DRILLED WELLS



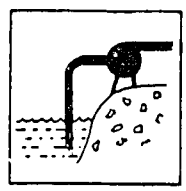
ALL WELLS DRILLED MECHANICALLY, EQUIPPED WITH DIESEL OR HAND PUMP

HAND DUG WELLS



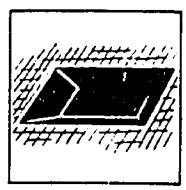
ALL WELLS DUG BY HAND, REGARDLESS OF DEPTH

INTAKES FROM RIVERS/STREAMS/ SPRINGS



CONSISTING OF PIPES IMMERSED INTO WATER AND CONNECTED TO A DIESEL PUMP

UARS/ RESERVOIRS

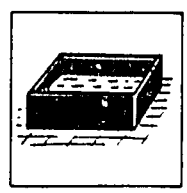


RESERVOIRS DUG IN RELATIVELY IMPERMEABLE GROUND TO CATCH RAIN-WATER AND SURFACE RUN-OFF

BALLEHS

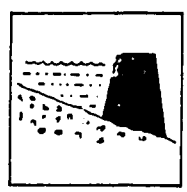
PONDS OR NATURAL DEPRESSIONS WHICH CATCH AND HOLD RAIN-WATER AND SURFACE RUN-OFF

BURKEDS/ CISTERNS



IN-GROUND MASONRY CIS-TERNS WHICH SERVE AS WATER STORAGE TANKS OR WHICH CATCH RAINWATER AND SURFACE RUN-OFF

DAMS/ DIVERSIONS

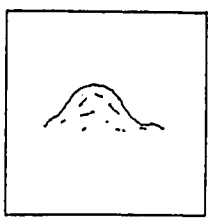


MAN-MADE STRUCTURES TO DIVERT OR HOLD BACK THE NATURAL FLOW OF A RIVER, STREAM, OR TUG

EXHIBIT I- 3

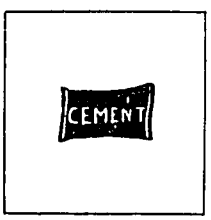
PRINCIPAL CATEGORIES OF INPUTS TO THE WATER INDUSTRY

RAW MATERIALS



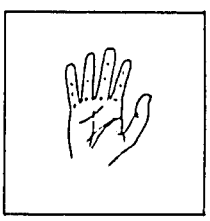
- SAND
- GRAVEL
- STONES
- OTHER

MANUFACTURED MATERIALS



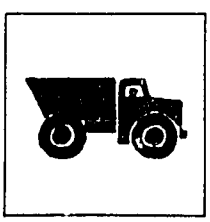
- CEMENT
- STEEL CASING
- STEEL SCREEN
- OTHER

LABOR



- SKILLED
- UNSKILLED

EQUIPMENT



- DRILL RIGS
- PUMP RIGS
- VEHICLES
- OTHER

5

need for inputs of capital, labor, and materials. The physical flows, of course, move in the opposite direction: inputs (Level III) are supplied to serve drilling and construction activity (Level II); water supply structures provide water to consumers (Level I) (see Exhibit I-4). Each of the three industry levels, and the submodels of WISyMS which analyze them, are explained below.

The Water Industry Systems Model for Somalia (WISyMS) serves the three basic functions of forecasting, constraint analysis, and integrated estimation. It is made up of three related sub-models which correspond to the three basic levels of the water industry structure in Somalia: Level I - water supply, Level II - well drilling and construction of water supply facilities, and Level III - provision of water industry inputs (See Exhibit I-5).

I-2.1 The Level I Submodel: Water Supply

Level I, water supply, is the business or economic activity of providing water to consumers. Water supply "activities" include water resource ownership, operation and maintenance of physical water supplies, and revenue collection. The Level I submodel analyses water consumption requirements in a given year and translates these into the required complement of water supply structures that need to be in place in that year. Characteristics of the submodel are described below:

- **Purposes:** Forecasts the effects of changes in population and water consumption on the magnitudes of Level I water supply activities; projects the total complement of water supply structures that will be owned, operated and maintained by the public and private sectors in Somalia.

- **Data Inputs:** demographic data, water consumption data, data on agricultural, livestock, and industrial activity including water use, data on historical patterns of water use and reliance on water supply structures.

- **Data Outputs:** requirements for volumes of water to be provided by each type of water supply structure and associated total numbers of each type of water supply structure needed to provide that water in a given year.

- **Principal Uses of Data Outputs:** planning for water system capacity; analysis of public/private roles in water supply; data input for the Level II submodel. The Level I "activities" of water resource ownership, operation, maintenance, and revenue collection, including an analysis of market shares for the local public and private sectors and the foreign import sector, are discussed in Section Three of the main body of the report.

6

EXHIBIT I- 4

OVERVIEW OF RELATIONSHIPS AMONG LEVELS OF THE WATER INDUSTRY

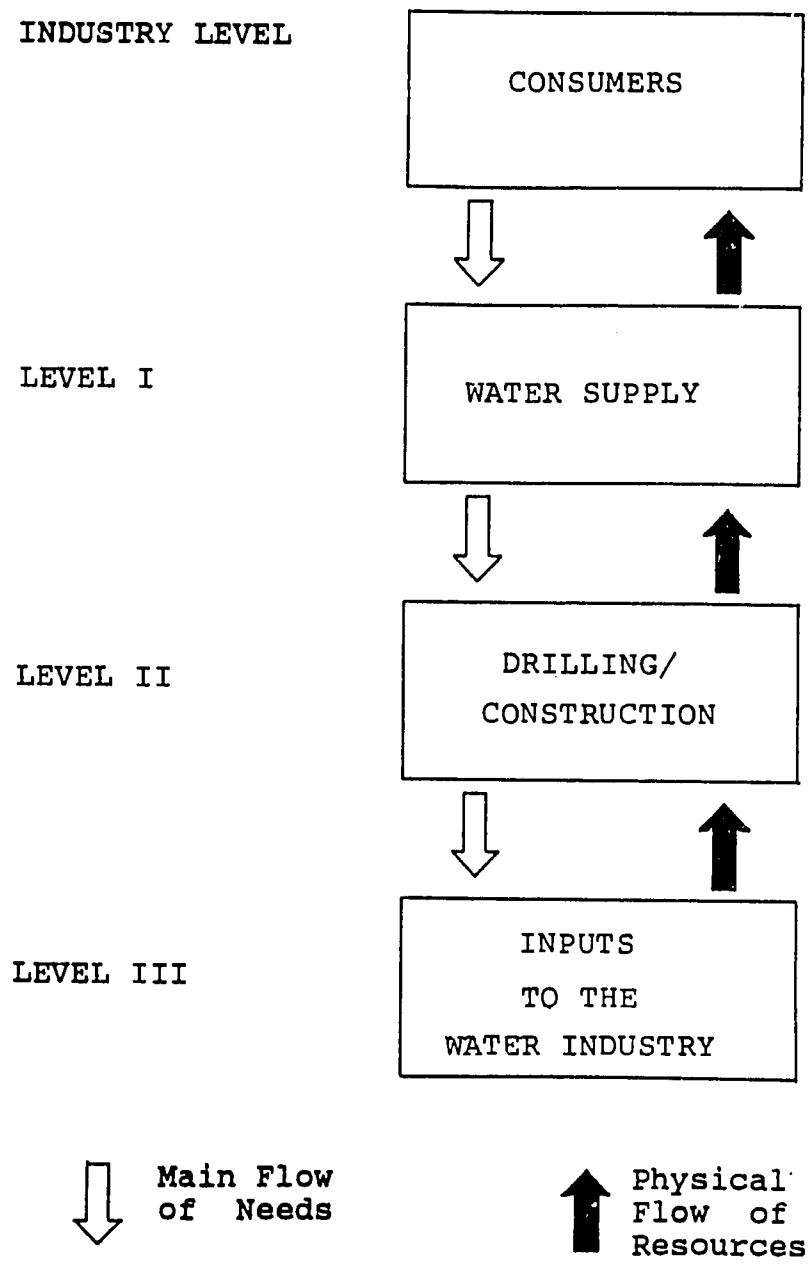


EXHIBIT I- 5

FUNCTIONS OF THE WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA

	FORECASTING	CONSTRAINT ANALYSIS	INTEGRATED ESTIMATION
LEVEL I SUBMODEL Water Supply	✓	✓	✓
LEVEL II SUBMODEL Drilling/ Construction	✓	✓	✓
LEVEL III SUBMODEL Inputs to the Water Industry	✓	✓	✓

-8'

I-2.2 The Level II Submodel: Well Drilling and Construction of Water Supply Facilities

Level II is the drilling and rehabilitation of wells and construction of related civil works structures, and the planning, design, and administration of drilling and construction. The Level II submodel translates the annual needed stock of water supply structures into annual drilling and construction requirements, taking into account both the need for replacement (or rehabilitation) of old, failing structures and the need for net addition to structural capacity. Elements of the Level II submodel are described below:

- **Purposes:** to forecast the effects of changes in water consumption on Level II requirements (well drilling and construction of other water supply facilities.)

- **Data Inputs:** Total numbers of each type of water supply structure needed to provide the water requirements for a given year (data output from the Level I Submodel).

- **Data Outputs:** Numbers of old water supply structures to be rehabilitated and numbers of new water supply structures needed to be constructed both to replace old, failing structures and to provide for net increases in water consumption for a given year.

- **Principal Uses of Data Outputs:** A Level II market study identifying needs for water supply drilling and construction activity; data for Level III Submodel. An analysis of the market shares for Level II activity in Somalia is presented in Section Three of the main body of the report.

I-2.3 The Level III Submodel: Water Industry Inputs

Level III is the production or provision of manufactured and raw material inputs, equipment, labor, and fuel for water supply, well drilling, and water supply construction activities. The Level III submodel translates Level II construction requirements into needed inputs for a given year. Elements of the submodel are described below:

- **Purposes:** Forecasts the effects of changes in needed water system capacity on Level III requirements (water industry inputs.)

- **Data Inputs:** Requirements for new drilling, rehabilitation, and construction (output from Level II Submodel); requirements for operation and maintenance of structures (output from Level I Submodel).

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- **Data Outputs:** Annual required quantities of raw material and manufactured material inputs, as well as labor and equipment inputs to the water industry for a given year.

- **Principal Uses for Data Outputs:** Level III market study identifying needs for expansion of facilities or new ventures which could supply inputs to the water industry; measuring the economic impacts of increased activity in the industry.

I-2.4 Types of Analyses Performed with WISyMS

Three types of analyses can be performed using WISyMS: forecasting, supply/constraint analysis, and integrated estimation. Exhibit I-6 shows the direction of analysis among the three sub-models, depending on the purpose for which the model is used.

I-2.4.1 Forecasting

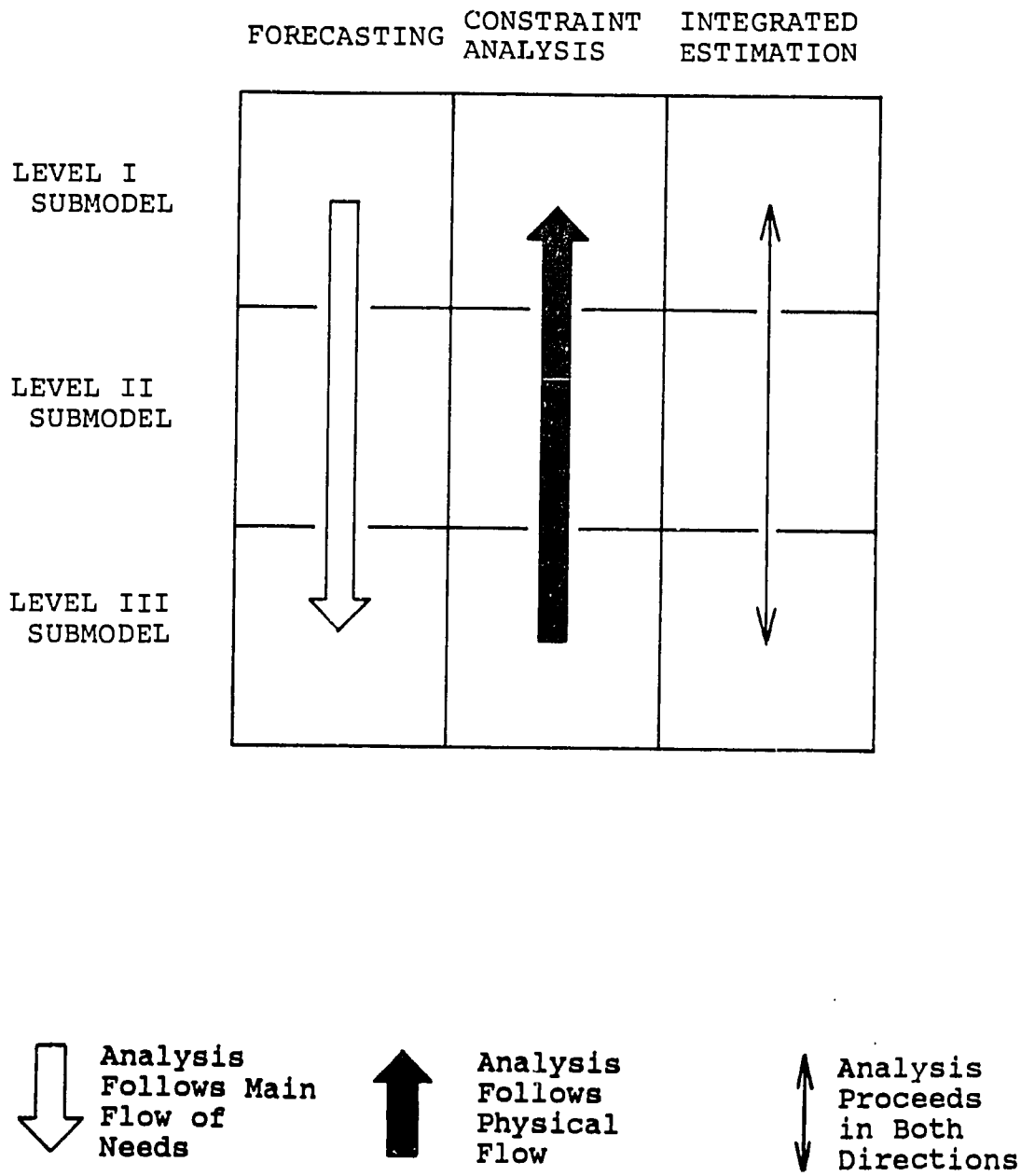
If used for forecasting, the analysis follows the flow of needs. First, demographic and economic data are gathered and used to forecast Level I demand for water for a given year and an associated stock of supply structures. This stock of structures is used to calculate Level II demand for the flow of drilling, rehabilitation and construction activity needed to expand the existing stock. The flow of new drilling/construction activity in turn is used to calculate Level III input requirements. This forecasting procedure is explained in greater detail in Section I-4 of this paper. Annexes I-4 through I-6 contain the Consultants' 1990 forecasts generated by running WISyMS.

I-2.4.2 Supply/Constraint Analysis

Constraint analysis, on the other hand, is used most often to evaluate the realism of proposed goals, programs, or large projects. It asks the question: "Are there bottlenecks, resource shortages, or other constraints in the system which will prevent the attainment of stated objectives?" Constraint analysis proceeds by making forecasts over the relevant time period, including specific goals and key assumptions of a particular program. The model is run first as a forecast, and the implications in terms of drilling/construction requirements are compared with past performance and resource availability. The major constraints are identified, and these constraints indicate restrictions on the degree to which desired goals can be achieved: the availability of inputs constrains the numbers and types of structures that can be produced in a given time frame, and this in turn constrains the amounts of, say, groundwater resources that can be made available for use in the nation. The crucial part of the analysis starts at Level III and works back toward Level I. This type of analysis is examined in more detail in Section I-5, as part of the Consultant's supply side and constraint analysis of national water supply objectives in Somalia.

EXHIBIT I- 6

THE DIRECTION OF ANALYSIS IN WISyMS



I-2.4.3 Integrated Estimation

Integrated estimation of system parameters, as presented in the Consultants' baseline (1984) estimates for the water industry system in Somalia (see Annexes I-1 through I-3) is actually the first step involved in building the model. It seeks to identify the historical patterns of water consumption and reliance on water supply structures.

The most readily available information includes some demographic data and inventories/estimates of the stock of existing water supply structures in Somalia. Other data can be generated through the Delphi Method, whereby a consensus on a variable is established on the basis of opinions supplied by a variety of informed sources; and by eclectic methods which combine, sift, weight, average, and then incorporate estimates in the framework of the model. Further, reasoned analyses of broad behavioral patterns (e.g., seasonal reliance on surface water resources) and technical constraints (e.g., on volumes of water output per structure) are incorporated in the model. Together, available data, estimates, and logical reasoning can be used to infer the parameters of key relationships between water consumption and water provision, as well as to infer logical estimates for variables on which we lack reliable data. Thus, the analysis for integrated estimation of system parameters proceeds in both directions among the submodels. This type of analysis is explained in more detail in Section I-6.

The overview of WISyMS provided above is expanded in Section I-3 to describe the workings of each of the three submodels. Detailed explanations of the procedures followed for forecasting, constraint analysis and integrated estimation, including examples of WISyMS' data output, are presented respectively in Sections I-4, I-5, and I-6.

I-3 EXPLANATION OF THE WISyMS SUBMODELS

This section explains how each of the three submodels of WISyMS works and how they fit together. A detailed methodology is presented in Section I-8.

I-3.1 WISyMS Level I Submodel - Water Supply: An Integrated Analysis of Water Consumption and Delivery Systems (Exhibit I-7).

This submodel analyzes water flow requirements in a given year, as determined by demographic, economic, and water consumption data, and translates these into the required complement or stock of water supply structures that need to be in place in that year. Actual data are presented in Annex I; notes and sources are discussed in Section I-9.

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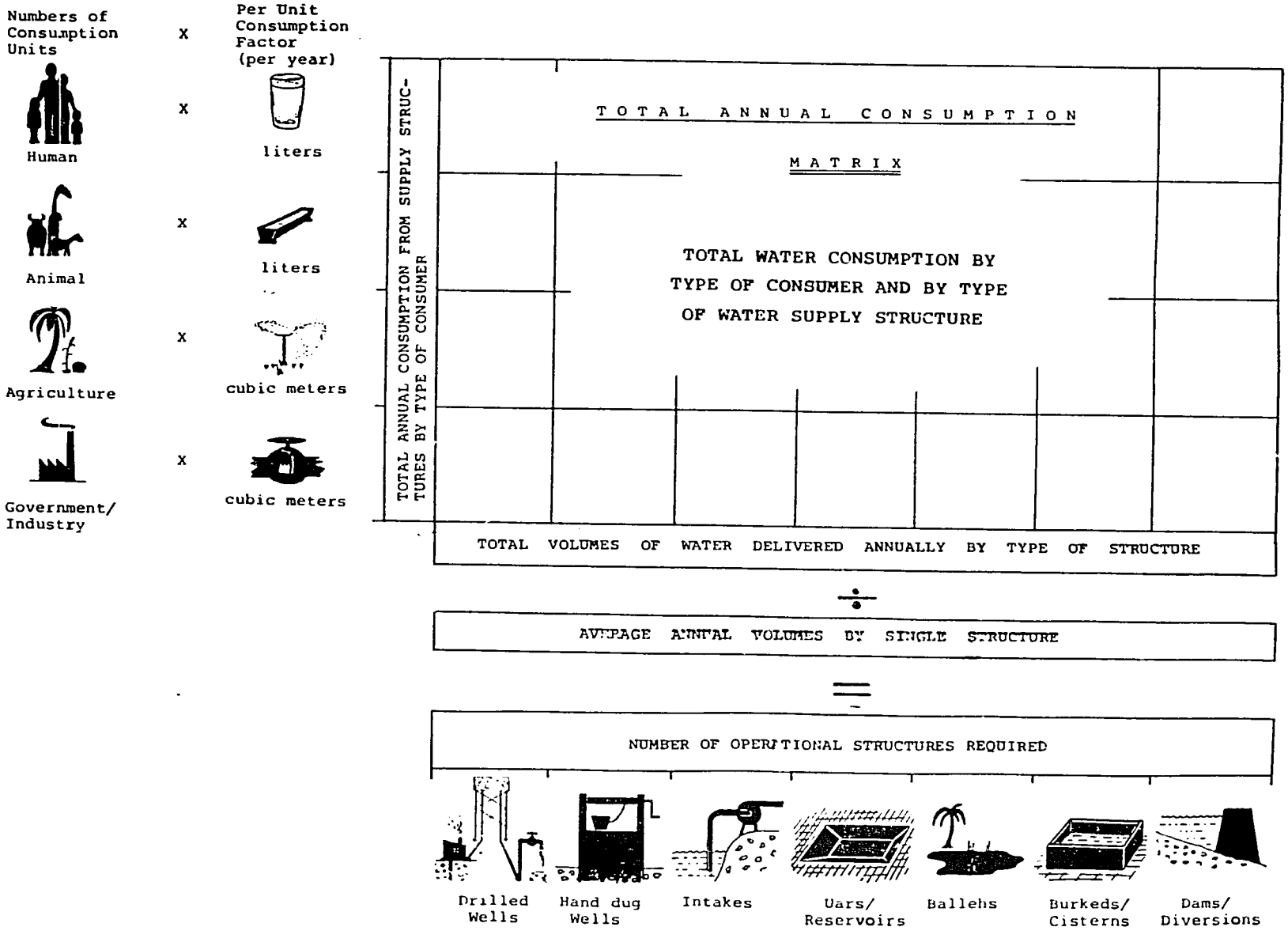
EXHIBIT I- 7

LEVEL I SUBMODEL

Integrated Analysis of Water Consumers and Delivery Systems



There are four basic types of consumption examined in the model*:

- **Human** consumption of water for drinking, cooking, washing and cleaning;
- **Livestock** consumption of water primarily for drinking;
- **Agriculture's** consumption of water for crop production; and
- **Government and Industrial** consumption of water for all purposes.

Specific numbers for each type of consumption unit are estimated: human populations, livestock populations, hectares under cultivation, and numbers of government institutions and industrial/commercial establishments.

Next, per unit consumption factors are estimated for each type of consumption unit: for humans - average annual water consumption per capita; for livestock - average annual water consumption per head; for agriculture - average annual water consumption per hectare; and for government and industry - average annual water consumption per institution, office, or establishment.

Multiplying numbers of consumption units (in each category) with the associated average per-unit consumption factors yields total estimated volume of consumption by type of consumption. The model focuses on water consumed through the use of man-made supply systems, as opposed to water consumed directly from nature.

The next step is to analyze historical patterns of reliance, (for each type of consumption) on each type of man-made water supply structure:

- **Drilled Wells** - deep wells drilled by heavy equipment, specifically drill rigs;
- **Hand Dug Wells** - shallow wells dug with the use of hand tools;
- **Intakes from Rivers** - pumps delivering water from rivers for various purposes;
- **Uars** - man-made reservoirs dug or excavated in relatively impermeable ground to hold rainwater;
- **Ballehs** - natural ponds or depression which collect rainwater and are often deliberately enlarged;

* Detailed definitions are provided in Section I-7.

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- **Burkeds** - masonry cistens for holding rainwater;

- **Dams/Diversions** - structures to hold back or divert the flow of permanent or seasonal rivers.*

The model uses estimates of the historical percentage distribution of reliance, for each type of consumption, on each type of supply structure, and uses this to create a matrix of water consumption, calculating the volume of water consumed for each type of consumption from each type of supply structure. This is shown in the rows of the matrix in Exhibit I-7. Summing down each of the columns yields:

- **Structural Supply Volumes:** the total volume of water estimated to be supplied annually by each type of supply structure.

At this point, we have specific estimates of the annual flow requirements for water consumption. The next step is to translate water flow requirements into associated stock requirements for structures. To do this, the Structural Control Totals are divided by:

- **Output per Structure per Year:** estimated average annual volume of output per structure for each type of supply structure.

This yields specific requirements for total stock levels for each type of water supply structure, presented as:

- **Total Numbers of Water Supply Structures** needed to provide the amounts of water indicated in the calculation of the structural supply volumes, above.

These stock totals are used in the second component of WISyMS, the Level II Submodel, to calculate the flow of annual construction requirements, as described below. This data output can also be used by planners at WDA to (a) forecast water consumption needs based on demographic trends or (b) to analyze objectives in terms of increased total consumption or increased use of particular types of structures.

I-3.2 WISyMS Level II Submodel - Drilling and Construction: Quantification of flow requirements for new water supply structures for replacement and expansion of existing capacity (Exhibit I-8).

The Level II Submodel starts with the bottom line of the Level I Submodel: the total numbers of water supply structures needed to provide the amounts of water indicated in the calculation of the structural supply volumes. Each type of supply structure is examined in the manner outlined below.

* These structures are defined in more detail in Section I-7.

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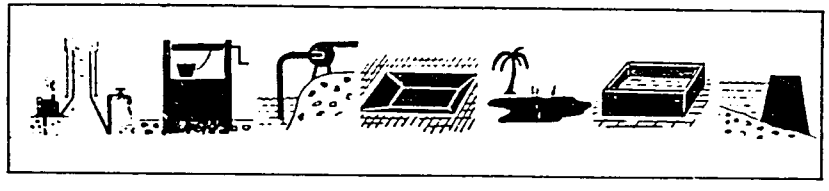
EXHIBIT I- 8

LEVEL II SUBMODEL

Quantification of Requirements for New Water Supply Structures
for Replacement and for Expansion of Existing Supply Capacity

Total Stock at Beginning of Year 1

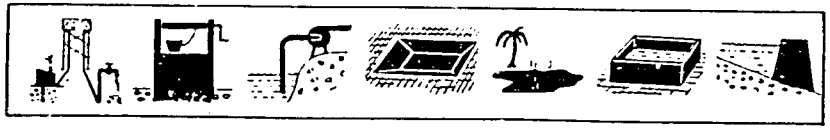


MINUS

Closure During Year 1

=

Remaining at End of Year 1

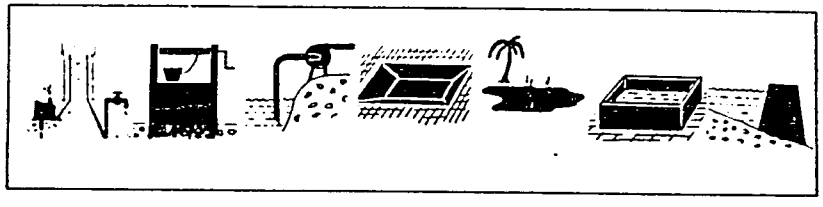


+%

EXPANSION

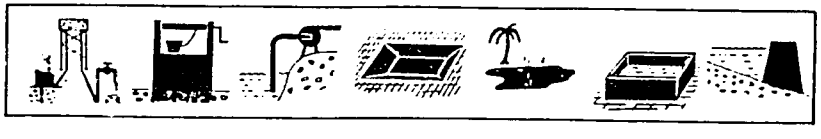
=

Total Needed Stock Year 2



MINUS

Stock at Beginning of Year 2



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NEEDED NEW/REHABILITED STRUCTURES IN YEAR 2

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For each type of supply structure, we have:

- **Total Numbers of Water Supply Structures** needed to provide the amounts of water indicated in the calculation of the structural supply volumes.

This is compared with:

- **Old Structures:** existing capacity on hand in a given year, which will be subject to a certain expected rate of deterioration/failure during the year.

  Drilled wells and other water supply structures can be expected to fail at a certain rate, for a variety of reasons. Some of these failed structures can be rehabilitated by replacing worn parts, cleaning the structure, or redrilling the well. In other cases, rehabilitation may prove to be more expensive or complicated than drilling or constructing a new unit. Thus, of the total number of failed structures, some may be rehabilitated, while other mays have to be replaced by new structures. Net increases to the supply of structures, however, can only be undertaken by new drilling/construction.

  Over the past several years in Somalia, drilled wells which have ceased functioning (due primarily to pump/generator failure) have rarely been rehabilitated. Instead, they may lay idle for a considerable period of time, until the old well is replaced entirely by a new drilled well.

Subtracting the numbers of functioning old structures from the total numbers of needed water supply structures in a given year then yields:

- **Numbers of New Water Supply Structures** needed to be rehabilitated or constructed to:

  a) replace or rehabilitate old structures as they fail during the course of the year, plus

  b) provide for expected net increases in consumption from all sources.

These numbers are used in the final Level III component of WISyMS, to calculate the input requirements for the water industry for a given year. These numbers can also be used for a market study for drilling and construction services.

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I-3.3 WISyMS Level III Submodel - Water Industry Inputs: Quantification of Inputs Required for Expansion of Water Supply Capacity. (Exhibit I-9)

The top row of Exhibit I-9 corresponds to the bottom line for each type of supply structure analyzed in the Level II submodel. The left hand column of Exhibit I-9 lists the types of inputs required to construct each type of water supply structure. These include:

- **Raw Materials** such as sand, gravel, and stone;
- **Manufactured Inputs** such as well casing and screen, pumps, cement, reinforcement steel, plastic and iron fixtures;
- **Labor Inputs** such as supervisors, drillers, or carpenters; and
- **Equipment Inputs** such as drill rigs, bulldozers, and pickup trucks.

For each type of structure, there are technical input coefficients for production, rehabilitation, maintenance and operation which are used to calculate the specific physical quantities of each type of input required, based on current technology and practices. These are presented in terms of, e.g., cubic meters of cement, meters of well casing, man-days of masonry labor, or equipment days of bull-dozer utilization for the construction of one unit. These per-structure input requirements are multiplied by the numbers of each type of structure to be produced, rehabilitated, maintained, and operated in a given year to yield total physical requirements for each type of input, and for each type of structure. These can be summed across each row to yield:

- **Total Input Requirements** for each type of input for all types of structures.

This forms an annual bill of materials of key inputs to the water industry. These numbers can be used for market studies for the various types of inputs to the water industry, although some of the inputs used in the water industry (such as reinforcement steel) are used much more heavily in other industries (such as basic construction), so that quantities used for the water industry form an insignificant portion of total demand for that input. A similar analytical procedure can, however, be applied to these industries as well.

Note that at present, the model considers only those water supply facilities which take water directly from natural sources. Municipal water distribution systems, irrigation systems, and water transport have not been examined, although they could be incorporated into the model in the future.

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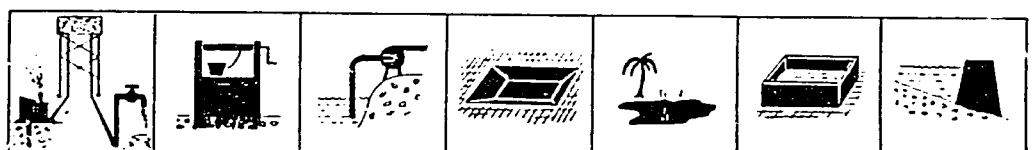
EXHIBIT I- 9

LEVEL III SUBMODEL

Quantification of Inputs Required for Expansion of Total Capacity of Supply

NUMBERS OF NEEDED NEW WATER SUPPLY STRUCTURES



RAW MATERIALS							
MANUFACTURED INPUTS							
LABOR							
EQUIPMENT							

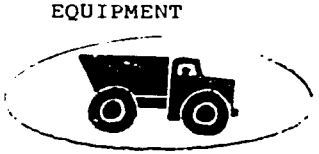
TOTAL INPUT REQUIREMENTS

RAW MATERIALS

MANUFACTURED INPUTS

LABOR

EQUIPMENT



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In summary, the three submodels of WISyMS work together to illustrate the relationships between the most important variables of the water system. The practical applications of the model are discussed in the following sections.

I-4 1990 FORECASTS

LBII'S Water Industry Systems Model for Somalia has been designed to facilitate practical applications for a range of forecasting needs. This section explains WISyMS' forecasting features and procedures and presents 1990 forecast data generated by the model.

I-4.1 Forecasting Features

The parameters of the model were estimated on the basis of the best available information on historical patterns of water use and relationships between types of consumption and types of structures; but WISyMS has also been designed to facilitate parameter adjustments based on changes in data or assumptions including the following:

- Expected demographic or economic trends affecting water use patterns;
- Expected technological advancements affecting the performance of the physical water supply system;
- Expected technological advancements affecting the technical input co-efficients for drilling and construction;
- Proposed policy changes expected to affect water use patterns; and/or
- New information or data.

I-4.2 Forecasting Procedures

The procedures involved in each of the above listed WISyMS forecasting features are described below.

I-4.2.1. Expected Demographic or Economic Trends

Demographic and economic trends are the most obvious influences on total water consumption needs and associated requirements for supply system capacity and system inputs. Starting from any assumed baseline data on, e.g., human and livestock population, estimates of annual growth rates for these categories (or sub-categories), can be used to project population levels for future years. The model then translates these projected population figures into requirements for water

consumption and associated requirements for supply system capacity and industry inputs.

Assumptions on growth in per capita water consumption and trends in patterns of reliance on different types of supply structures (such as wells vs surface catchments) can be similarly incorporated into the model's projections for a given year and translated into estimates of requirements for water, supply system capacity and industry inputs.

Actual 1990 forecast data generated by WISyMS and a discussion of the major assumptions involved are presented below in Section I-4.3.

I-4.2.2 Technological Advancements in Supply System Performance

The effects of technological advancements in supply system performance on the basic relationships analyzed in the WISyMS can be incorporated in parameter changes in the model. For instance, an improvement in maintenance capabilities in the country can extend the useful life of supply structures and correspondingly reduce the need for new construction for replacement purposes. This can be translated into changes in the need for inputs - more inputs going into maintenance and rehabilitation and fewer inputs required for new construction.

I-4.2.3 Technological Advancements in Construction

Changes in drilling and construction procedures will affect the technical input co-efficients for specific water supply structures and will therefore affect the total quantities of associated inputs required to support drilling/construction. For example, over time, it can be expected that drilling/construction procedures will become gradually more capital intensive. This would tend to decrease the per-unit labor input requirements and increase the per-unit equipment and fuel requirements and thus alter the expected annual totals of employment and equipment units needed by the industry as a whole.

I-4.2.4 Future Policy, Program and Project Changes

The effects of possible future changes in government policies on various aspects of water use can be analyzed by WISyMS. For example, a change in the price of groundwater sold to the public relative to the price of surface water can be assumed to alter the pattern of reliance on groundwater vs. surface water sources of supply. This can be translated by the model into estimates of requirements for specific types of supply systems and related industry inputs. Other such elements are examined in more detail in Section I-5, "Constraint Analysis".

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I-4.2.5 New Information or Data:

As the relevant data base for use in WISyMS improves, adjustments can be made to any of the variables or parameters used in the model, and these adjustments will be translated into associated changes in downstream variables. For instance, if new data is available on the numbers of industrial establishments in the country, this adjustment may affect the total volume of water estimated to be consumed by industrial sources, which will in turn affect the estimates of the numbers of required supply structures, the numbers of new supply structures needed, and the quantities of each of the inputs involved. This element is discussed in greater detail in Section I-6, "1984 Integrated Estimates".

I-4.3 1990 Forecasts

Exhibit I-10 presents the key data generated by the Level I submodel (Water Supply) for the 1990 projections. The data incorporates official estimates of population and herd growth, urbanization trends, and increases in agricultural and industrial activity. The consultant made other additional assumptions, (e.g. that per capita human water consumption would exhibit a growth rate in the range of 6 - 13% per anum) and incorporated those into the model as well. Exhibit I-11, which is drawn from the "Structural Control Volumes" column of Exhibit I-10, provides a graphic representation of the distribution of water by type of consumer. Exhibit I-12, which is drawn from the "Structural Supply Volumes" row of Exhibit I-10, shows the distribution of water by type of structure. A detailed presentation of the data is contained in Annex I-4; notes and sources for the data are discussed in Section I-9.

Exhibit I-13 presents the key data generated by the Level II submodel (drilling, construction and rehabilitation activities) for the 1990 projections. For each type of structure, the first row shows the stock of structures expected to be in place in a given year. The second row shows the existing stock of old structures available, taking into account the rate of failure of each type of structure. The third row shows the numbers of new structures which need to be constructed or rehabilitated in a given year to make up the difference between the needed stock of structures (including net expansion of capacity) and the existing stock of old structures (taking into account their rate of failure). A more detailed presentation of the data is contained in Annex I-4.

Exhibit I-14 presents the data generated by the Level III submodel (inputs to the water industry) for the 1990 projections. The full model contains four parts, one analyzing inputs for drilling/construction, one analysing inputs for well rehabilitation, one analyzing inputs for maintenance, and one analyzing inputs for well operation and revenue collection. Here we present only the part analyzing new drilling/construction. The full level III sub-model is presented in Annex I-4.

EXHIBIT I-10

* * * * * * Total Consumption of Water by Types of Consumption and by Types of Structure * * * * * *

CONSUMPTION UNITS	(000s)	MEASURE	PER UNIT CONS'N DAILY USE FACTOR	MEASURE	TOTAL DISTRIBUTION OF WATER BY STRUCTURE * * TOTAL DISTRIBUTION OF WATER BY STRUCTURE: STRUCT'L CONTROL VOLUME M^3*K/YR	DRILLED WELLS URBAN/ IND/GOVT M^3*K/YR	DRILLED WELLS DP RURAL BOREWELL M^3*K/YR	DRILLED WELLS HP RURAL BOREWELL M^3*K/YR	DRILLED WELLS IRRIG'N WELLS M^3*K/YR	HAND DUG WELLS M^3*K/YR	INTAKES FOR RIV/ STREAMS M^3*K/YR	UARS/ RESER-VOIRS M^3*K/YR	BALLEHS/ PONDS M^3*K/YR	BURKEDS/ CISTERNS M^3*K/YR	EARTH DAMS/DIV M^3*K/YR
HUMAN															
Urban HC	174	persons	100	liters	6287	4716	0	0	0	629	629	126	0	189	0
Urban SP	1567	persons	25	liters	14013	10510	0	0	0	1401	1401	280	0	420	0
Rural Set	1853	persons	15	liters	9638	193	1677	58	0	4337	1446	482	193	1253	0
Nomadic	2757	persons	10	liters	9057	109	1195	54	0	3170	1811	906	906	906	0
SUBTOTAL 1	6351	persons			38995	15527	2872	112	0	9537	5287	1794	1098	2768	0
ANIMAL															
Camels	5308	head	25	liters	31483	252	2771	126	0	6297	6297	6297	7871	1574	0
Cattle	4246	head	25	liters	30996	930	3534	186	0	10849	4649	6199	3100	1550	0
SheepGoats	28661	head	3	liters	23538	471	1789	94	0	8238	4001	3531	3766	1648	0
OtherAn	10615	head	3	liters	581	12	33	2	0	174	99	116	116	29	0
SUBTOTAL 2	13190	LSU			86598	1664	8126	408	0	25558	15046	16143	14853	4801	0
AGRICULTURE															
Irrigfarm	64	hectares	68	cu.meters	1350208	0	0	0	40506	13502	1215187	13502	13502	0	54008
Rainfarm	804	hectares	35	cu.meters	67536	0	0	0	0	0	0	0	0	0	67536
Floodfarm	161	hectares	25	cu.meters	7245	0	0	0	0	0	0	0	0	0	7245
SUBTOTAL 3	1029	hectares			1424989	0	0	0	40506	13502	1215187	13502	13502	0	128789
GOVT/INDUS															
Govt	2	estabs	13	cu.meters	7800	7032	144	0	0	390	234	0	0	0	0
Industry	0.73	estabs	8	cu.meters	1752	1494	30	0	0	175	53	0	0	0	0
SUBTOTAL 4	2.73	estabs	9552		9552	8526	174	0	0	565	287	0	0	0	0
STRUCT'L SUPPLY VOLUMES (M^3*K/YR)					1560134	25717	11172	520	40506	49162	1235807	31438	29453	7568	128789
COMMERCIAL SCALE STRUCTURES						232	398	189	230	4634	6180	953	230	14166	156

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EXHIBIT I-11

1990 FORECASTS OF DISTRIBUTION OF WATER
FROM SUPPLY STRUCTURES BY TYPE OF STRUCTURE

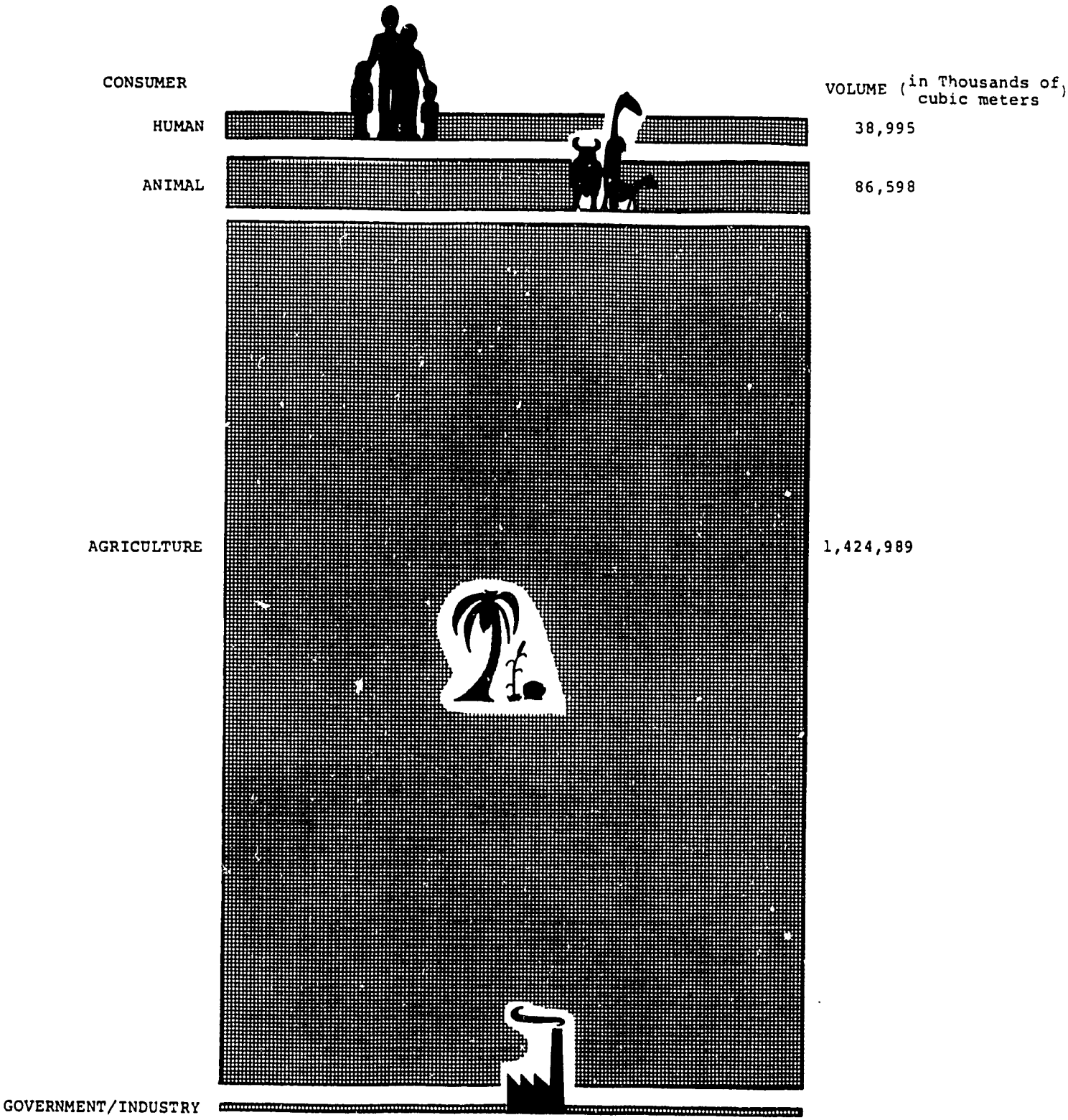

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EXHIBIT I-12

1990 FORECASTS OF DISTRIBUTION OF WATER BY TYPE OF SUPPLY STRUCTURE

Total 1,560,134 (in Thousands of Cubic Meters)

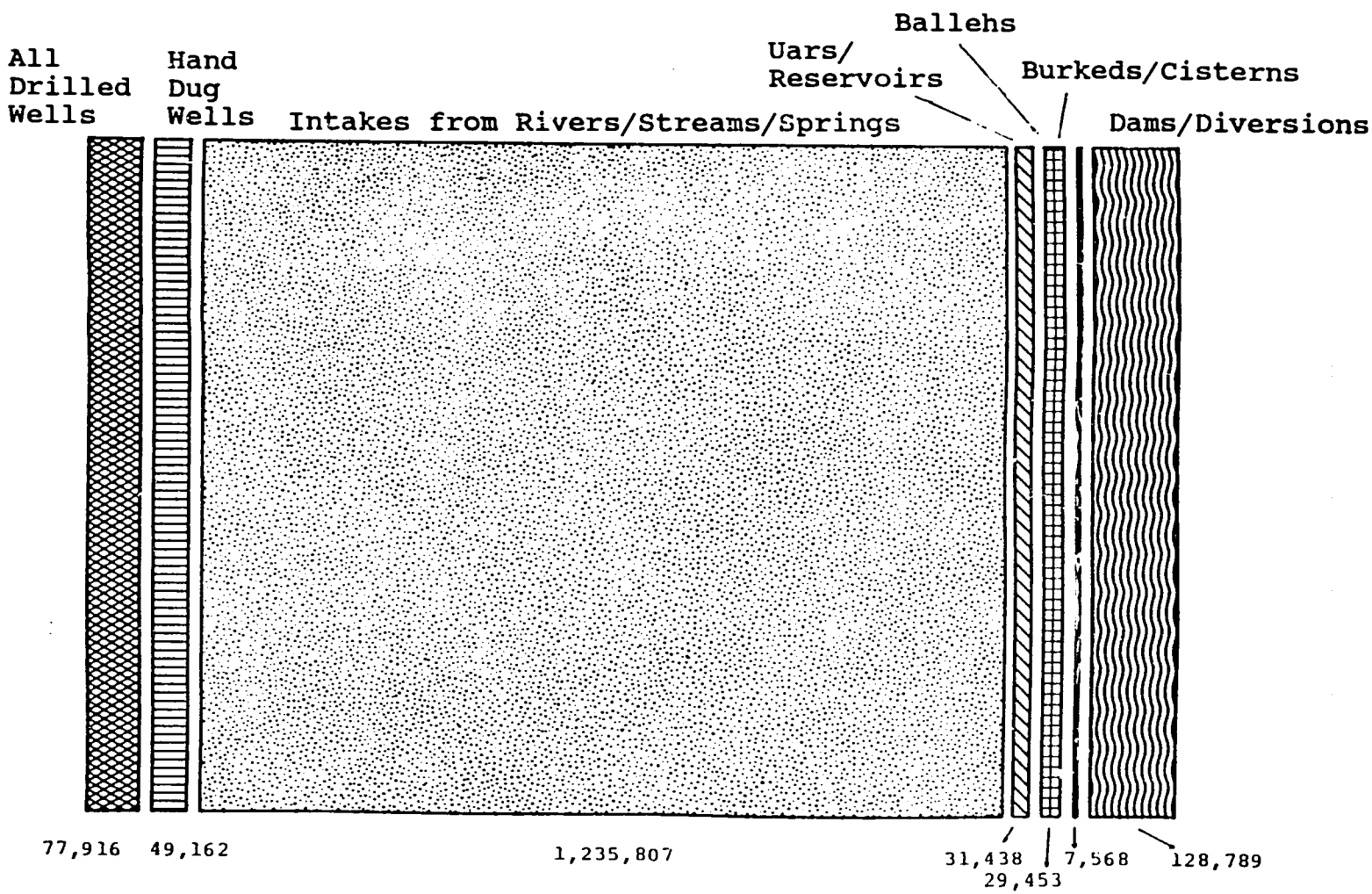

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EXHIBIT I-13

* * * Projections of Requirements for New Water Supply Structures for Somalia 1985 - 1990, at Prevailing Useful Life

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
URBAN WELLS											
Needed Total	56	74	107	123	124	138	153	170	188	209	232
Old	51	51	68	99	112	111	124	137	152	169	188
Needed New or Rehab	5	23	39	24	12	27	29	32	36	40	45
DP RURAL BOREHOLES											
Needed Total	120	142	159	177	199	223	251	281	316	354	398
Old	107	110	130	144	159	179	200	224	251	282	317
Needed New or Rehab	13	32	29	34	40	45	51	57	64	72	81
HP RURAL BOREHOLES											
Needed Total	99	105	110	115	122	131	141	152	163	176	189
Old	92	89	95	98	102	108	115	124	133	142	153
Needed New or Rehab	7	16	14	17	19	23	25	28	30	33	36
IRRIGATION WELLS											
Needed Total	91	102	123	141	155	166	177	189	202	215	230
Old	75	84	92	113	127	139	148	158	168	179	191
Needed New or Rehab	16	18	31	28	28	26	29	31	34	36	39
HAND DUG WELLS											
Needed Total					2500	2771	3071	3404	3772	4181	4634
Old					2250	2275	2521	2774	3059	3376	3731
Needed New					250	496	550	630	714	805	903
INTAKES											
Needed Total					5000	5180	5366	5559	5759	5966	6180
Old					4500	4550	4680	4808	4943	5084	5232
Needed New					500	630	686	751	816	881	948
UARS/RESERVOIRS											
Needed Total					750	780	812	845	880	915	953
Old					675	683	705	728	752	777	804
Needed New					75	98	107	117	127	138	149
BALLEHS/PONDS											
Needed Total					200	205	209	214	219	224	230
Old					180	182	185	187	190	193	196
Needed New					20	23	25	27	29	31	34
BURKEDS/CISTERNS											
Needed Total					10000	10598	11231	11902	12613	13367	14166
Old					9333	9378	9931	10486	11079	11709	12379
Needed New					667	1220	1300	1416	1535	1658	1787
DAMS											
Needed Total					100	108	116	125	135	145	156
Old					80	84	88	92	97	102	124
Needed New					20	24	28	33	38	43	32

EXHIBIT I-14

WISyMS LEVEL III SUBMODEL

1990 MIDDLE PROJECTIONS

(Please turn over)

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MISYAS LEVEL III SUBMODEL
ANNEX I-4
1990 MIDDLE PROJECTIONS

OUTPUTS — CONSTRUCTION

INPUTS	Measure	Urban Drilled Wells	D.P Rural Bore-Wells	H.P Rural Bore-Wells	Irrig-ation Wells	Hand Dug Wells	Non Prod Wells	Inlts from Riv	Dars	Ballehs	Bur-Beds	Dams	ANNUAL CONSTR INPUTS
		WELLS						OTHER STRUCTURES					
APR	Number of struct.	45	81	36	31	903	49	948	149	34	1787	32	
UL	Years	10	10	10	10	10		10	10	10	15	5	
MATERIALS													
Cement per st	cubic meters	200	200	7	200	7	0.5	[illegible]	0	0	3	0	
Annual cement	cubic meters	8914	16241	251	6248	6321	24	3792	0	0	5360	0	47152
Stones per st	cubic meters					16		10	0	0	7	440	
Annual stones	cubic meters					14449		9479	0	0	12508	20251	56687
Gravel per st	cubic meters	35	35	5	35								
Annual gravel	cubic meters	1560	2842	180	1093								5675
Sand per st	cubic meters	120	120	2	120	2					2	0	
Annual Sand	cubic meters	5348	9744	72	3749	1806					3574	0	24293
8" Steel Casing per st	meters	75	75	50	50		20						
Ann.8"Steel Casing	meters	3343	6090	1796	1562		970						13761
8"Steel Screen per st	meters	45	45	30	30								
Ann.Steel Screen	meters	2006	3654	1077	937								7674
Conduct.casing per st	meters	6	6	6	6		6						
Ann.conduct.casing	meters	267	487	215	187		291						1449
Shelter per st	units	1	1	0.2	0.2	0.1					0.5		
Annual Shelter	units	45	81	7	6	90					893		1123
Pipe&Fittings per st	meters	200	200	0	200	0		15			10		
Annual Pipe&Fittings	meters	8914	16241	0	6248	0		14218			17868		63490
Drilling Fluid per st	sacks	24	24	16	16		5						
Annual Drilling Fluid	sacks	1070	1949	575	500		243						4336
Drill Bits per st	units	0.12	0.12	0.08	0.08		0.08						
Annual Drill Bits	units	5.3	9.7	2.9	2.5		3.9						24
Hand Pump per st	units			1		0.2							
Annual Hand Pumps	units			34		181							217
Diesel Pump per st	units	1	1		1			1					
Annual Diesel Pumps	units	45	81		31			948					1105
Rebars & Wood per st	meters	30	30		13						20		
Annual Rebars&Wood	meters	1337	2436		406						35737		39916
Plastic Sheet per st	sq.meters								104	1500			
Annual Plastic sheets	sq.meters								15463	10000			25463

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LABOUR

Skilled:

Supervisory per St.	man-days	10	10	6	6		5						
Annual Supervisory	man-days	446	812	215	187		243						1903
Drilling per St.	man-days	25	20	17	17		14						
Annual Drilling	man-days	1114	1624	611	531		679						4559
Excavation per st.	man-days					6.4			10	10	30	30	
Annual Excav.Wrks	man-days					5780			1487	335	53605	949	62156
Civil Wrks.per st.	man-days	50	36	18	15	5		1.2	0.5	1.5	15	30	
Annual Civil Wrks.	man-days	2229	2923	646	469	4515		1137	74	50	26802	949	39796
Mech.Wrks per st.	man-days	20	12	6	6	0.6		5			3		
Ann.Mechanic Wrks.	man-days	891	974	215	187	542		4739			5360		12911
Carp.Wrks per st.	man-days	5	2	2	2								
Ann.Carpentry Wrks.	man-days	223	162	72	62								520

Unskilled:

Drilling per St.	man-days	300	240	200	200		150						
Annual Drilling	man-days	13371	19489	7183	6248		7276						53567
Excavation per st.	man-days					6.4					3		
Annual Excav.Wrks	man-days					5780					5360		11140
Civil.Wrks per st.	man-days	300	218	36	175	5		2	0.5	1.5	15	90	
Ann.Civil Wrks.	man-days	13371	17540	1293	5467	4515		1896	74	50	26802	2848	73857
Mech.Wrks. per st	man-days	20	12	3.6	8	3.6		12			6		
Ann.Mechanic Wrks.	man-days	891	974	129	250	3251		11375			10721		27592
Other Unskilled per st.	man-days												
Annual Other Unskilled	man-days												0

EQUIPMENT

Drill Rigs per st	Eq-days	30	24	20	18		10						
Annual Drill Rigs Use	Eq-days	1337	1949	718	562		485						5052
Pump Rigs per st	Eq-days	3	3	2	2		1						
Annual Pump Rigs Use	Eq-days	134	244	72	62		49						560
Heavy Vehicles per st	Eq-days	223	168	70	45	10	35	2	10	10	8	30	
Annual Heavy Vehcl Use	Eq-days	9939	13642	2514	1406	9030	1698	1896	1487	375	14295	949	57191
Light Vehicles per st	Eq-days	250	240	120	100	10	40	3	5	12	4	30	
Annual Light Vhcls Use	Eq-days	11143	19489	4310	3124	9030	1940	2844	743	402	7147	949	61122

FUEL CONSUMPTION

Drill Rigs per st	Liters	4500	3600	3000	2700		1200						
Annual Drill Rigs Fuel	Liters	200566	292334	107745			58208						658852
Pump Rigs per st	Liters	336	336	224	224		112						
Annual Pump Rigs Fuel	Liters	14976	27284	8045	6998		5433						62736
Heavy Vehicles per st	Liters	8920	6720	2800	1800	400	1400	80	400	400	320	1200	
Annual Heavy Vhcl Fuel	Liters	397566	545690	100562	56233	361219	67909	75832	59474	13408	571784	37971	2287648
Light Vehicles per st	Liters	6690	5040	2100	1350	300	1050	60	300	300	240	900	
Annual Light Vhcls Fuel	Liters	298174	409267	75421	42175	270914	50932	56874	44605	10056	428838	28478	1715736

The top row of the model for drilling and construction shows the number of new structures which need to be constructed in the year 1990. The left hand column lists the major inputs required for all types of drilling and construction, while the far right hand columns show:

1) the total annual quantities required for each type of input
2) the unit cost for each type of input
3) the total annual cost for each type of input

Detailed presentations of the methodology, the coefficients, and the sources of data are contained in Sections I-8 and I-9.

The forecasting application of WISyMS can be used by private sector entrepreneurs in the water industry to provide the basis for market studies for both Level II and Level III. Although the model can not be expected to provide precise predictions of future activity in the water industry, it can provide useful information on the industry as a whole and its key elements. This is the type of information on which businessmen everywhere must rely for their decision-making.

I-5 SUPPLY SIDE AND CONSTRAINT ANALYSIS

Use of WISyMS for evaluating national objectives for standards of water consumption is another important application of the model, and can provide useful insights into the physical resource and financial implications of official goals, policies, and programs.

I-5.1 Features of Constraint Analysis

Use of the model to evaluate national objectives can be regarded as a special forecasting application focussing on the supply side of the industry, in which the purpose of the forecast is to determine whether the objectives have been set at realistic levels. The objectives are translated into rates of build and/or investment requirements. An assessment of the realism of the objectives can be made by comparing the implied rates of build and/or investment to historical rates of build, funding availability, resource availability, or other measures.

While simple forecasting proceeds in a straight forward manner through the three submodels, the most important aspect of constraint analysis concentrates on Level III. Constraints affecting the water industry can be tangible and physical (e.g., a shortage of well casing) and explicitly analyzed by the submodel, or they can be more general (e.g., difficult licensing procedures), and may affect Level II activity indirectly.

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Constraint analysis thus analyses the implications of constraints located at the industry input level on maximum achievable rates of construction at Level II and therefore on maximum achievable rates of water provision at Level I.

I-5.2 Procedures for Constraint Analysis

Generally, use of the WISyMS for this purpose proceeds as follows:

1. One or more runs of the model are made with standard projections assuming there is no change in policy (as discussed above in Section I-4, Forecasting). The output, in terms of numbers of new structures needed and the associated input requirements provides a basis for comparison with the implications of the new policy.

2. Demographic data, some economic data (e.g., livestock population figures and growth rates), and some technological data (e.g., output per structure, average useful life of structures) are considered as "givens".

3. Explicit policy goals (e.g., specific levels of per capita water consumption) are inserted in place of standard projections or parameters as appropriate.

4. Where goals are announced in conjunction with the adoption of new policies or programs, assumptions associated with the implementation of the new policy are used to adjust certain parameters (e.g., new drilled well water systems installed in rural areas, although intended primarily for human consumption, will also be used by livestock, so that the percentage reliance by livestock on drilled well water supplies would have to be adjusted upward).

5. The model is run using the variables and parameters associated with the proposed policy. The output of this run indicates the total numbers of new structures and associated inputs needed, taking into account policy goals.

6. Output from the "with goals" run of the model is compared with the output from the "without goals" run of the model to indicate the physical requirements, in terms of quantities of new structures and associated inputs, that are solely attributable to the policy being examined.

7. The data provided by steps 5 and 6 can be compared with funding and resource availability to determine first - whether the goals can be considered reasonably attainable, and second - what, if any, efforts can or must be made to alleviate or circumvent particular constraints. Here the model may be particularly useful

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in revealing unsuspected constraints and/or in showing that what was thought to be a constraint is not necessarily so.

I-5.3 Constraint Analysis of Somalia's National Objectives

Somalia's 1990 objectives with regard to water consumption have been outlined in the MMWR's document "Planning for the Drinking Water Supply and Sanitation Decade for Somalia". In brief, these are objectives with regard to the provision of safe, reliable, permanent water supplies for the Somali people. Specifically, they include targets for "water service" for 80% of the urban population and 50 - 60% of the rural population. Of those so served, there are targets for water consumption of 130 liters per capita per day (lcd) for urban dwellers with individual household connections (up to 40% of urban dwellers served by the system), 50 lcd for urban dwellers with access to public stand posts, 30 lcd for rural dwellers served by public watering systems and 20 lcd for all other rural dwellers.

A constraint analysis of these goals was undertaken by incorporating them into the WISyMS framework for evaluation. The model employs a global analysis taking into account the explicit goals plus:

- the water supply needs of populations who can not be served by publicly provided water supply systems before 1990,
- all other types of water supply needs, including livestock, industry and agriculture,
- water supply needs to be met by all types of potentially available water supply systems, both public and private, and
- the need for replacement or rehabilitation of aging water supply structures.

The model further makes the following assumptions:

- That groundwater resource (from both drilled wells and hand-dug wells) are the major source of safe, reliable, and permanent water supplies,
- That water resources provided primarily for human consumption will also be used by industry in urban areas and by livestock in rural areas; and
- That each community will make use of a range of groundwater, surface water and catchment structures, depending on seasonal availability, cost, and convenience.

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Examining the national goals in light of the above considerations and assumptions, data provided by the model indicate a needed rate of construction of drilled wells between 1985 and 1990 that is almost two and a half times the rate achieved during the previous four years. While the average annual rate of drilled well construction was about 101 between 1981 and 1984, realization of national goals would require an average rate of construction of 283 wells between 1985 and 1990. Assuming a construction program for the national goals was begun in 1985, this would start with a rate of 168 in 1985 and rise to 440 for 1990 (see Exhibits I-15 and I-16; detailed data are presented in Annex I-7).

A second run of the model was made on the basis of a more modest set of goals presented in the MMWR's planning document. The second set of goals was more practically oriented, implying less of an attempt to develop groundwater resources and relying relatively more heavily on surface water resources and catchments to serve its target populations. Examining the second set of goals in light of the above outlined considerations and assumptions, data provided by the model indicate a needed rate of drilled well construction for the six years 1985 through 1990 which would be more than double the rate actually achieved during the previous four years. The needed construction program would require an average of 224 wells per year, starting with 149 in 1985 and rising to 319 in 1990 (see Exhibits I-17 and I-18; detailed data are presented in Annex I-8).

In either case, a greatly expanded rate of well drilling is implied, and in all likelihood, a rate of well drilling that can not be achieved given existing resource and institutional limitations.

Interestingly, an examination of the resource requirements associated with implied drilling programs reveals that the traditional approach of foreign assistance in this industry does not necessarily address the most severe constraints. Many of the foreign aid projects in the drilling industry have involved the mobilization of a large ex-patriot drilling firm, complete with new drilling equipment. However, there are now 35 drilling rigs in Somalia judged by the Consultants to be in operation or capable of operation. Assuming each rig could drill eight production wells per year (and four non-production wells), Somalia could theoretically sustain a production rate of 280 wells per year.

A more cost-effective approach for foreign assistance would be to target:

- the more immediate physical resource constraints, such as well drilling materials, consumables, and spares; and
- the institutional constraints such as administrative capabilities and market restrictions on private sector participation.

EXHIBIT I-15

* * * * * * Total Consumption of Water by Types of Consumption and by Types of Structure * * * * * *

CONSUMPTION UNITS	(000s)	MEASURE	PER UNIT CONS'N DAILY USE FACTOR	MEASURE	TOTAL DISTRIBUTION OF WATER BY STRUCTURE * * TOTAL DISTRIBUTION OF WATER BY STRUCTURE: STRUCT'L CONTROL VOLUME M^3*K/YR	DRILLED WELLS URBAN/ IND/GOVT M^3*K/YR	DRILLED WELLS DP RURAL BOREWELL M^3*K/YR	DRILLED WELLS HP RURAL BOREWELL M^3*K/YR	DRILLED WELLS IRRIG'N WELLS M^3*K/YR	HAND DUG WELLS M^3*K/YR	INTAKES FOR RIV/ STREAMS M^3*K/YR	UARS/ RESER-VOIRS M^3*K/YR	BALLEHS/ PONDS M^3*K/YR	BURKEDS/ CISTERNS M^3*K/YR	EARTH DAMS/DIV M^3*K/YR
HUMAN															
Urban HC	696	persons	130	liters	32695	26156	0	0	0	2616	2943	327	0	654	0
Urban SP	1045	persons	41	liters	15326	12261	0	0	0	1226	1379	153	0	307	0
Rural Set	1853	persons	26	liters	16706	501	4444	67	0	6682	2506	501	334	1671	0
Nomadic	2757	persons	26	liters	23548	353	3673	94	0	8242	4710	2002	2119	2355	0
SUBTOTAL 1	6351	persons			88274	39271	8117	161	0	18766	11537	2983	2453	4986	0
ANIMAL															
Camels	5308	head	25	liters	31483	315	5856	126	0	4722	4722	6297	7871	1574	0
Cattle	4246	head	25	liters	30996	1550	6075	124	0	9299	3100	6199	3100	1550	0
SheepGoats	28661	head	3	liters	23538	706	3907	94	0	7767	2825	3531	3060	1648	0
OtherAn	10615	head	3	liters	581	12	73	2	0	163	87	116	99	29	0
SUBTOTAL 2	13190	LSU			86598	2582	15912	346	0	21951	10734	16143	14129	4801	0
AGRICULTURE															
Irrigfarm	64	hectares	68	cu.meters	135020B	0	0	0	40506	13502	1215187	13502	13502	0	54008
Rainfarm	804	hectares	35	cu.meters	67536	0	0	0	0	0	0	0	0	0	67536
Floodfarm	161	hectares	25	cu.meters	7245	0	0	0	0	0	0	0	0	0	7245
SUBTOTAL 3	1029	hectares			1424989	0	0	0	40506	13502	1215187	13502	13502	0	128789
GOVT/INDUS															
Govt	2	estabs	13	cu.meters	7800	7176	156	0	0	312	156	0	0	0	0
Industry	0.73	estabs	8	cu.meters	1752	1524	53	0	0	123	53	0	0	0	0
SUBTOTAL 4	2.73	estabs	9552		9552	8700	209	0	0	435	209	0	0	0	0
STRUCT'L SUPPLY VOLUMES (M^3*K/YR)					1609413	50553	24237	507	40506	54654	1237667	32628	30085	9786	128789
COMMERCIAL SCALE STRUCTURES						457	863	184	230	5151	6189	989	234	18318	156

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EXHIBIT I-16

* * * Projections of Requirements for New Water Supply Structures for Somalia 1985 - 1990, at Prevailing Useful Life

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
URBAN WELLS											
Needed Total	56	74	107	123	124	154	191	238	296	367	457
Old	51	51	68	99	112	111	140	174	217	270	336
Needed New or Rehab	5	23	39	24	12	43	51	64	79	98	121
DP RURAL BOREHOLES											
Needed Total	120	142	159	177	199	254	324	414	529	676	863
Old	107	110	130	144	159	179	231	295	377	483	618
Needed New or Rehab	13	32	29	34	40	75	94	119	152	193	245
HP RURAL BOREHOLES											
Needed Total	99	105	110	115	122	130	140	150	160	172	184
Old	92	89	95	98	102	108	115	123	131	140	150
Needed New or Rehab	7	16	14	17	19	23	25	27	29	32	35
IRRIGATION WELLS											
Needed Total	91	102	123	141	155	166	177	189	202	215	230
Old	75	84	92	113	127	139	148	158	168	179	191
Needed New or Rehab	16	18	31	28	28	26	29	31	34	36	39
HAND DUG WELLS											
Needed Total					2500	2820	3181	3589	4048	4567	5151
Old					2250	2275	2570	2879	3233	3635	4091
Needed New					250	545	611	709	815	932	1061
INTAKES											
Needed Total					5000	5181	5369	5563	5764	5973	6189
Old					4500	4550	4681	4811	4947	5090	5239
Needed New					500	631	688	752	817	883	950
DARS/RESERVOIRS											
Needed Total					750	785	822	861	902	944	989
Old					675	683	710	738	767	798	831
Needed New					75	103	112	123	135	146	158
BALLEHS/PONDS											
Needed Total					200	205	211	217	222	228	234
Old					180	182	185	189	192	196	200
Needed New					20	23	26	28	30	32	35
BURKEDS/CISTERNS											
Needed Total					10000	11061	12236	13534	14971	16560	18318
Old					9333	9378	10395	11460	12646	13962	15422
Needed New					667	1684	1841	2075	2325	2598	2896
DAMS											
Needed Total					100	108	116	125	135	145	156
Old					80	84	88	92	97	102	124
Needed New					20	24	28	33	38	43	32

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EXHIBIT I-17

* * * * * * Total Consumption of Water by Types of Consumption and by Types of Structure * * * * * *

CONSUMPTION UNITS	(000s)	MEASURE	PER UNIT CONS'N DAILY USE FACTOR	MEASURE	TOTAL DISTRIBUTION OF WATER .... STRUCT'L CONTROL VOLUME M^3*K/YR	DRILLED WELLS URBAN/ IND/GOVT M^3*K/YR	DRILLED WELLS DP RURAL BOREWELL M^3*K/YR	DRILLED WELLS HP RURAL BOREWELL M^3*K/YR	DRILLED WELLS IRRIG'N WELLS M^3*K/YR	HAND DUG WELLS M^3*K/YR	INTAKES FOR RIV/ STREAMS M^3*K/YR	UARS/ RESER- VOIRS M^3*K/YR	BALLEHS/ PONDS M^3*K/YR	BURKEDS/ CISTERNS M^3*K/YR	EARTH DAMS/DIV M^3*K/YR
HUMAN															
Urban HC	696	persons	130	liters	32695	26156	0	0	0	2616	2943	327	0	654	0
Urban SP	1045	persons	41	liters	15326	12261	0	0	0	1226	1379	153	0	307	0
Rural Set	1853	persons	26	liters	16706	334	2088	84	0	5012	3341	1671	2506	1671	0
Nomadic	2757	persons	26	liters	23548	471	2943	118	0	7064	4710	2355	3532	2355	0
SUBTOTAL 1	6351	persons			88274	39222	5032	201	0	15918	12373	4506	6038	4986	0
ANIMAL															
Camels	5308	head	25	liters	31483	315	3337	126	0	6297	4732	7241	7871	1574	0
Cattle	4246	head	25	liters	30996	775	3719	155	0	9299	3100	7749	4649	1550	0
SheepGoats	28661	head	3	liters	23538	471	2260	94	0	7061	2825	5884	3295	1648	0
OtherAn	10615	head	3	liters	581	12	56	2	0	116	87	139	139	29	0
SUBTOTAL 2	13190	LSU			86598	1572	9372	377	0	22773	10734	21014	15955	4801	0
AGRICULTURE															
Irrigfarm	64	hectares	68	cu.meters	1350208	0	0	0	40506	13502	1215187	13502	13502	0	54008
Rainfarm	804	hectares	35	cu.meters	67536	0	0	0	0	0	0	0	0	0	67536
Floodfarm	161	hectares	25	cu.meters	7245	0	0	0	0	0	0	0	0	0	7245
SUBTOTAL 3	1029	hectares			1424989	0	0	0	40506	13502	1215187	13502	13502	0	128789
GOVT/INDUS															
Govt	2	estabs	13	cu.meters	7800	7254	156	0	0	234	156	0	0	0	0
Industry	0.73	estabs	8	cu.meters	1752	1524	53	0	0	123	53	0	0	0	0
SUBTOTAL 4	2.73	estabs			9552	8778	209	0	0	357	209	0	0	0	0
STRUCT'L SUPPLY VOLUMES					1609413	49572	14612	579	40506	52549	1238502	39022	35495	9786	128789
COMMERCIAL SCALE STRUCTURES						448	520	210	230	4953	6194	1182	277	18318	156

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EXHIBIT I-18

* * * Projections of Requirements for New Water Supply Structures for Somalia 1985 - 1990, at Prevailing Useful Life

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
URBAN WELLS											
Needed Total	56	74	107	123	124	154	190	236	292	361	448
Old	51	51	68	99	112	111	140	173	215	266	330
Needed New or Rehab	5	23	39	24	12	43	50	62	77	95	117
DP RURAL BOREHOLES											
Needed Total	120	142	159	177	199	234	274	322	378	443	520
Old	107	110	130	144	159	179	210	247	290	340	400
Needed New or Rehab	13	32	29	34	40	55	64	75	88	103	121
HP RURAL BOREHOLES											
Needed Total	99	105	110	115	122	133	146	160	175	192	210
Old	92	89	95	98	102	108	118	129	141	154	168
Needed New or Rehab	7	16	14	17	19	26	28	31	35	38	42
IRRIGATION WELLS											
Needed Total	91	102	123	141	155	166	177	189	202	215	230
Old	75	84	92	113	127	139	148	158	168	179	191
Needed New or Rehab	16	18	31	28	28	26	29	31	34	36	39
HAND DUG WELLS											
Needed Total					2500	2802	3140	3519	3944	4420	4953
Old					2250	2275	2552	2840	3167	3537	3953
Needed New					250	527	588	679	776	883	1000
INTAKES											
Needed Total					5000	5182	5370	5565	5767	5977	6194
Old					4500	4550	4682	4812	4949	5092	5242
Needed New					500	632	688	753	818	884	951
UARS/RESERVOIRS											
Needed Total					750	809	873	942	1016	1096	1182
Old					675	683	734	786	843	905	972
Needed New					75	127	139	156	173	191	211
BALLEHS/PONDS											
Needed Total					200	211	223	235	248	262	277
Old					180	182	191	200	210	220	231
Needed New					20	29	32	35	38	42	46
BURKEDS/CISTERNS											
Needed Total					10000	11061	12236	13534	14971	16560	18318
Old					9333	9378	10395	11460	12646	13962	15422
Needed New					667	1684	1841	2075	2325	2598	2896
DAMS											
Needed Total					100	108	116	125	135	145	156
Old					80	84	88	92	97	102	124
Needed New					20	24	28	33	38	43	32

The Consultants' forecast of reasonably attainable water consumption standards and associated drilling and construction activity would include a rate of drilled well construction for 1985 - 1990 which would be about 50% higher than that achieved over the previous four years. (See Section I-4, above). This middle-level program could be comfortably achieved with the existing stock of drilling rigs; the constraints mentioned above could be addressed by the Consultants' Recommended Phase One and Phase Two programs in order for the targets to be achieved.

The full goals contained in the MMWR's Plan for the Drinking Water Supply and Sanitation Decade could, however, reasonably be achieved by 1995, with the implementation of the Consultant's Recommended Program (Phases One through Three) as outlined in Section Two of the main body of the final report. This is discussed in greater detail in Section I-5.5, below.

I-5.4 WISyMS Supply Side Analysis

WISyMS has also been used for a straightforward supply side analysis of the water industry based on projections of Level II well drilling activities. This type of analysis begins directly with data, estimates, or projections of Level II drilling and construction activities, based on historical performance and/or known future plans. The impact of this activity on Level III (inputs to the industry) is analyzed in a straighford manner, as discussed above. However, the impact of Level II activity on Level I variables, such as stocks of wells, volumes of water output, and per-capita water consumption, are of greater interest, and the analysis is a bit more involved.

For example, we obtained data on well drilling over a period of time, and used that to make projections into the future. We then translated the drilling projections (Level II data) into projections of stocks of wells (Level I data) by utilizing the estimated rate of old well deterioration. The stocks of wells are in turn translated into volumes of water by utilizing the estimated average output per well. Finally, total annual volumes of water are translated into average per-capita water consumption volumes by assuming that a certain proportion of water production will be consumed by humans (and/or livestock, agriculture, etc.) and dividing the resulting figure by the relevent population.

Exhibit I-19 illustrates how the analysis proceeds:

First, as with the standard Level II (drilling and construction) submodel described in previous sections, we assume a certain number of "old" structures as a given point in time, which will deteriorate at a fixed rate, and be added to by each previous year's drilling. This data is contained in the first row of the table.

EXHIBIT I-19

LEVEL II SUPPLY SIDE ANALYSIS: ALL NON-IRRIGATION DRILLED WELLS

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total old + prev.	250	250	294	341	374	397	443	495	606	705	810	951	1106	1266	1428	1596
New Drilling	25	71	82	74	71	98	89	92	100	106	117	131	136	138	144	149
Total Stock	275	321	376	415	445	495	554	631	730	835	951	1106	1266	1428	1596	1769
Ave. Volume/Well	36	39	44	44	44	44	45	45	45	45	46	47	48	49	49	50
Volume of Water (M^3*k/yr)	9843	12471	16594	18914	19635	22005	24765	28357	32988	37932	43419	51783	60570	69587	78981	88665
Human cons (M^3*K/yr)					6574	7854	9446	11544	14333	17589	21485	26885	32983	39732	47273	55617
Proportion for human consumption:					33%	36%	38%	41%	43%	46%	49%	52%	54%	57%	60%	63%
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354
Ave. Human cons (M^3/capita/yr)					1.23	1.43	1.67	1.98	2.39	2.85	3.38	4.11	4.90	5.73	6.62	7.56

The second row contains the data and projections on annual drilling or construction activity. Adding the number of new structures to the number of old structures available in a given year gives us the number of total stock of structures available for use, as shown in row three.

The fourth row shows the average volume of output per structure per year, which is used to calculate the total volume of water available from the total stock of structures available in a given year; this is shown in row five.

We proceeded another step by making an assumption about the proportion of the total water available which would be consumed by humans. This is shown in row six. We present the total human population for each year in row seven, then calculate the average annual human consumption in cubic meters per capita per year in row eight.

I-5.5 Supply Side Analysis of Consultants' Recommended Program

The Consultants' supply side analysis for well drilling in Somalia began with a survey and inventory of all known well drilling activity in the country between 1980 and 1984, and planned drilling activity through 1987. Exhibit I-20 contains a comprehensive list of wells drilled by project (or type of client) and by year. The wells are categorized in two ways:

1. The drilling agencies are categorized as "Government" (Somali), "Foreign" and "Private" (Somali); and

2. The wells for each project are subdivided by type of well (urban, rural, and irrigation).

Any combination of the two categories and six classifications of characteristics could be analyzed. Exhibit I-21 contains a large selection of such combinations.

For the purposes of this study, we were particularly interested in the numbers of non-irrigation wells (i.e., rural and urban wells) drilled in Somalia, the market shares attained by each of the three types of drilling agencies, and the trends in non-irrigation drilling by each type of drilling agency.

The average number of non-irrigation wells drilled each year between 1981 and 1984 was about 75; of which an average of 20 (or 27%) were drilled by government agencies, 41 (or 55%) were drilled by foreign firms, and 14 (or 19%) were drilled by local private firms.

Of more importance than the averages, however, have been the trends in drilling activity. The number of wells drilled each year in Somalia has exhibited high variability, although the

EXHIBIT I-20

AMOUNT OF DRILLING BY PROJECT IN SOMALIA 1980 - 1987

PROJECT TITLE OR CLIENT	DRILLING AGENCY	TYPE OF WELL	Combo	NW80	NW81	NW82	NW83	NW84	NW85*	NW86**	NW87**	TOTAL WELLS
Rural Water Supply (WDA)	G-WDA	Rural	GR	12	12	7	14	10	12			67
Other Drilling (WDA)	G-WDA	U-Other	GU	3	3	1	3	2	3			15
Irrigation (Min. Defence)	G-MinDef	Irrig	GI	8	10	10	8	8				44
Other (Min. Defence)	G-MinDef	R-Other	GR	5	7	7	6	6				31
Urban Water Supply (GKW)	F-GKW	Urban	FU	0	4	5	5	0				14
Urban Water Supply (WILD)	F-WILD	Urban	FU	0	5	5	0	0				10
Mogadishu Water Supply (MOWLEN)	F-MOWLEN	Urban	FU	0	4	4	0	0				8
Mogadishu Water Supply (KAMPIHL)	F-KAMPIHL	Urban	FU	0	3	8	8	5				24
CGDP (LBII/RMC)	F-ROSC MOS	Rural	FR	0	0	9	10	17	20			56
Hargeisa Water Supply (CHINA)	F-CHINESEf	Urban	FU	0	0	6	0	0	2	4		12
N.E. Water Supply (CHINA)	F-Chinese	Rural	FR	0	0	0	0	6	7	6		19
N. Water Exploration (CHINA)	F-Chinese	Rural	FR	0	0	4	11	0				15
Refugee Water Supply (UNICEF)	F-UNICEF	Rural	FR	0	24	14	0	0				38
N.W. Water Supply (UNICEF)	F-Unicef	Rural	FR	0	0	0	0	0	5			5
Rural Water Supply (WILD)	F-WILD	Rural	FR	0	0	0	0	1	20	18		39
Banana Irr. (SOMALFRUIT)	P-Somalfru	Irrig	PI	7	6	15	12	10	20			70
Grapefruit Irr. (MUURI)	P-MUURI	Irrig	PI	0	0	4	5	0				9
Mogadishu Water Supply (JAPAN)	F-Japanese	Urban	FU	0	0	0	0	0	4	10	15	29
Government (HORN OF AFRICA)	P-HOA	U-govt	PU	0	0	8	6	0				14
Other, (HORN OF AFRICA)	P-HOA	R-Other	PR	0	3	0	0	2	2			7
Foreign Financed (MUURI)	P-Muuri	R-Other	PR	0	0	1	2	5				8
Government, (MUURI)	P-Muuri	U-govt	PU	1	2	0	1	2				6
Other, (MUURI)	P-Muuri	R-Other	PR	1	1	0	2	3				7
Mine Well (KAMPIHL)	F-KAMPIHL	R-indus	FR	0	0	0	0	5	1			6
Berbera, (SOMALI DRILLING)	P-Som Dril	Urban	PU	0	0	0	0	2				2
Private, (SOMALI DRILLING)	P-Som Dril	R-Other	PR	0	0	0	3	1	4			8
Government, (NAT'L DRILLING)	P-Nat'l Dr	U-Govt	PU	1	2	2	1	1				7
Other, (NAT'L DRILLING)	P-Nat'l Dr	R-Other	PR	2	1	1	2	3				9
Private Irr. (SOMALI-GERMAN)	P-SOM DRIL	Irrig	PI	0	0	0	0	6	1			7
Aid Irrig. (PESINA-JUBA)	P-Pes-Juba	Irrig	PI	1	2	2	3	4	4			16
TOTAL				41	89	113	102	99	105	38	15	602

* Estimate
** Planned

G - Government
F - Foreign
P - Private

U - Urban
R - Rural
I - Irrigation

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EXHIBIT I-21

CATEGORIES OF WELL DRILLING 1980 - 1985

YEAR			1980	1981	1982	1983	1984	1985	AVERAGE '81-'84	PERCENT '81-'84
TOTAL WELLS DRILLED			41	89	113	102	99	105	101	100%
DRILLING AGENCY	TYPE OF WELL									
Government	any	G*	28	32	25	31	26	15	29	28%
Government	rural	GR	17	19	14	20	16	12	17	17%
Government	urban	GU	3	3	1	3	2	3	2	2%
Government	irrig.	GI	8	10	10	8	8	0	9	9%
Government	non-irrig.	G*-GI	20	22	15	23	18	15	20	19%
Foreign agencies	any	F*	0	40	55	34	34	59	41	40%
Foreign agencies	rural	FR	0	24	27	21	29	53	25	25%
Foreign agencies	urban	FU	0	16	28	13	5	6	16	15%
Foreign agencies	irrig.	FI	0	0	0	0	0	0	0	0%
Foreign agencies	non-irrig.	F*-FI	0	40	55	34	34	59	41	40%
Private (local)	any	P*	13	17	33	37	39	31	32	31%
Private (local)	rural	PR	3	5	2	9	14	6	8	7%
Private (local)	urban	PU	2	4	10	8	5	0	7	7%
Private (local)	irrig.	PI	8	8	21	20	20	25	17	17%
Private (local)	non-irrig.	P*-PI	5	9	12	17	19	6	14	14%
any	rural	?R	20	48	43	50	59	71	50	50%
any	urban	?U	5	23	39	24	12	9	25	24%
any	irrig.	?I	16	18	31	28	28	25	26	26%
any	non-irrig.	?* - ?I	25	71	82	74	71	80	75	74%

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overall trend has been positive. Simple linear correlation estimates were made on the number of wells drilled, by agency, over a five year period. These data, for all non-irrigation wells, are contained in Exhibit I-22.

For non-irrigation wells drilled by Somali government agencies, the overall trend has been slightly (and insignificantly) negative, with a variability of plus or minus 3 or 4 in any given year For non-irrigation wells drilled by Foreign firms, the overall trend has been to expand production by about 2 wells per year, but this has been highly erratic: the variability has been plus or minus about 13 wells in any given year. For non-irrigation wells drilled by local private firms, the overall trend has been to expand production by between three and four wells each year, and the variability has been low: not even one full unit above or below the trend line.

These trends have been projected forward, on the assumption that past conditions affecting the market continue into the future. These projections are shown in Exhibit I-23. Actual numbers of wells drilled, by agency and by year through 1984, are presented, along with projected numbers of wells to be drilled through 1990, on the basis of past established time trends. Along with the trend-line numbers, an illustration of the likely variability is presented for projections of non-irrigation wells.

Exhibit I-24 through I-26 present the same data in graphic form: for each category of drilling agency, the exhibits show the number of non-irrigation wells actually drilled through 1984 (or, in the case of foreign wells, 1985) and the trend line projected to 1990. The likely variability about the trend line is presented also, for illustrative purposes.

The assumptions on which these trend projections are based, however, are subject to change. Government drilling achievements are largely dependent on the overall budgets (and particularly foreign exchange budgets) authorized by the Ministries of Finance and Planning. Foreign drilling is similarly dependent on the foreign aid budgets of a few foreign donors, and by the foreign aid policies of those donors. Local private drilling activity is driven mainly by market forces (however severely constrained), on both the demand side (for drilled wells), and on the supply side (particularly concerning availability of finance and of foreign exchange with which to purchase imported materials, equipment, and spare parts).

In addition, overall drilling activity is dependent on hydrogeological conditions and past drilling activity in areas of likely demand for drilling: too many wells tapping a single, limited aquifer can cause the water table to fall, making required well depths progressively deeper and more expensive. Drilling supply is also limited by the country's existing stock (and quality) of drilling equipment, and by the number and expertise of its drillers.

EXHIBIT I-22

TREND LINE EQUATIONS FOR WELL DRILLING BY AGENCY

Government Drilled Non-Irrigation Wells

$Wt = 20.2 - 0.3\ (T) \pm 3.6651$ $(S^2 = 13.4333)$

Foreign Drilled Non-Irrigation Wells

$Wt = 41 + 1.7\ (T) \pm 13.3204$ $(S^2 = 177.4333)$

Privatly Drilled Non-Irrigation Wells

$Wt = 5.2 + 3.6\ (T) \pm 0.7303$ $(S^2 = 0.5333)$

Where:

Wt = Wells drilled in year "t"

T = Year T (1...n)

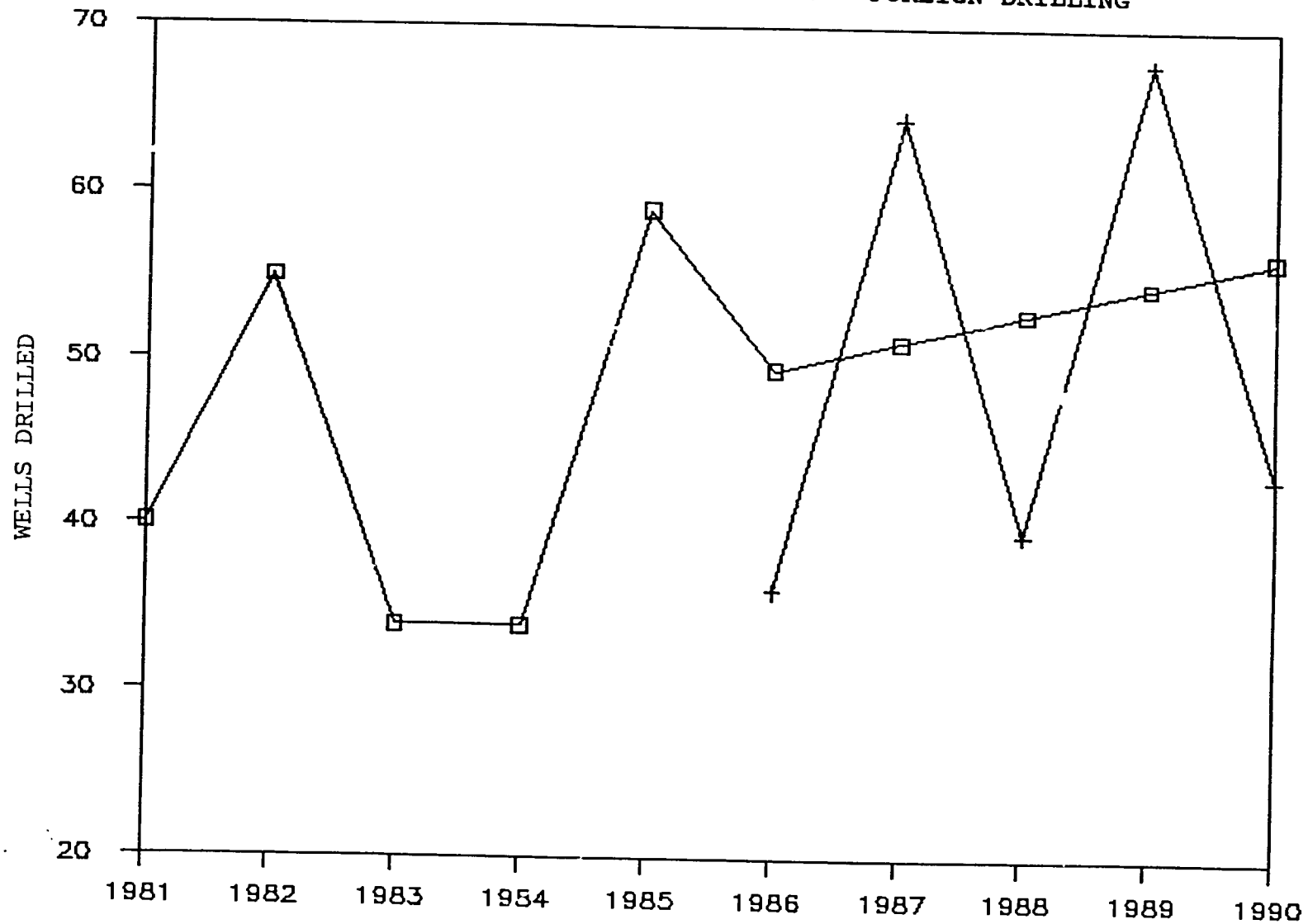
EXHIBIT I-23

WELL DRILLING SERVICES SUPPLY: 1980 - 1984 ACTUAL, 1985 - 1990 PROJECTIONS BASED ON PAST WORK

YEAR/CATEGORY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Government Drilling	28	32	25	31	26	27	26	26	25	25	24
Foreign Drilling		40	55	34	34	59	50	51	53	55	56
Private Drilling	13	17	33	37	39	49	57	64	71	78	85
Total Drilling	41	89	113	102	99	135	133	141	149	158	166
Government non-irrigation	20	22	15	23	18	19	18	18	18	18	17
Government variability							15	22	14	21	14
Foreign non-irrigation		40	55	34	34	59	50	51	53	55	56
Foreign variability							36	65	40	68	43
Private non-irrigation	5	9	12	17	19	23	27	30	34	38	41
Private variability							26	31	33	38	40
Total non-irrigation	25	71	82	74	71	101	95	100	105	110	115
Total (variable model)							77	117	87	127	97

EXHIBIT I-24

TRENDS AND VARIABILITY IN DRILLING - FOREIGN DRILLING

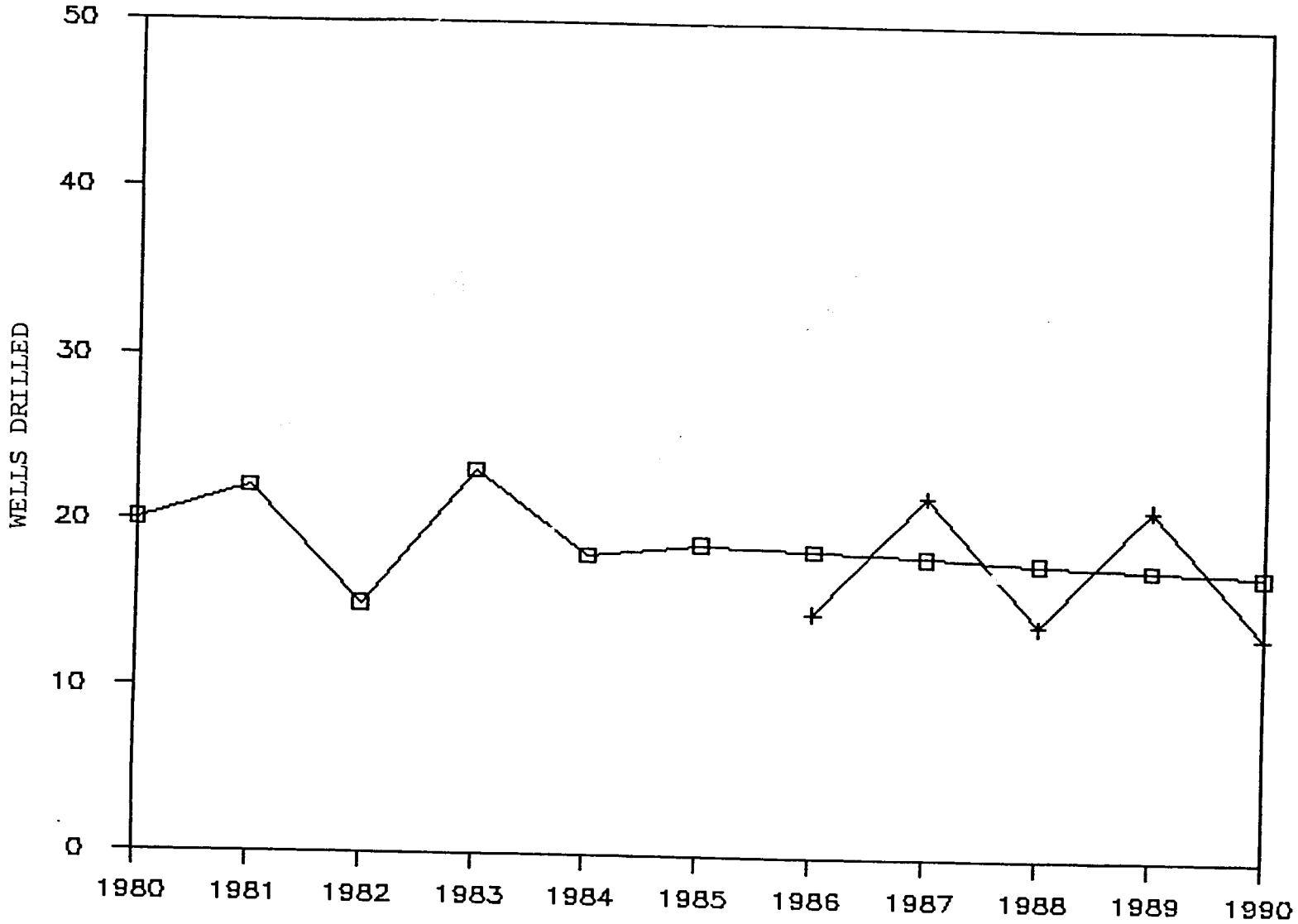


□ Foreign
1981-1985 Actual/Planned
1986-1990 Trend Line

+ Foreign
Variability
About Trend Line

EXHIBIT I-25

TRENDS AND VARIABILITY IN DRILLING - GOVERNMENT DRILLING

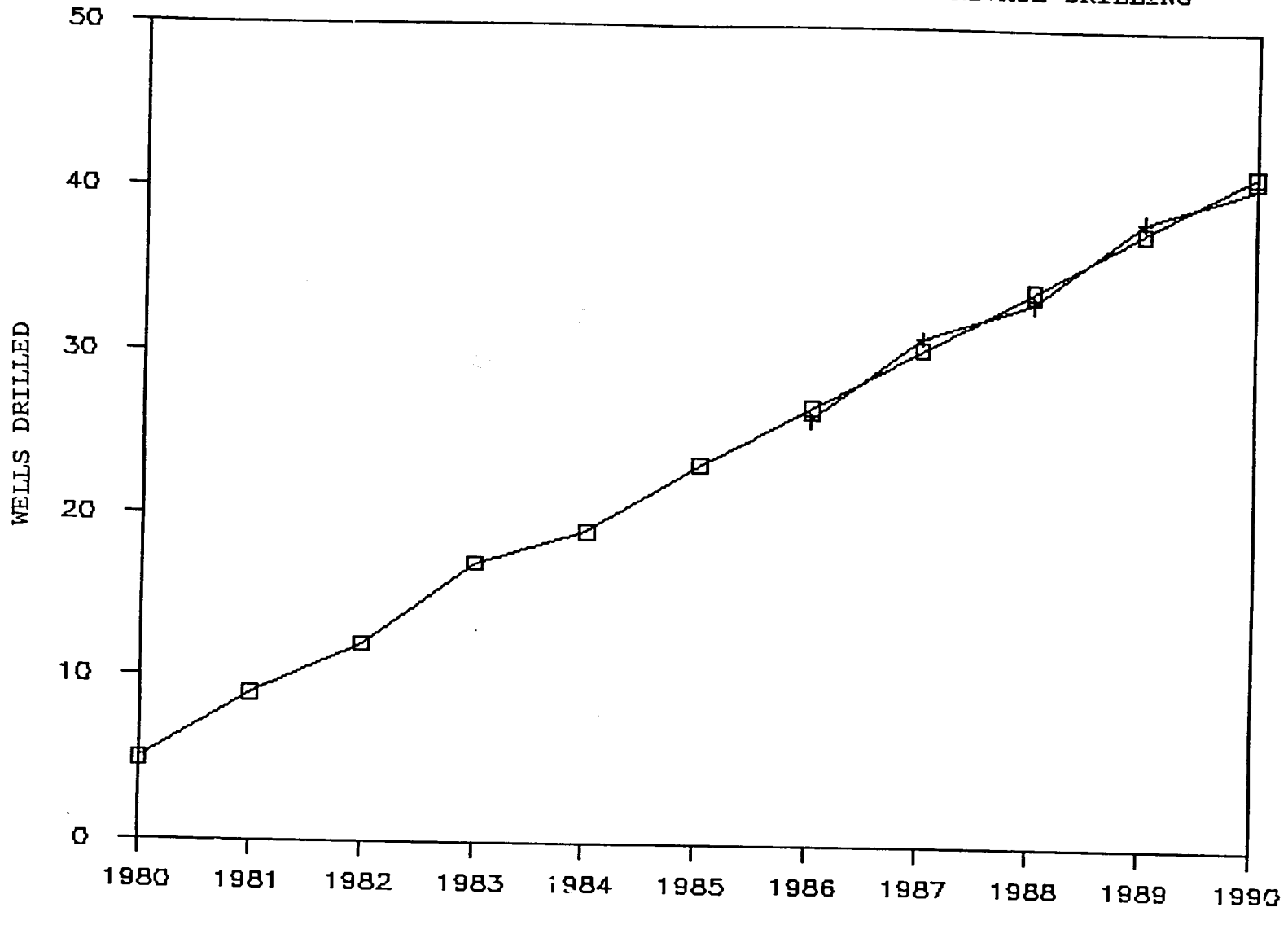


□ Government
1980-1985 Actual
1985-1990 Trend Line

+ Government
Variability
About Trend Line

EXHIBIT I-26

TRENDS AND VARIABILITY IN DRILLING - LOCAL PRIVATE DRILLING



□ Private
1980-1984 Actual
1985-1990 Trend Line

+ Private
Variability
About Trend Line

Drilling demand may depend, among other things, on the average effective volume of output per well (e.g., the more water one can get from each well, the fewer wells are needed, given a certain overall level of demand for water).

Thus drilling activity in the future could be substantially different from (either higher or lower than) the trends projected and discussed above.

The supply side and demand side of well drilling are most appropriately compared using the WISyMS Level I and Level II submodels, highlighting in particular the volumes of water, averages of per-capita water consumption, and average volumes of output per well. On the demand side, as discussed in section I-4, above, WISyMS works with categories of wells broken down into urban, rural diesel pump, rural hand pump, and irrigation wells. These differ, in particular, by the volume of output of each type of well. However, the numbers of wells and volumes of water needed can each be summed to determine the total volumes of non-irrigation water needed and the total stock of non-irrigation wells needed in a given year. On the supply side, the principal analytical divisions used are those between the categories of drilling agencies (government, foreign, and local private).

I-5.5.1 The Consultants' 1995 Supply Side Projections (Without Program)

Exhibit I-27 compares demand side and supply side projections of drilling in Somalia. The demand side projections of the needed volumes of water and stock of wells each year through 1995 were made on the assumption that the national goals for water supply (as described in the MMWR's Plan for the Drinking Water Supply and Sanitation Decade) should be met by 1995. The full WISyMS data for these projections are contained in Annex I-9. The supply side projections are explained below.

In projecting local government drilling, we assumed it would follow its projected trend through 1995.

Local private drilling, we assumed, would follow its projected trend through 1990, and then flatten out, reaching a combination of market, equipment, and hydrogeological limits: The private drilling market has been largely confined to areas in or near urban centers, relatively simple geological formations, and relatively shallow wells. Unless market circumstances change, they may face growth limitations within five years.

Foreign drilling, according to current donor plans, may easily decrease to about 50% of the average levels achieved over the past five years by 1990, and sink to 30% or less by 1995. (See Section Three of the main body of the Final Report).

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EXHIBIT I-27

WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA: LEVEL II SUBMODEL

Demand Side Projections for Requirements for new/rehabilitated wells; Supply Side Projections Assuming No Program

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Growth Rate P.A. '84-'90	Growth Rate P.A. '90-'95
TOTAL NON-IRRIGATION...																		
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Volume of Water (M^3*K/yr)	9843	12471	16616	18907	19656	21879	24255	27111	30182	33601	37409	44816	53709	64384	77203	92597	11.32%	19.87%
Human consumption (M^3*K/yr)					6581	7819	9290	11037	13113	15580	18511	23268	29247	36762	46209	58083	18.81%	25.70%
Ave. Ann. Human cons. (M^3/cap/yr)					1.23	1.42	1.64	1.89	2.19	2.52	2.91	3.56	4.34	5.30	6.47	7.90	15.46%	22.06%
Stock of Wells	275	321	376	415	445	492	545	603	668	739	819	957	1122	1321	1560	1847	10.70%	17.66%
Needed Rehabilitation	0	25	28	34	42	47	52	59	66	74	82	66	75	88	103	122		
Needed Drill//Rehabilitation	25	71	82	75	71	94	105	117	131	145	162	204	241	287	342	409		

WELL DRILLING SERVICES SUPPLY: 1980 - 1984 ACTUAL, 1985 - 1990 PROJECTIONS BASED ON PAST WORK, CURRENT PLANS AND MARKET CONDITIONS

YEAR/CATEGORY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
GOVERNMENT NON-IRRIGATION DRILLING																
Consultants' projection w/o program	20	22	15	23	18	19	18	18	18	18	17	17	17	16	16	16
FOREIGN NON-IRRIGATION DRILLING																
Consultants projection w/o program	0	40	55	34	34	56	40	35	30	25	20	19	18	17	16	15
PRIVATE NON-IRRIGATION DRILLING																
Consultants' projection w/o program	5	9	12	17	19	23	27	30	34	38	41	41	41	41	41	41
TOTAL NON-IRRIGATION DRILLING																
Consultants' projection w/o program	25	71	82	74	71	98	85	84	82	80	78	77	76	74	73	72

CONSULTANTS' SUPPLY SIDE PROJECTIONS, WITHOUT PROGRAM

ALL NON-IRRIGATION WELLS

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Growth Rate P.A. '84-'90	Growth Rate P.A. '90-'95
Old	250	225	200	175	150	125	100	75	50	25	0	0	0	0	0	0		
(Previous)		25	94	166	224	272	343	394	438	476	508	536	559	579	595	609		
Total old + previous	250	250	294	341	374	397	443	469	488	501	508	536	559	579	595	609		
Need Rehabilitation	0	25	28	34	42	47	52	59	64	69	73	51	54	56	58	60		
Rehabilitated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
New Drilling	25	71	82	74	71	98	85	84	82	80	78	77	76	74	73	72		
Total Stock	275	321	376	415	445	495	528	552	570	581	587	613	635	653	668	681	4.74%	3.01%
Volume of Water (M^3*k/yr)	9843	12471	16594	18914	19635	22005	23611	24835	25759	26407	26804	27994	28999	29838	30528	31084	5.32%	3.01%
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Human consumption (M^3*K/yr)					6574	7864	9006	10111	11192	12245	13263	13852	14350	14765	15106	15381	12.41%	3.01%
Ave. Ann. Human cons. (M^3/cap/yr)					1.23	1.43	1.59	1.73	1.87	1.98	2.09	2.12	2.13	2.13	2.12	2.09	9.24%	0.03%

Following the normal WISyMS analysis in the opposite direction, we have summed all projected drilling activity, used this to calculate an estimated stock of wells for a given year (taking into account deterioration of old stock). We assumed that the proportions of types of wells projected to be drilled on the supply side are roughly the same as the proportion of wells projected as needed on the demand side, and that the volumes of output of each type of well will remain constant over time. From the above calculations and assumptions, we estimated a total volume of water output based on the supply side drilling projections.

Taking the analysis one step further, we used the same population projections used in the WISyMS demand side analysis to estimate average annual per capita water consumption based on the supply side projections.

The estimates contained in Exhibit I-27 are presented graphically below. Exhibit I-28 contains a bar chart of past actual and projected well drilling by source through 1995. Although this is expeced to exhibit a downward trend from 1985, under the assumptions outlined above, it would not decline below the levels achieved during the early 1980s.

Translating the annual drilling activity into annual stocks of wells and thence into overall volumes of water indicates that the projected supply of water will grow at a very slow rate, and fall far short of the national goals. (See Exhibit I-29).

Assuming that the proportion of water production going for human consumption remains constant, Exhibit I-30 shows per capita water consumption increasing slightly, and then falling off again, as the declining levels of drilling activity fail to keep pace with the need to increase the stock of wells for a growing population (and to replace failing structures in the absence of adequate well maintenance and rehabilitation programs). Human per capita water consumption could be maintained, of course, at the cost of decreasing water availability for livestock, government, industry, or other consumption needs.

I-5.5.2 Water Industry Downside Risk

The supply side projections described in the foregoing sections do not take into account certain downside risks. The following downside risks have been identified:

- Government drilling programs may face more severe budget cuts in the future than they have been subject to in the past, leading to a slightly steeper decline in well drilling activity.

- Foreign aid drilling may, under current donor plans, drop off to 38 wells in 1986, and 15 in 1987. This may signal the beginning of a serious dropoff in foreign aid

EXHIBIT I-28

PROJECTIONS OF DRILLING SUPPLY - WELLS BY SOURCE, NO PROGRAM

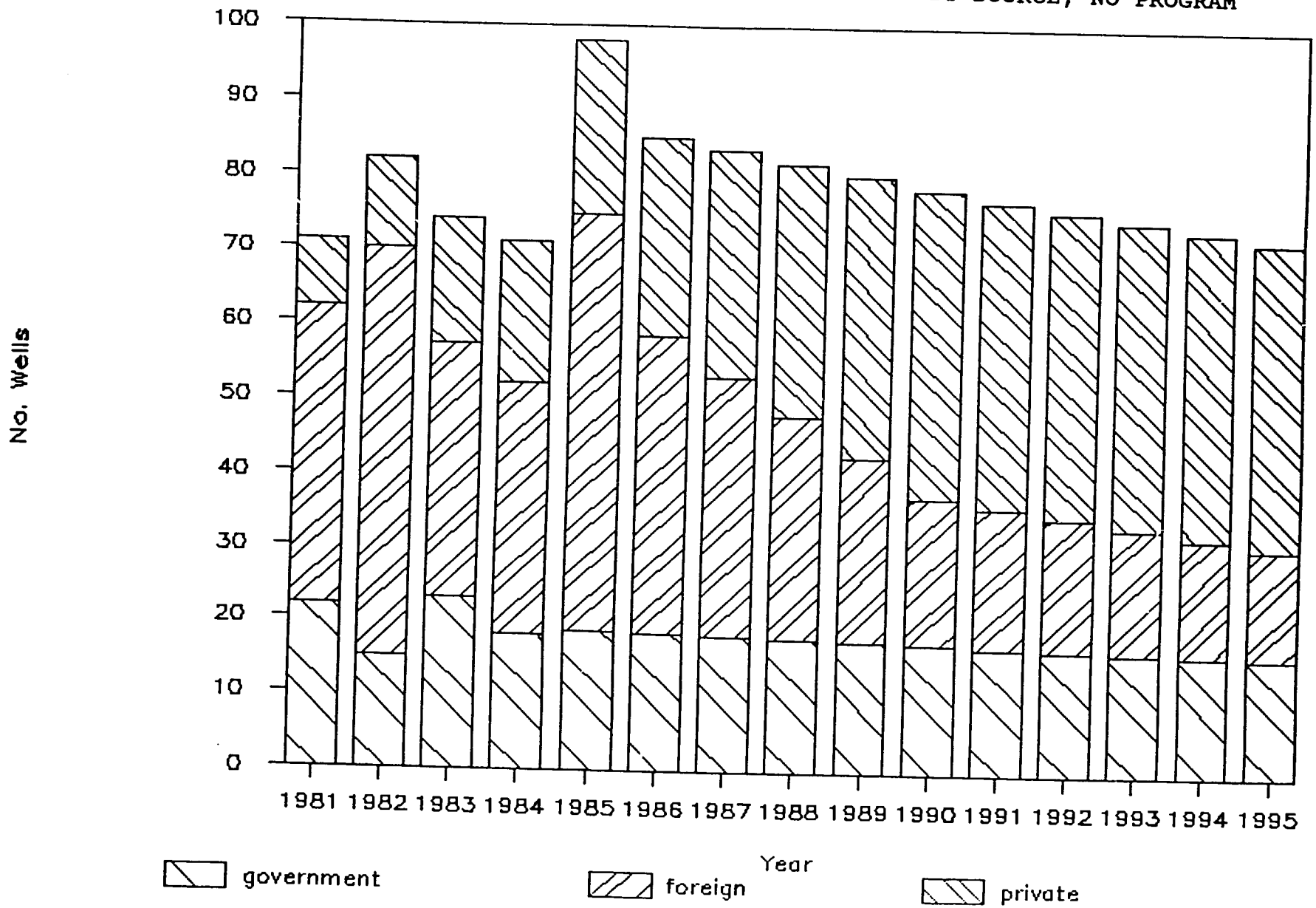


EXHIBIT I-29

PROJECTED VOLUME OF WATER CONSUMPTION -
SUPPLY SIDE vs DEMAND SIDE, NO PROGRAM

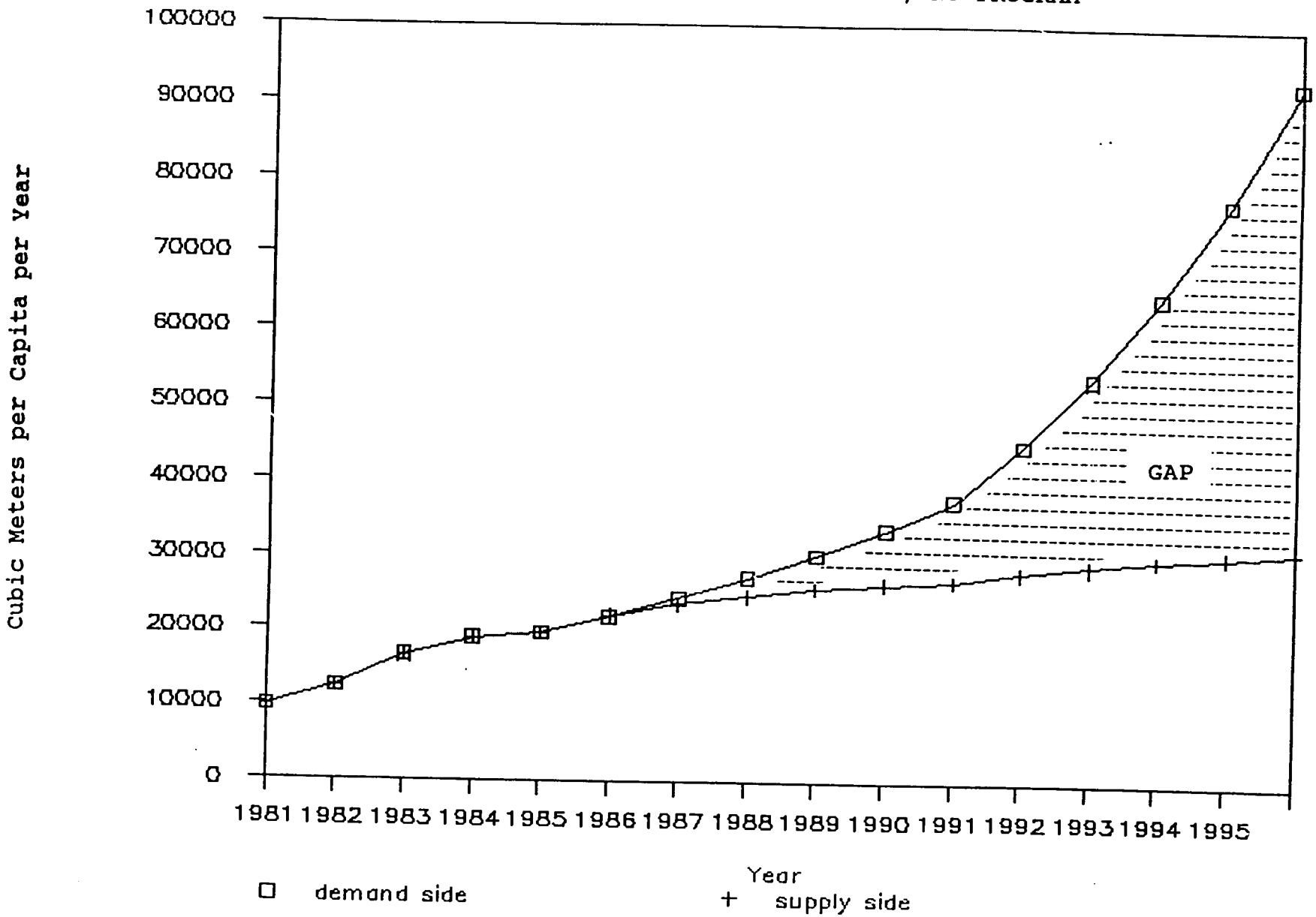
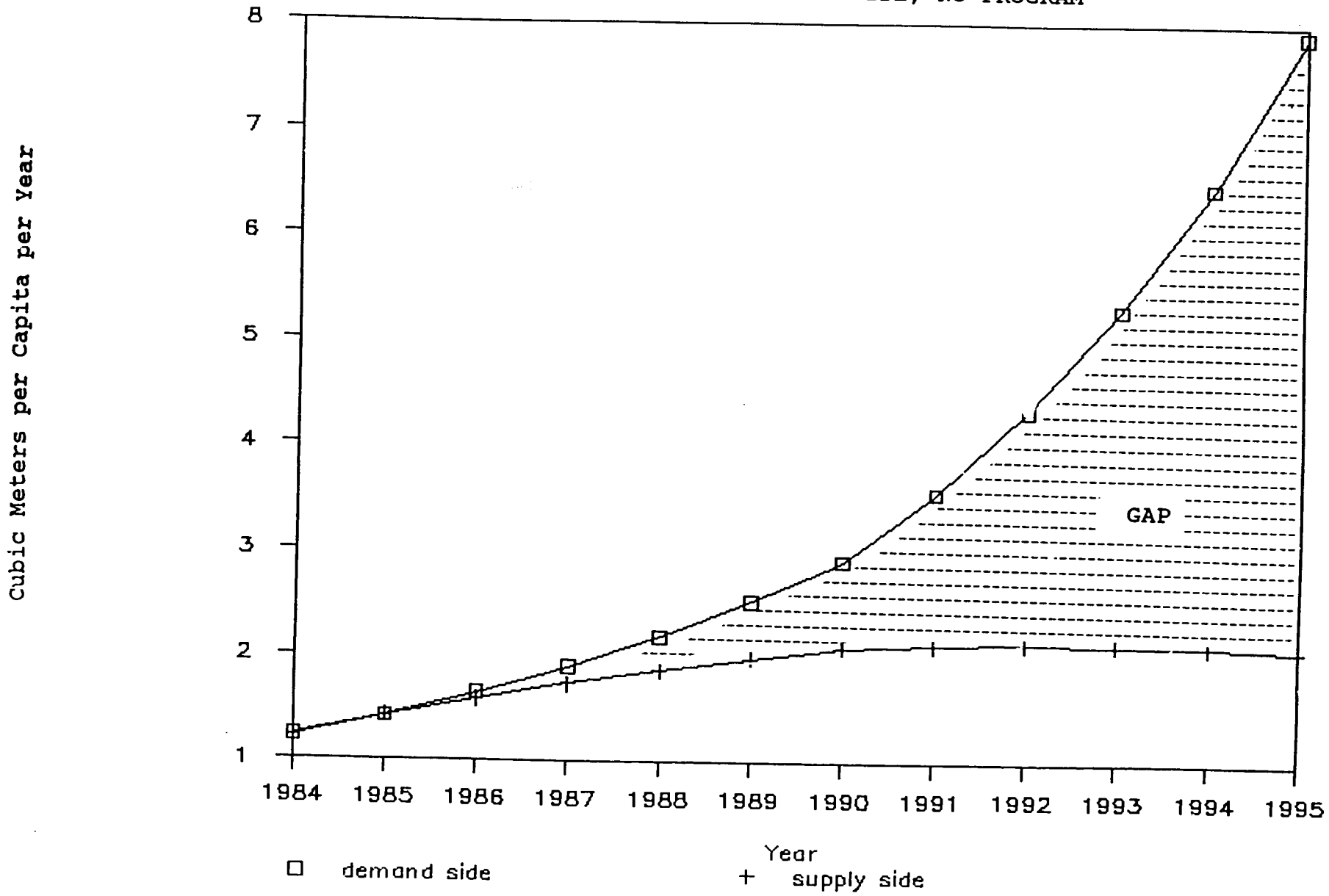


EXHIBIT I-30

PROJECTIONS OF HUMAN WATER CONSUMPTION - SUPPLY SIDE vs DEMAND SIDE, NO PROGRAM



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due to a discontinuation of major donor-funded drilling programs such as USAID's CGDP, GTZ's Urban wells project, and the Saudi's rural well drilling project.

- Private sector drilling activity may have recently peaked, and thus may start declining almost immediately due to a combination of severe input supply constraints (including supplies of credit and foreign exchange for needed imported inputs) and market constraints (including price and licensing constraints as discussed in section 3.4.9 of the main body of the Final report).

Thus overall drilling activity could conceivably suffer a serious decline even before 1990, falling significantly below levels achieved during the past five years.

Exhibit I-31 presents estimates concerning the possible downside risk facing the water industry in Somalia. Exhibit I-32 displays the estimates on drilling for this scenario graphically, through 1990. Although it is unlikely that the Somali government would let the situation deteriorate so drastically for too many years, if such a trend were to continue through, say, 1995, the stock of wells and output of water from that stock of wells could actually decline, as the rate of failure of wells could be even higher than the rate of new drilling.

If that were to occur, and assuming that human water consumption as a proportion of total water production remains constant, then the standards of water consumption of the nation as a whole could actually sink below currently prevailing levels estimated for the country. (See Exhibits I-33 and I-34). Under the circumstances outlined above, a decline in human water consumption standards could only be avoided by sacrificing other water consumption needs.

I-5.5.3 1995 Supply Side Projections (With Consultants' Recommended Drilling and Rehabilitation Programs)

The same analysis can be used to analyze the effects of the Consultants' Recommended Program of well drilling and rehabilitation (leaving aside, for the time being, the contract operations and maintenance programs, the effects of which will be analyzed below).

Exhibit I-35 involves the same demand side analysis presented above; but for the supply side, adds the drilling and rehabilitation portions of the Consultants' recommended program to the trend line data used above in Section I-5.5.1. This brings about a steady increase in new and rehabilitated wells each year through 1995 (See Exhibit I-36).

These portions of the Consultants' recommended program would keep the stock of wells and the volume of water above the demand side projections of needed volumes of water through 1994,

EXHIBIT I-31

WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA: LEVEL II SUBMODEL

Demand Side Projections for Requirements for new/rehabilitated wells; Supply Side Projections Assuming Downside Risk

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Growth Rate P.A. '84-'90	Growth Rate P.A. '90-'95
TOTAL NON-IRRIGATION...																		
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Volume of Water (M^3K/yr)	9843	12471	16616	18907	19656	21879	24355	27111	30182	33601	37409	44816	53709	64384	77203	92597	11.32%	19.87%
Human consumption (M^3K/yr)					6581	7819	9290	11037	13112	15580	18511	22268	29247	36762	46209	58083	18.81%	25.70%
Ave. Ann. Human cons. (M^3/cap/yr)					1.23	1.42	1.64	1.89	2.19	2.52	2.91	3.56	4.34	5.30	6.47	7.90	15.46%	22.06%
Stock of Wells	275	321	376	415	445	492	545	603	668	739	819	957	1122	1321	1560	1847	10.70%	17.66%
Needed Rehabilitation	0	25	28	34	42	47	52	59	66	74	82	66	75	88	103	122		
Needed Drill//Rehabilitation	25	71	82	75	71	94	105	117	131	145	162	204	241	287	342	409		

WELL DRILLING SERVICES SUPPLY: 1980 - 1984 ACTUAL, 1985 - 1990 PROJECTIONS BASED ON PAST WORK, AND POSSIBLE DOWNSIDE RISKS

GOVERNMENT NON-IRRIGATION DRILLING																
Downside Risk	20	22	15	23	18	19	18	18	18	17	17	17	16	16	16	15
FOREIGN NON-IRRIGATION DRILLING																
Downside Risk	0	40	55	34	34	56	38	15	14	13	12	11	10	9	8	7
PRIVATE NON-IRRIGATION DRILLING																
Downside Risk	5	9	12	17	19	23	23	22	21	20	19	18	17	16	15	14
TOTAL NON-IRRIGATION DRILLING																
Downside Risk							79	55	53	50	48	46	43	41	39	36

CONSULTANTS' SUPPLY SIDE PROJECTIONS, DOWNSIDE RISK

ALL NON-IRRIGATION WELLS

Old	250	225	200	175	150	125	100	75	50	25	0	0	0	0	0	0		
(Previous)		25	94	166	224	272	343	388	404	417	425	431	434	433	431	427		
Total old + previous	250	250	294	341	374	397	443	463	454	442	425	431	434	433	431	427		
Need Rehabilitation	0	25	28	34	42	47	52	59	64	65	67	42	43	43	43	43		
Rehabilitated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
New Drilling	25	71	82	74	71	98	79	55	53	50	48	46	43	41	39	36		
Total Stock	275	321	376	415	445	495	522	518	507	492	473	477	477	474	470	463	1.05%	-0.43%
Volume of Water (M^3K/yr)	9843	12471	16594	18914	19635	22005	23352	23298	22928	22346	21613	21769	21766	21672	21475	21150	1.61%	-0.43%
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Human consumption (M^3K/yr)					6574	7864	8907	9485	9962	10361	10695	10772	10770	10724	10626	10466	8.45%	-0.43%
Ave. Ann. Human cons. (M^3/cap/yr)					1.23	1.43	1.57	1.63	1.66	1.68	1.68	1.65	1.60	1.55	1.49	1.42	5.39%	-3.31%

EXHIBIT I-32

PROJECTIONS OF DRILLING SUPPLY -
WELLS DRILLED BY SOURCE, DOWNSIDE RISK

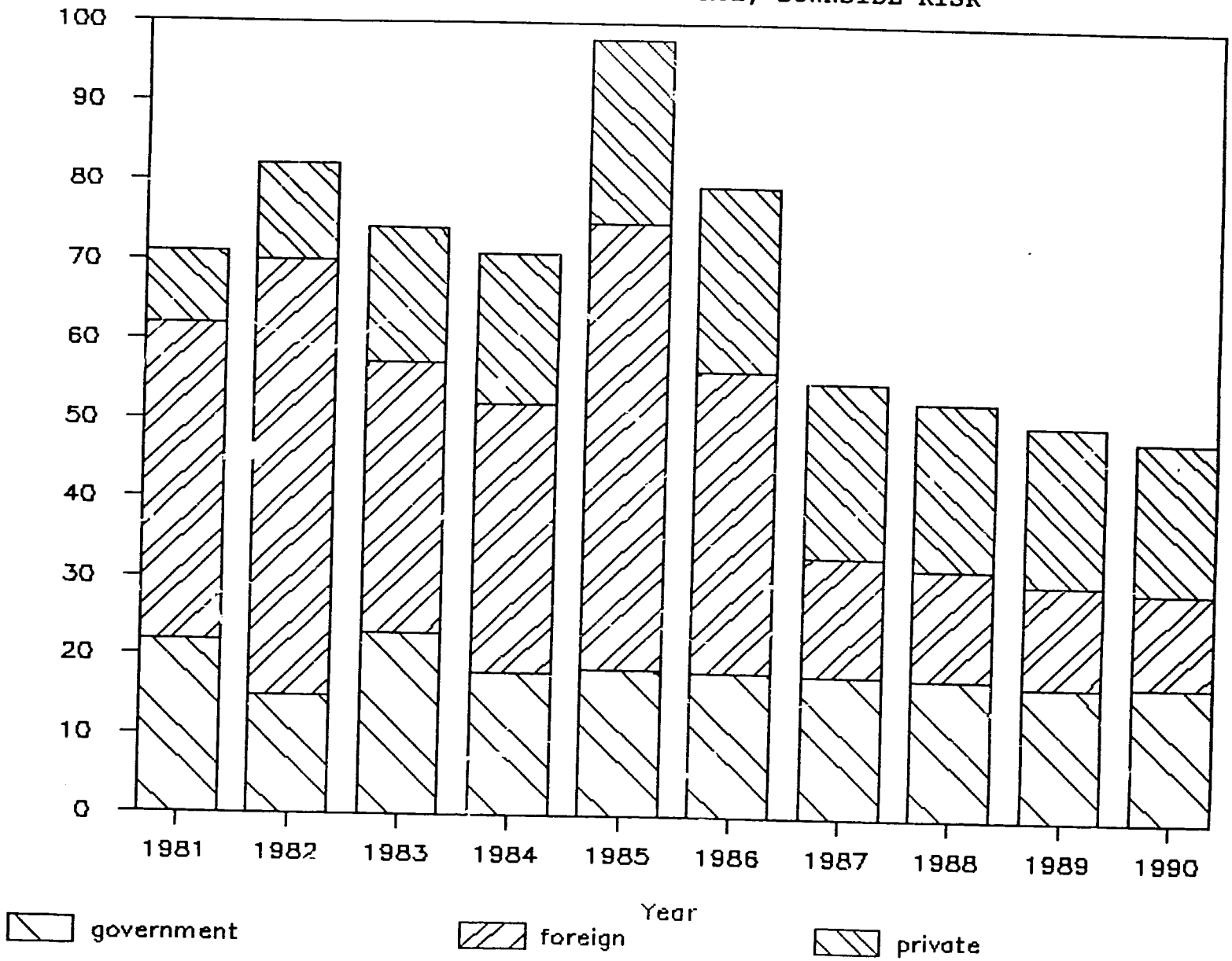


EXHIBIT I-33

PROJECTED VOLUME OF WATER CONSUMPTION -
DEMAND SIDE vs SUPPLY SIDE, DOWNSIDE RISK

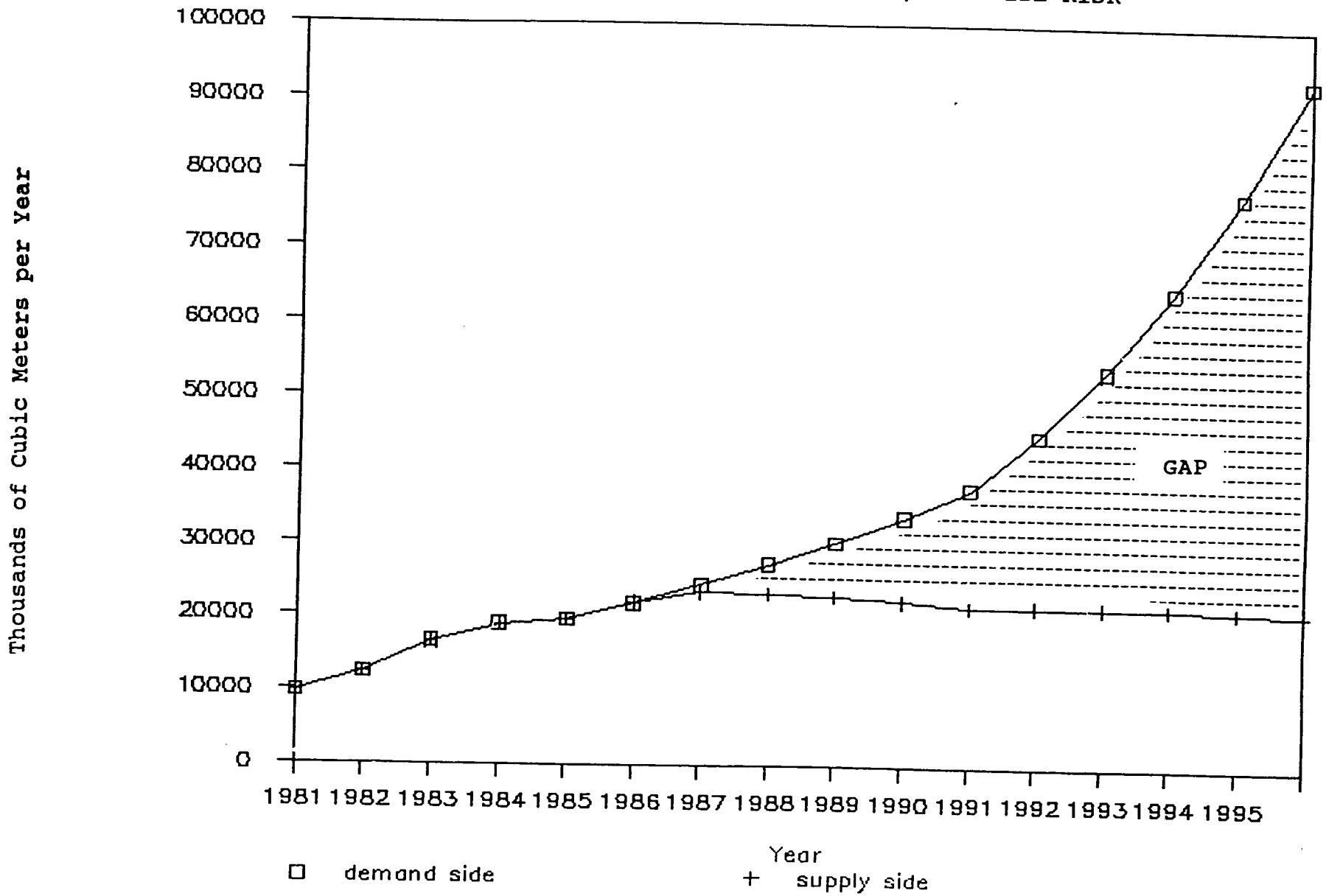


EXHIBIT I-34

PROJECTIONS OF HUMAN WATER CONSUMPTION -
DEMAND SIDE vs SUPPLY SIDE, DOWNSIDE RISK

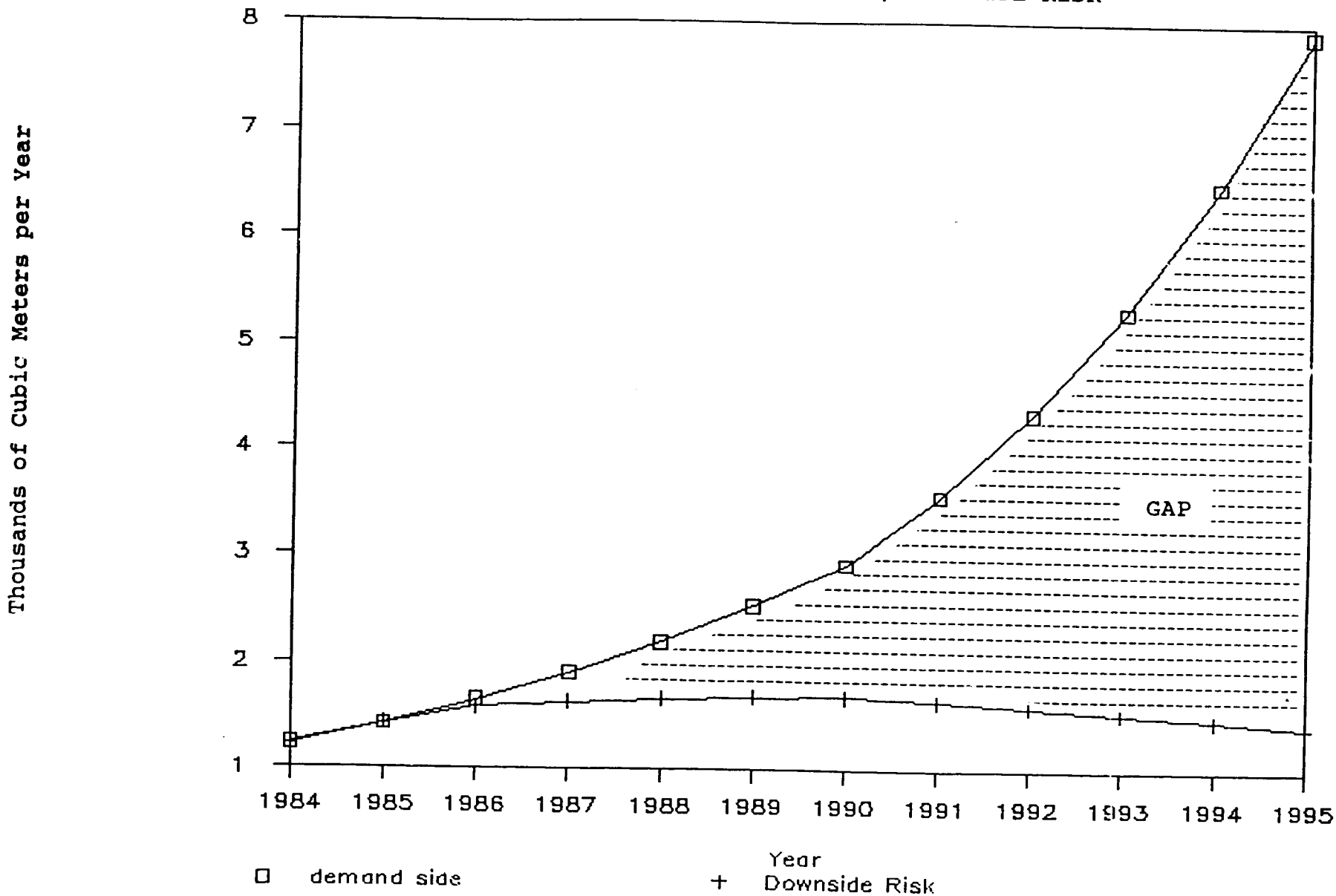


EXHIBIT I-35

WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA: LEVEL II SUBMODEL

Demand Side Projections for Requirements for new/rehabilitated wells; Supply Side Projections Assuming Consultants' Recommended Drilling and Rehabilitation Programs

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Growth Rate P.A. '84-'90	'90-'95
TOTAL NON-IRRIGATION...																		
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Volume of Water (M^3*k/yr)	9843	12471	16616	18907	19656	21879	24355	27111	30182	33601	37409	44816	53709	64384	77203	92597	11.32%	19.87%
Human consumption (M^3*k/yr)					6581	7819	9290	11037	13117	15580	18511	23268	29247	36762	46209	58083	18.81%	25.70%
Ave. Human cons (M^3/capita/yr)					1.23	1.42	1.64	1.89	2.19	2.52	2.91	3.56	4.34	5.30	6.47	7.90	15.46%	22.06%
Stock of Wells	275	321	376	415	445	492	545	603	668	739	819	957	1122	1321	1560	1847	10.70%	17.66%
Rehabilitation	0	25	28	34	42	47	52	59	66	66	66	41	41	41	41	41		
Needed Drill or Rehabilitation	25	71	82	75	71	94	105	117	90	97	105	130	165	199	239	287		
Minimum Needed Drilling							52	58	24	31	39	97	124	158	198	246		

WELL DRILLING SERVICES SUPPLY: 1980 - 1984 ACTUAL, 1985 - 1990 PROJECTIONS BASED ON PAST WORK AND CONSULTANTS' RECOMMENDED DRILLING AND REHABILITATION PROGRAMS

YEAR/CATEGORY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
GOVERNMENT NON-IRRIGATION DRILLING																
Consultants' Projections with Program	20	22	15	23	18	19	18	18	18	20	24	20	16	12	12	12
FOREIGN NON-IRRIGATION DRILLING																
Consultants' Projections with Program		40	55	34	34	56	40	36	32	28	24	24	24	24	24	24
PRIVATE NON-IRRIGATION DRILLING																
Consultants' Projections with Program	5	9	12	17	19	23	31	38	50	58	69	87	96	102	108	113
Contract Well Rehabilitation							22	44	24	24	24	24	24	24	24	24
TOTAL NON-IRRIGATION DRILLING																
Consultants' Projections with Program	25	71	82	74	71	98	89	92	100	106	117	131	136	138	144	149
Contract Well Rehabilitation							22	44	24	24	24	24	24	24	24	24

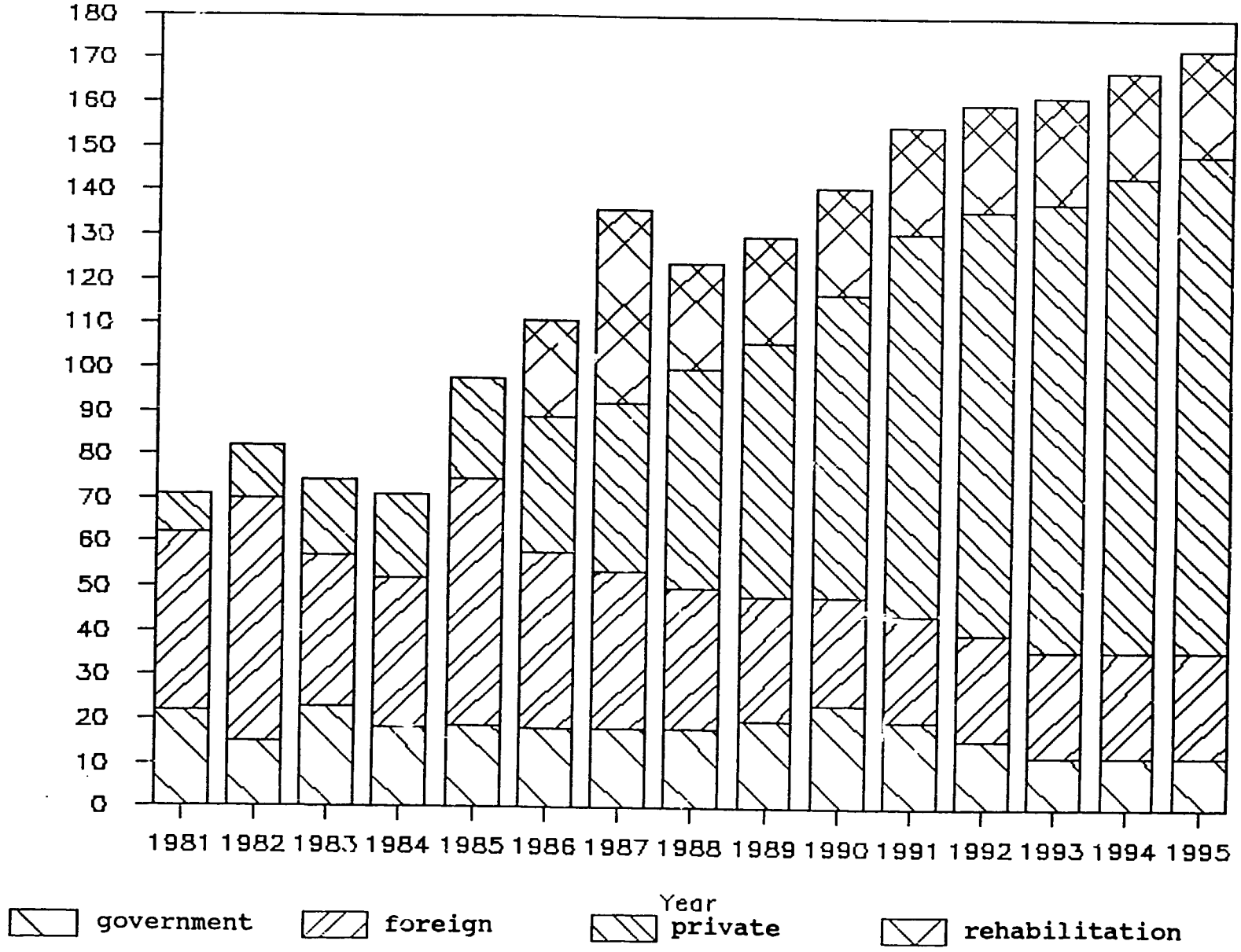
CONSULTANTS' SUPPLY SIDE PROJECTIONS, WITH DRILLING AND REHABILITATION PROGRAMS

ALL NON-IRRIGATION WELLS

Old	250	225	200	175	150	125	100	75	50	25	0	0	0	0	0	0		
(Previous)		25	94	166	224	272	343	420	556	680	810	951	1106	1266	1428	1596		
Total old + previous	250	250	294	341	374	397	443	495	606	705	816	951	1106	1266	1428	1596		
Need Rehabilitation	0	25	28	34	42	47	52	59	67	67	67	42	42	42	42	42		
Rehabilitated							22	44	24	24	24	24	24	24	24	24		
New Drilling	25	71	82	74	71	98	89	92	100	106	117	131	136	138	144	149		
Total Stock	275	321	376	415	445	495	554	631	730	835	951	1106	1266	1428	1596	1769	13.50%	13.22%
Volume of Water (M^3*k/yr)	9843	12471	16594	18914	19635	22005	24765	28357	32988	37932	43419	51783	60570	69587	78981	88665	14.14%	15.35%
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Human consumption (M^3*k/yr)					6574	7864	9446	11544	14333	17589	21485	26885	32983	39732	47273	55617	21.82%	20.95%
Ave. Human cons. (M^3/capita/yr)					1.23	1.43	1.67	1.98	2.39	2.85	3.38	4.11	4.90	5.73	6.62	7.56	18.39%	17.46%

EXHIBIT I-36

PROJECTIONS OF DRILLING SUPPLY -
WELLS DRILLED BY SOURCE, WITH PROGRAM



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but would fall behind in 1995 and fail to satisfy the national drinking water goals. (See Exhibit I-37). This same shortfall would be reflected in the ultimate target variable, per capita water consumption (See Exhibit I-38). Thus the drilling and rehabilitation portions of the Consultants' Recommended program, if implemented alone, would fail to achieve the nation's goals as outlined in the MMWR's Plan for the Drinking Water Supply and Sanitation Decade.

I-5.5.3 Supply Side Analysis of Consultants' Full Recommended Program

We have analyzed separately the effects of the contract maintenance and rehabilitation portions of the Consultants' recommended program in order to highlight their importance. In the past, in spite of carefully designed projects including provisions for ongoing maintenance of donor-funded facilities, host governments have often failed to implement, and donors have failed to enforce these maintenance programs in practice. This section illustrates the tangible water benefits of such a program.

A program of contract operations and routine maintenance should have the effect of increasing the annual volume of water output from each well by reducing the downtime, leakage and wastage of each well so served. By the end of 1995, we estimate that a minimum of 630 wells, out of a total national stock of about 1500 non-irrigation wells, will be under a program of routine maintenance (these are the WDA wells to be included in the recommended program. If other public and private wells receive routine maintenance, the benefits will be correspondingly higher).

The average annual output from un-maintained or irregularly maintained rural, diesel-pump borewells is about 28,000 cubic meters per well. We should expect that wells under contract operations and maintenance would yield about a 33% increase in annual production, or over 37,000 cubic meters per well. We assume that about 400 of the projected 929 rural diesel-pump borewells will be under contract operation and maintenance in 1995. Then the total output from all rural borewells would be about 14% higher than if no wells were in such a program.

Exhibit I-39 presents the data on the estimates of drilling, stocks of wells, and volumes of water assuming that the Consultants' full recommended program (including contract operation and maintenance as well as well drilling and rehabilitation) has been in effect through 1995. Increased output per well reduces the stock of wells needed to satisfy demand for a given amount of water. Thus, with the contract operation and maintenance program in effect, the drilling and rehabilitation programs as outlined in Section Two of the main body of the Final Report can comfortably achieve the national drinking water goals by 1995 (see Exhibits I-40 and I-41).

EXHIBIT I-37

PROJECTED WATER CONSUMPTION -
SUPPLY SIDE vs DEMAND SIDE, WITH PROGRAM

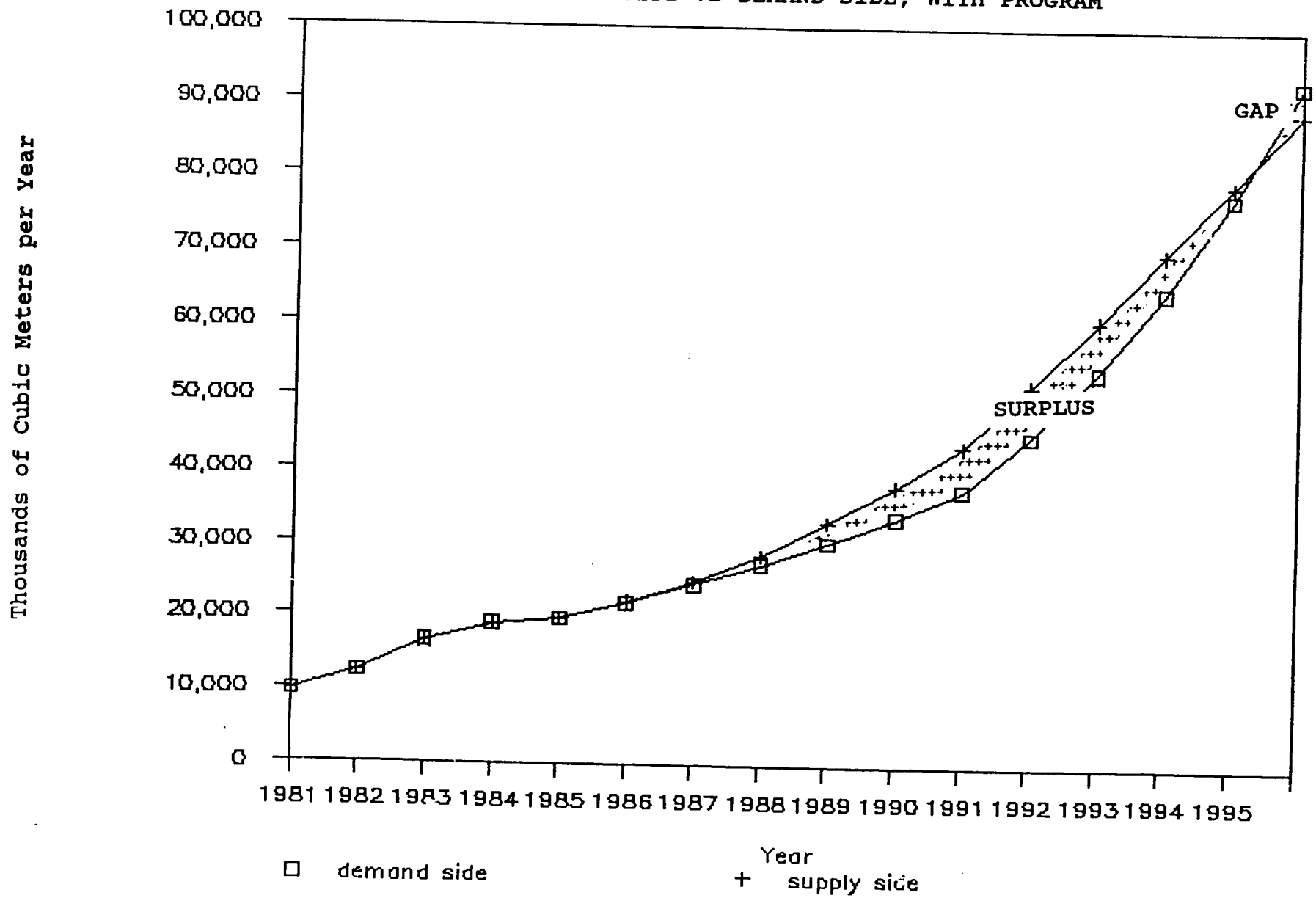

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EXHIBIT I-38

PROJECTED PER CAPITA WATER CONSUMPTION -
SUPPLY SIDE vs DEMAND SIDE, WITH PROGRAM

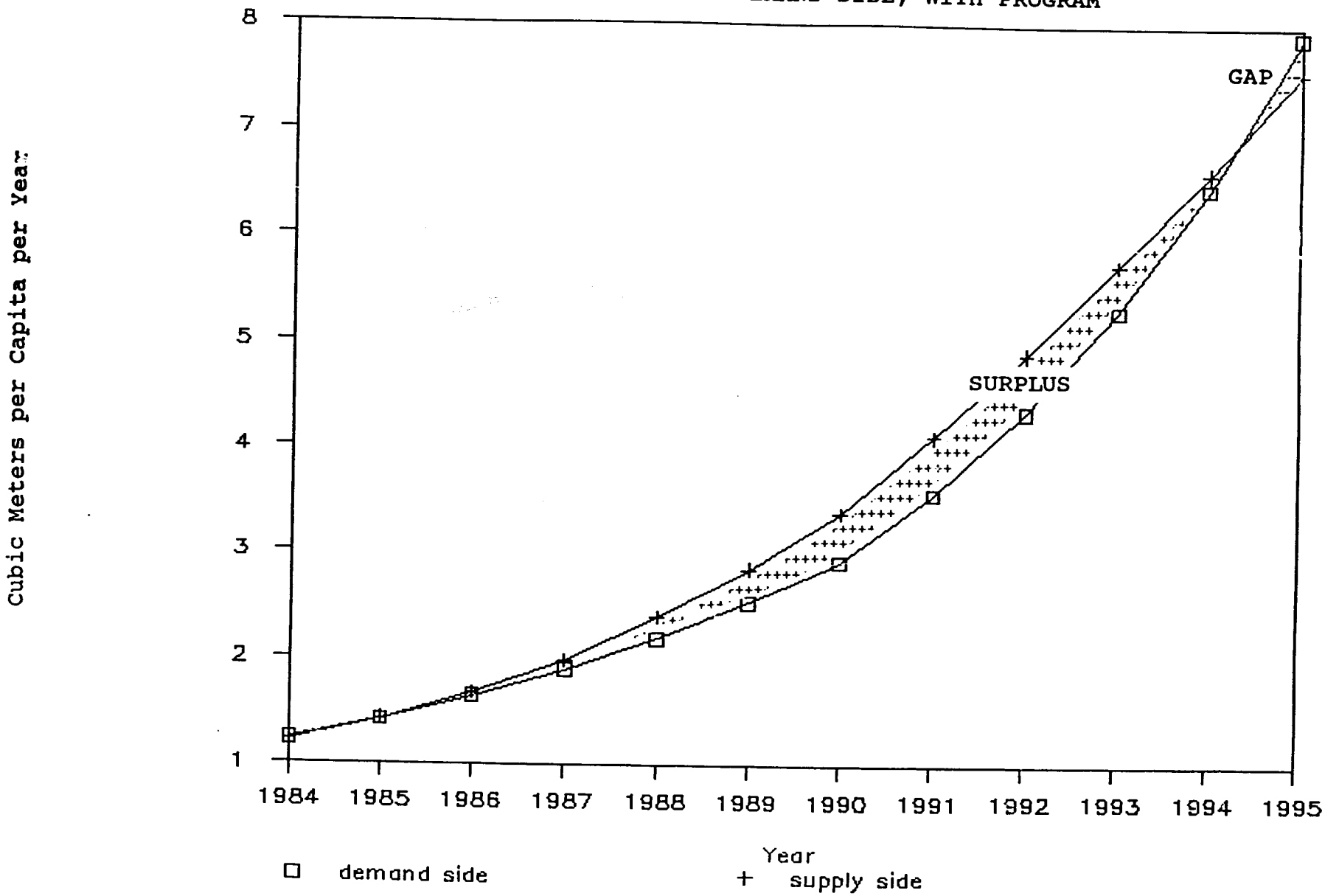

EXHIBIT I-39

WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA: LEVEL II SUBMODEL

Demand Side Projections for Requirements for new/rehabilitated wells; Supply Side Projections Assuming Consultants' Full Recommended Program

STRUCTURE/YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Growth Rate P.A. '84-'90	'90-'95
TOTAL NON-IRRIGATION...																		
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Volume of Water (M^3*k/yr)	9843	12471	16616	18907	19656	21879	24355	27111	30182	33601	37409	44816	53709	64384	77203	92597	11.32%	19.87%
Human consumption (M^3*K/yr)					6581	7819	9290	11037	13113	15580	18511	23268	29247	36762	46209	58083	18.81%	25.70%
Ave. Human cons (M 3/capita/yr)					1.23	1.42	1.64	1.89	2.19	2.52	2.91	3.56	4.34	5.30	6.47	7.90	15.46%	22.06%
Stock of Wells	275	321	376	415	445	490	540	595	656	723	797	913	1050	1212	1404	1631	10.20%	15.40%
Need Rehabilitation	0	25	28	34	42	47	52	59	66	66	66	41	41	41	41	41		
Needed Drill or Rehabilitation	25	71	82	75	71	92	102	114	86	92	99	116	137	162	192	227		
Minimum Needed Drilling							50	55	20	27	34	75	96	122	151	186		

WELL DRILLING SERVICES SUPPLY: 1980 - 1984 ACTUAL, 1985 - 1990 PROJECTIONS BASED ON FAST WORK AND CONSULTANTS' RECOMMENDED FULL PROGRAM

YEAR/CATEGORY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
GOVERNMENT NON-IRRIGIATION DRILLING																
Consultants' Projection with Program	20	22	15	23	18	19	18	18	18	20	24	20	16	12	12	12
FOREIGN NON-IRRIGATION DRILLING																
Consultants' Projection with Program		40	55	34	34	56	40	36	22	28	24	24	24	24	24	24
PRIVATE NON-IRRIGATION DRILLING																
Consultants' Projection with Program	5	9	12	17	19	23	31	38	50	58	69	87	96	100	108	113
Contract Well Rehabilitation							22	44	24	24	24	24	24	24	24	24
TOTAL NON-IRRIGATION DRILLING																
Consultants' Projection with Program	25	71	82	74	71	98	89	92	100	106	117	131	136	136	144	149
Contract Well Rehabilitation							22	44	24	24	24	24	24	24	24	24

SUPPLY SIDE PROJECTIONS, WITH CONSULTANTS' RECOMMENDED FULL PROGRAM

ALL NON-IRRIGATION WELLS

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995		
Old	250	225	200	175	150	125	100	75	50	25	0	0	0	0	0	0		
(Previous)		25	94	166	224	272	343	420	556	680	810	951	1106	1266	1426	1594		
Total old + previous	250	250	294	341	374	397	443	495	606	705	810	951	1106	1266	1426	1594		
Need Rehabilitation	0	25	28	34	42	47	52	59	67	67	67	42	42	42	42	42		
Rehabilitated							22	44	24	24	24	24	24	24	24	24		
New Drilling	25	71	82	74	71	98	89	92	100	106	117	131	136	136	144	149		
Total Stock	275	321	376	415	445	495	554	621	730	835	951	1106	1266	1426	1594	1767	13.50%	13.20%
Volume of Water (M^3*k/yr)	9843	12471	16594	18914	19635	22103	24987	28740	33587	38799	44617	54270	64730	75717	87628	100294	14.66%	17.59%
Human Population (000s)					5350	5505	5665	5829	5998	6172	6351	6540	6735	6935	7141	7354	2.90%	2.98%
Human consumption (M^3*K/yr)					6574	7899	9531	11700	14593	17991	22078	28176	35248	43233	52448	62911	22.37%	23.30%
Ave. Human cons (M^3/capita/yr)					1.23	1.43	1.68	2.01	2.43	2.91	3.48	4.31	5.23	6.23	7.34	8.55	18.92%	19.73%

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EXHIBIT I-40

PROJECTED WATER CONSUMPTION -
SUPPLY SIDE vs DEMAND SIDE, WITH PROGRAM

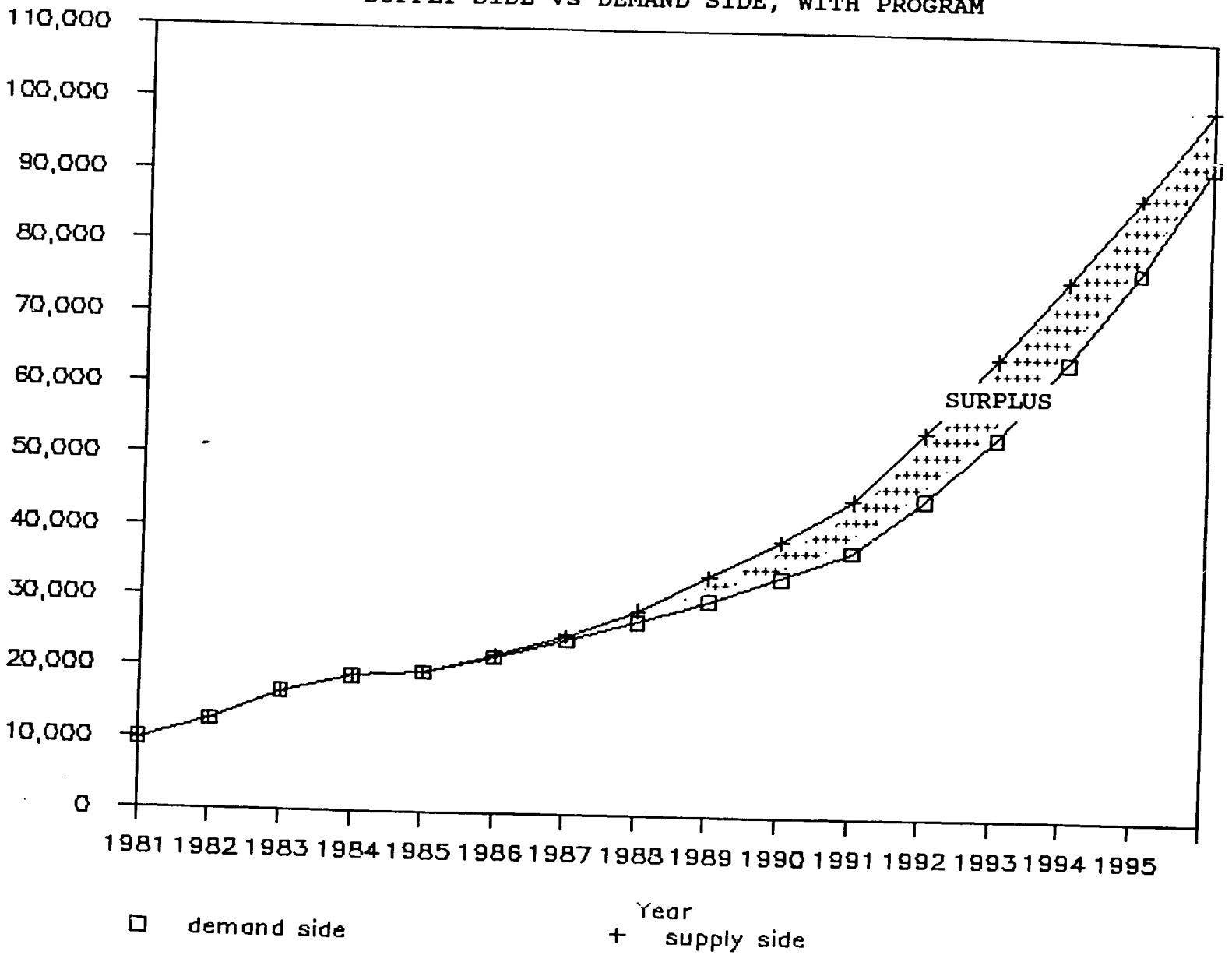
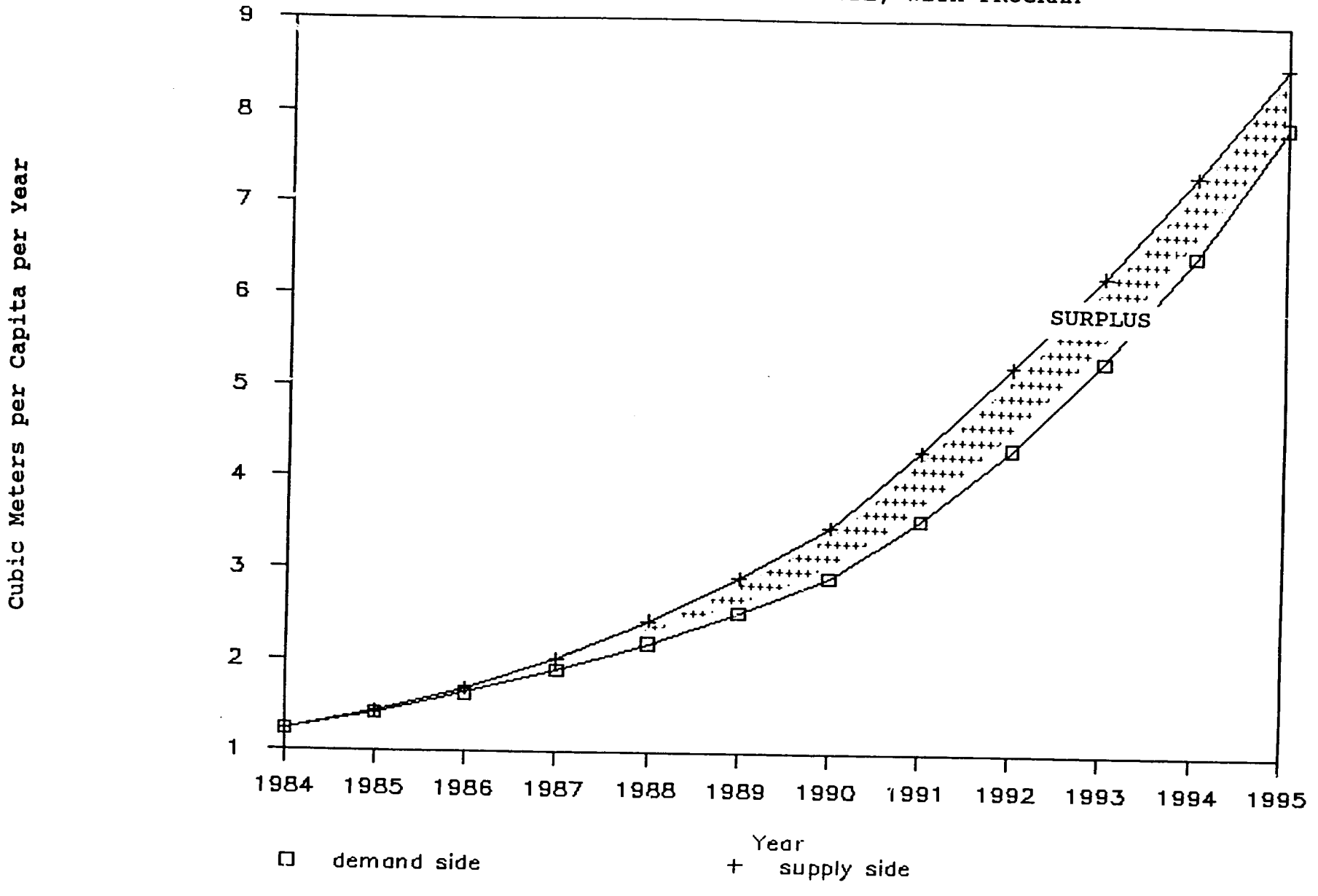


EXHIBIT I-41

PROJECTED PER CAPITA WATER CONSUMPTION -
SUPPLY SIDE vs DEMAND SIDE, WITH PROGRAM



I-6 USE OF WISyMS TO ESTIMATE CURRENT SYSTEM PARAMETERS

I-6.1 Introduction

This Section provides a description of the use of WISyMS to provide estimates of the current characteristics and parameters of the water system in Somalia. It gives an overview of the "Integrated Analysis of Conformed Estimates" (IACE) which was used to weave together a coherent and consistent profile of water consumption and facilities from a variety of data sources, technical estimates and informed opinions. It provides a summary of WISyMS' quantitative estimates for 1984, which are presented in detail in Annex I-1 through I-3.

The forecasting and constraint analysis applications of WISyMS were introduced earlier in this appendix (Sections I-4 and I-5) because they are less complicated and are easier to understand than the estimating applications. However, analytically and chronologically, estimation of the characteristics of the existing system comes first. Integration of available information to define existing relationships between water consumption and facilities is a prerequisite for making sound projections of future needs and for making realistic assessments of national water supply objectives.

I-6.2 IACE Methodology

Somalia's data base on water consumption and water supply systems is incomplete. Some information is very much out of date; other information is not reliable. Estimates of certain system parameters vary widely. In order to provide an improved data base and rational framework for market studies and an analysis of the distribution of functions between the public and private sectors, Louis Berger International, Inc. used its IACE methodology to:

- Determine current and historical relationships between types of water use and types of supply structures (i.e., what types of structures supply how much water for what types of uses); and

- Synthesize information and generate internally consistent estimates for variables on which we lack reliable data, but which form a logical and indentifiable part of the system being analyzed.

Prior to applying IACE procedures, the information requirements of the three submodels comprising WISyMS were defined. In the case of the Submodel for Level I, these information requirements included consumption units, per-unit consumption factors, a matrix of percentage distribution of water use across the range of supply structures, and the associated numbers of supply structures.

The first step in the IACE methodology was to gather as much relevant data as possible. Official estimates and/or estimates contained in well conceived studies were available on: human population (and its breakdown between urban, rural settled, and nomadic categories), livestock populations, and hectares of land under cultivation. Other estimates derived from aerial surveys were available on numbers of water supply structures such as hand-dug wells, uars, and ballehs. The Consultant conducted an investigation of well drilling activity over the past five years to estimate the number of operational drilled wells currently in the country.

Estimates on the average useful life of each type of structure were available from experts and technicians who were familiar with each type of structure, and were used in the Level II submodel to help translate stocks of structures into flows of needed new structures.

Estimates on the technical co-efficients of production inputs for each type of structure were provided by engineers who had designed or worked with the systems currently in use in Somalia.

Missing pieces of data, such as numbers of burkeds, diversion dams, and intake structures from rivers, were filled in with rough estimates.

The Delphi Method was used to obtain estimates on some variables: a variety of informed opinions were solicited; these opinions were sifted, weighted, averaged, compared with other data in the framework, and adjusted until a consensus was achieved. This process of comparative analysis was used in particular to approximate per-unit consumption factors and the percentage distribution of water consumption across the range of water supply structures.

All the above sources of information were incorporated into the model, and used to estimate the average volume of output per (single) supply structure per year. Knowledge of the reasonable range of annual volumes of output for each type of structure provided a basis for adjusting or "conforming" the rough estimates. For example, during the first run of the model, output per burked was calculated as several thousands of cubic meters per year. This appeared unreasonably high and was considered as evidence that the numbers of burkeds in the country had been under-estimated.

Since there is a fairly wide range of estimates on most of the variables examined in the model, three versions were made: one incorporating the low end of the range of estimates for each variable, one incorporating the high end of the range, and one incorporating the middle, average, or most commonly accepted estimate for each variable.

The above described process of gathering, estimating, integrating, and conforming information inputs is called "IACE" for Integrated Analysis of Conformed Estimates. Stated in another way, IACE is an orderly eclectic estimating procedure by means of which available data, opinions, and technical analyses are combined to provide consistent, reasonable approximations of the quantitative characteristics of water systems in Somalia.

I-6.3 1984 System Estimates Summarized

Examples of data on the water system in Somalia as of end-1984 generated by WISyMS (middle estimates) are outlined below. A full presentation of data, including the range of high and low estimates as well as the middle-range estimates for the year are contained in Annex I.

On the basis of estimates generated by the model, water consumption through the use of supply structures in Somalia in 1984 was about 1.2 billion cubic meters. Of this total, about 4% was supplied by drilled wells; 2% by hand-dug wells; 2% by uars, 2% by ballehs, 7% by diversion dams, less than 1% by burkeds and over 80% by intakes from rivers.

Of that same 1.2 billion cubic meters of water, use on agricultural cropland accounted for over 92% of the total; livestock consumption accounted for about 5%, human consumption accounted for less than 2%; and government institutions and industry accounted for less than 1%.

Of the 47 million cubic meters of water provided by drilled wells, 58% was consumed by agricultural crops, 16% was consumed by government institutions and industry, 14% by humans, and 12% by livestock.

As of end-year 1984, there was a stock of approximately 600 operational drilled wells in the country, 17,000 hand dug wells, 18,000 uars, 12,000 ballehs, at least 10,000 burkeds, perhaps 5000 intake structures from rivers, and 5000 earth diversion dams. Many of these are very small structures, built on an individual or community self-help basis. Others, however, are larger or more sophisticated structures requiring substantial capital input and at least the potential for provision on a commercial scale. These would include all the drilled wells, river intakes, and burkeds; it would also include perhaps 2500 hand dug wells, 750 uars, 200 improved ballehs, and 100 earth diversion dams.

The absolute minimum commercial scale construction needed during 1985, solely to replace failing or obsolete structures, included at least 60 drilled wells, 250 hand dug wells, 75 uars, and 20 earth dams.

The replacement program implies a minimum need for locally produced or available inputs as follows: cement - 22 thousand cubic meters, stone - 48 thousand cubic meters, gravel - 2

thousand cubic meters, sand - 10 thousand cubic meters, skilled labor - 551 thousand man-days, unskilled labor - 80 thousand man-days, fuel - 4 million liters, drill/pump rigs - 7 thousand equipment days, and other vehicles - 211 equipment days.

The model, as used for integrated estimation of current system characteristics, presents the "big picture" of the water industry in Somalia as well as an indication of the orders of magnitude of each of its elements. The Consultant expects that the data base will be continuously updated to provide ever more accurate analyses, and that the framework will be expanded to provide more detail in the future.

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I-7 WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA DEFINITION OF TERMS, CATEGORIES, AND CONCEPTS

I-7.1 Introduction

This Appendix has three sections including this introduction. Section I-7.2 contains an alphabetical listing of the principal terms, categories, and concepts used in the Water Industry Systems Model for Somalia (WISyMS) together with cross references to the definition of these terms in Section I-7.3. Section I-7.3 organizes definitions under nine principal categories as follows:

A. Water Industry/WISyMS Structure

B. Consumption Units

C. Per Unit Water Consumption Factors

D. Water Consumption/Intake Structure Flow Relationships

E. Types of Water Supply Structures

F. Subset of Commercial-Scale Water Supply Structures

G. Volumes of Water Provided through Supply Structures

H. Numbers of Each Type of Water Structure

I. Inputs to Water Industry

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I-7.3 Definitions

I-7.3.1 Industry Structure

The Water Industry Systems Model for Somalia and its respective submodels provide outputs useful in analyzing water industry structure at three levels. These levels and the reflecting submodels are defined below.

1. **Level I: Water Supply** - The direct provision of water to the ultimate consumer, including water resource ownership, water supply operation, maintenance and revenue collection. Water supply needs are analyzed by the Level I Submodel of WISyMS.

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2. **Level II: Well Drilling and Construction of Water Supply Facilities** - The drilling and rehabilitation of wells and construction of related civil works structures; planning, design, and administration of drilling and construction. This is analyzed by the Level II Submodel of WISyMS.

3. **Level III: Water Industry Inputs** - The production or provision of manufactured or raw material inputs, equipment, labor, and fuel for water supply, well drilling, and water supply construction activities. These are analyzed by the Level III Submodel of WISyMS.

I-7.3.2 Consumption Units:

A consumption unit is defined as an individual consumer of water in Somalia. Consumption Units are classified into human populations, animal populations, agricultural land, and government and industry. Definitions of these categories are presented below.

1. **Human Population:** Measured in numbers of people. For the purpose of detailed analysis, the estimates of total human population in Somalia are divided into four categories:

   a. **Urban HC** - urban population with private Household Connections for provision of water,

   b. **Urban SP** - urban population with access to Standpipes for provision of water,

   c. **Rural Settled** - rural populations that tend to live year round in one location, and

   d. **Nomadic** - rural populations that tend to move from place to place during the year.

Total urban population for this study is defined as populations in and around cities and towns containing municipal water distribution systems. These are: Mogadishu, Hargeisa, Berbera, Burao, Johar, Balad, Merka, Afgoi, Kismayo, and Baidoa. The distinction between "rural settled" and "nomadic" (or even for "urban" vs "rural") is conceptually useful but arbitrary in practice. Many people move some years but not others; or move for only short periods of time in any given year. We used official estimates for the percentage breakdown of these categories (See Section I-9).

2. **Animal Population:** measured in numbers of head. They are divided into four basic categories: a. **Camels**, b. **Cattle**, C. **Sheep and Goats** (one category) and d. **Other**, which is intended to include other household animals including poultry, donkeys, cats, and dogs.

3. **Agriculture:** Measured by Hectares under cultivation. It includes:

   a. **Irrigated Agriculture** - land under controlled channel irrigation;

   b. **Rainfed Agriculture** - land fed almost exclusively by natural rainfall; and

   c. **Flood-fed Agriculture** - land fed by rainfall plus flood water and tugs (small seasonal rivers) diverted by earth dams.

4. a. **Government** and b. **Industry:** Measured in numbers of establishments. They are primarily urban and include government offices or institutions and industrial or commerical establishments employing five or more people.

I-7.3.3 Per-unit Water Consumption Factors:

A per-unit consumption factor is defined as the average volume of water consumed per day by an individual consumption unit in a particular category. Factors for each category of consumption are discussed in the following paragraphs.

1. **Human Consumption:** Daily per capita consumption of water varies drastically by area and by season. Rural dry season consumption may be no more than the minimum required for subsistence (3 - 5 liters), while urban consumption can easily exceed 100 liters per day.

2. **Animal Consumption:** Although the figures presented in WISyMS are for consumption per head per day, camels are actually watered once every one to three weeks, cattle are watered once every other day on average, and sheep and goats are watered once every two to six days.

3. **Agricultural Consumption:** Total amount of water used for growing crops on agricultural land, whether or not the water is actually absorbed by the plants (i.e., water applied to crops which evaporates directly or percolates through to lower strata is included here.)

4. **Government and Industrial Consumption:** Weighted average volume of water used in these categories.

I-7.3.4 Water Consumption/Supply Structure Flow Relationships

At least three types of calculations/estimates are required to relate consumption flows to flow through particular types of supply structures. These are discussed below.

1. **Structural Control Percentage:** For each type of consumption, the percentage of water taken from nature with the use of man-made water supply structures or improvements to natural sources. (What is excluded, **"no structure"**, is water consumed directly from natural sources, such as springs, ponds, or rivers, without the use of man-made supply structures.)

2. **Structural Control Volume:** For each type of consumption, the actual volume of water consumed through man-made water supply structures.

3. **Percentage Distribution Across Structures:** For each type of consumption, the percentage distribution of consumption across the range of types of water supply structures listed below.

I-7.3.5 Types Of Water Supply Structures

Ten types of water supply structures are covered by WISyMS. They are: drilled wells (including urban, rural diesel pumped, rural hand pumped, and irrigation), hand-dug wells, intakes from rivers, uars, ballehs, burkeds, and diversion dams. Each of the types of structures is defined below. Note that wells are structures used to reach sources of groundwater and may be almost any depth from two meters to over 300 meters in Somalia. Although wells are sometimes classified as "shallow" vs "deep", in the context of WISyMS they are classified as "drilled" or "hand dug" in order clearly to reflect the type of input that goes into the structure (see below).

1. **Drilled Wells:** All wells drilled mechanically by cable, hydraulic, or rotary rig, regardless of depth. They may be **production wells**, which are completed, operational structures equipped with a pump and producing water, or **non-production wells**, which are test boreholes abandoned after it has been determined that quantity and/or quality is not suitable. Production wells can be further classified into: **a) urban wells,** including both public, municipal wells serving the city as a whole, and private wells serving individual households or business establishments, **b) rural diesel pump wells,** including all rural drilled wells operated by diesel pumps, **c) rural hand pump wells,** including all drilled wells operated by handpumps, and **d) irrigation wells,** including all drilled wells serving irrigated argiculture.

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2. **Hand Dug Wells:** All wells dug by hand tools, regardless of depth. There are three basic types, depending on local geological conditions: i) wells dug in or near stream or river beds; ii) wells dug in sand dune areas; and iii) wells dug in gypsiferous, limestone, or sandstone formations. These are important sources of water during the dry season in rural areas.

3. **Intakes from Rivers:** Pipes immersed into a river and connected to a diesel powered pump. Water is then distributed to irrigation channels or, if for drinking water, to water purification facilities.

4. **Uars:** Reservoirs dug in relatively impermeable ground to catch rainwater and surface run-off and to serve as retention basins. They are usually intended for livestock watering, though they are also used by people.

5. **Ballehs:** Ponds or natural depressions which tend to catch and hold rainwater and surface run-off, which have been or could be deliberately improved, deepened, or enlarged. They are a traditional source of water during the rainy season for both human and livestock consumption.

6. **Burkeds:** In-ground masonry cisterns which serve as water storage tanks or which catch rainwater or surface run-off. They are primarily a wet season source of water, although water may be transported to them for storage and use during the dry season.

7. **Diversion Dams:** Man-made structures to divert or hold back the natural flow of a river, stream, or tug. They are used in all forms of agriculture, especially "flood-fed" agriculture.

I-7.3.6 <u>Subset of Commercial Scale Water Supply Structures:</u>

For each type of above-listed supply structure there is a subset of structures the construction of which involves some capital input and at least the potential for construction on a commercial basis. These supply structure subsets are important because they help identify potential markets for drilling and construction firms. The subsets include:

1. All **drilled wells,** because they require the use of a drill rig;

2. Only those **hand dug** wells with a cement or stone lining;

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3. All **intakes** from rivers because of the need for diesel pumps;

4. Only those **uars** excavated with heavy equipment;

5. Only those **ballehs** improved with the use of heavy earth-moving equipment;

6. All **burkeds** because of the need for skilled masons and cement; and

7. Only those **diversion dams** built with the use of heavy earth-moving equipment.

I-7.3.7 Volumes of Water Provided Through Supply Structures

Three terms are important in understanding the process by which WISyMS calculates volumes of water provided through supply structures. These are discussed below.

1. **Total Consumption of Water by Type of Consumption and by Type of Structure:** A matrix in which the rows illustrate the amounts of water used for each type of consumption and its distribution across types of structures. The columns of the matrix illustrate the amounts of water provided by each type of structure and its distribution among different types of use. Therefore, the cells of the matrix specify the amount of water used for each particular use AND supplied by a particular type of structure (see Section I-8, Methodology, for the concise mathematical formulae).

2. **Structural Supply Volumes:** The sums of the volume of water consumed for each type of structure for all uses.

3. **Output per Structure:** The weighted average volume of water provided per single supply structure per year for each type of supply structure.

I-7.3.8 Numbers of Each Type Of Water Supply Structure

This section presents definitions of terms used to describe the process by which numbers of water supply structures are calculated.

1. **Total Needed Numbers of Structures:** For the purposes of WISyMS analysis, defined as the numbers of each type of structure needed to keep up with growth in consumption from all sources, depending upon the average volume of output per single operational structure.

2. **Average Useful Life:** For each type of structure, the expected number of years it will be operational and providing water before it becomes worn out, fails, and needs to be replaced or rehabilitated.

3. **Old Structures:** For the purposes of WISyMS analysis, defined as those operational structures which had been in existence before the year being analyzed in the model, and which will be subject to a certain expected rate of deterioration/failure during the year being analyzed. (See also "Previously Constructed" structures in Section I-8).

4. **Needed New or Rehabilitated Structures:** For the purposes of the WISyMS analysis, are defined as the numbers of each type of structure needed to be constructed or rehabilitated to:

   - Replace or rehabilitate those old structures which are expected to fail during the course of the year being analyzed, plus

   - Provide for expected net increases in consumption from all sources.

I-7.3.9 Inputs to The Water Industry

WISyMS deals with four categories of inputs to the water industry: raw materials, manufactured materials, labor and capital equipment. These are described below.

1. **Material Inputs:** presented in WISyMS include those of primary importance to the water resource development industry, and focus on those materials with a potentially significant impact on "Level III" industries and entrepreneurs' decision making. They include:

   a. **Raw Materials** available in Somalia - sand, gravel, stone, and some wood:

   b. **Manufactured Materials**, some of which are potentially available in Somalia - cement, pipes, plastic sheets, storage tanks, and hand pumps; and other materials which must be imported - drilling fluid (bentonite), drill bit, well casing and screen, diesel pumps, reinforcement steel, and fuel;

2. **Labor** - for supervision, drilling, excavation, construction, mechanical and other services;

3. **Capital Equipment** - drill rigs, pump rigs, heavy vehicles such as flatbed trucks, dump trucks, water tankers, and fuel tankers; and light vehicles and equipment.

I-8 DETAILED METHODOLOGY FOR THE WATER INDUSTRY SYSTEMS MODEL FOR SOMALIA

I-8.1 Introduction

This presentation of the methodology employed by the Water Industry Systems Model for Somalia (WISyMS) contains three sections, corresponding to the three submodels for each of the levels of the water industry in Somalia. The Level I Submodel analyses water supply, the Level II submodel analyses well drilling and construction of water supply facilities, and the Level III submodel analyses water industry inputs. (Detailed definitions of terms used in this appendix are presented in Section I-F).

Actual data generated by WISyMS has been bound separately in Annex I. It is suggested that Annex I-4, "1990 Middle Level Projections" data be referred to throughout the following discussion (unless otherwise noted) for illustration. Familiarity with the general structure of the model, as presented in Sections I-2 and I-3, above, is assumed in the discussion that follows.

I-8.2 Level I Submodel

The Level I submodel is composed of three sections. The first section employs data on numbers of consumption units and per unit consumption factors to calculate total annual volumes of water consumed by type of use, and estimates the percentage and volumes of water consumed through the use of man-made water supply structures. The second section contains a matrix of estimates on the percentage distribution of consumption across the range of types of water supply structures. The third section uses the estimates provided by the first and second sections to calculate a matrix of volumes of water by type of use and by type of supply structure. This section also contains estimates on numbers of

each type of supply structure and average volume of output per single supply structure.

I-8.2.1 Level I Submodel, First Section

The first column of figures represents consumption units in thousands: N.

The second column of figures represents average amounts of water consumed daily per unit in each consumption category, and is expressed in liters or cubic meters: c.

The third column of figures represents the relevent number of consumer-days per year: D.

The fourth column of figures represents the relevent conversion factor for each category of consumption to cubic meters (liters * 1000 or M^3 * 1): F.

The fifth column of figures represen s the total annual volume of water consumed by each category in thousands of cubic meters per year: V.

Columns 1 - 5 relate to each other according to the following formula:

$$V = (N * c * D) / F$$

Of all water consumed, some is provided through the use of man-made supply structures and the rest is consumed directly from nature, (e,g., Urban populations with private household connections for water have 99% of their water consumption needs provided through the use of man-made water supply structues; the other 1% is taken directly from nature without the use of such supply structures). In order to assess the volume of water consumed through water supply control structures V_c for each

category of consumption, we multiply by the appropriate percentage of total annual consumption:

e.g.: $V_c = .99 * 6351 = 6287$

where V_c = Structural Control Volume by category of consumption (volume of consumption from supply structures).

Similarly, "No Structure" is the volume of water consumed directly from nature.

I-8.2.2 Level I Submodel, Second Section

The second section repeats the columns representing consumption units, total annual consumption, structural control percentage and structural control volume. To the right of these columns is a matrix representing, for each category of consumption, the percentage distribution (% of V_c) of reliance on each of ten types of water supply structures. (e.g., Human Urban Consumption from urban drilled wells accounts for 75% of the total urban consumption from all types of supply structures). Each row of the matrix sums to 100%.

I-8.2.3 Level I Submodel, Third Section

The third section repeats the columns representing consumption units, total annual consumption, structural control percentage, and structural control volume. To the right of these columns is a matrix representing the total consumption of water (V_{cs}) by type of consumption and by type of structure (e.g., for the Human consumption category, urban (HC) consumption from urban drilled wells is : $.75 * 6287 = 4716$).

This produces the matrix: $[V_{cs}]$

or:

$$
\begin{array}{c|cccccc}
 & V_{s1} & V_{s2} & V_{s3} & \cdots & & V_{sM} \\
\hline
V_{c1} & V_{c1s1} & V_{c1s2} & V_{c1s3} & \cdots & & V_{c1sM} \\
V_{c2} & V_{c2s1} & V_{c2s2} & V_{c2s3} & \cdots & & V_{c2sM} \\
V_{c3} & V_{c3s1} & V_{c3s2} & V_{c3s3} & \cdots & & V_{c3sM} \\
\vdots & \vdots & \vdots & \vdots & & & \\
V_{cN} & V_{cNs1} & V_{cNs2} & V_{cNs3} & \cdots & & V_{cNsM}
\end{array}
$$

where: V_{ci} is the volume of water (V_c) consumed by consumption category i,

V_{sj} is the volume of water (V_s) consumed through type of supply structure j, and

V_{cisj} is the volume of water consumed by consumption category i and through type of structure j.

Knowing the volumes of water for each supply structure per category of consumption, we can calculate the total volumes of water for each type of supply structure (V_s) (in thousands of cubic meters per year) by summing down each column of the [V_{cs}] matrix.

$$V_{sj} = \sum_{i=1}^{n} V_{cisj}$$

No comprehensive figures existed, in 1984, on average volumes of output per single supply structure for each type of structure. However, using the available estimates of numbers of each type of supply structure (S_j), it was possible to calculate an estimated output per single structure V_o:

$$V_{oj} = V_{sj}/S_j$$

These estimates were then taken as fixed and given for use in projections of needed water supply structures for each type of structure for 1990 and 1995 for the "without program" projections:

$$S_j = V_{sj}/V_{oj}$$

For the "with program" projections (Annex I-10), V_{oj} was was increased due to less down-time and wastage from drilled wells, assuming programs of contract operations and routine maintenance are functioning.

To provide an additional point of reference, the model includes two extra rows as follows:

- **DAYS/YEAR:** is the weighted average number of days per year each type of structure is in use: D_j
- **M^3/STR/DAY:** volume of output in cubic meters per single supply structure per day, calculated as "Output per Structure per Year" V_{oj} divided by "Days per Year" D_j.

For each type of water supply structure, a fixed proportion is assumed to form the subset of commercial scale structures:

$$SC_j = S_j * P_j$$

where SC_j is the number of structures in the subset of Commercial Scale Structures for category j, and P_j is the proportion of commercial scale structures in category j.

Estimates of an average useful life U_j for each category of commercial scale structure can be used for a rough notion of replacement or rehabilitation requirements R_j (in the absence of

detailed knowledge of the ages and conditions of the structures concerned):

$$R_j = SC_j/U_j$$

This would represent the bare minimum replacement or rehabilitation rate without suffering a loss in crude supply capacity. For the 1984 middle-base estimates (Annex I-1), these replacement rates were introduced directly into the Level III submodel to illustrate the quantities of inputs required solely for replacement purposes at the drilling/construction level, (assuming no rehabilitation takes place).

I-8.3 Level II Submodel

Section I-4, above, discussed the procedures for using the Level I submodel for making water consumption forecasts for future years and presented estimates on, among other things, projections of the numbers of needed new structures in 1990. Section I-6 discussed the use of the model to make estimates of the current (end-1984) system. This provides the basis for comparison between years, which is necessary to derive needed flows of drilling and construction from needed stocks of structures.

The columns of the Level II submodel present numbers of commercial scale structures by year. The rows of the Level II submodel are grouped by type of structure. The first row in each group represents "Needed Total Structures" for each year: SC_{jt}. Numbers of operational commercial scale structures in existence as of end-year 1984 were taken as the basis of comparison. Projections of needed structures in 1990 ("needed" to keep pace with growth in consumption from all sources without the Consultants' recommended maintenance and rehabilitation program) were made assuming that the 1984 level of output per single structure V_{oj} was constant (see above). With-Program projections

for 1995 were made on the assumption that decreased downtime and waste would increase the effective annual output of drilled wells. (see above).

Assuming there will be a constant growth rate (g) in the stock of structures between 1984 and 1990, the total needed structures for each year between 1984 and 1990 can be calculated by expotential interpolation. For example:

1984 Total existing urban drilled wells = 124; and
1990 Total needed urban drilled wells = 232; then

$$232/124 = (1 + g)^6$$

$$g = (232/124)^{1/6} - 1 = 0.11 \text{ or } 11\%$$

therefore 1985 Total needed urban wells = 124 * 1.11 = 138

The second row of each grouping presents the stock of old structures, SO_{jo}, in existence at the beginning of the period of analysis (pre-1980 for drilled wells; pre-1984 for all other types of structures) and assumes a deterioration rate equal to the inverse of useful life for that type of structure: $(1/U_j)$. From those figures can be calculated the numbers of remaining old structures (SO_{jt}) for each type of structure j and for any succeeding year:

$$So_{jt} = SO_{jo} * [1 - (t/U_j)];$$

where t = the number of years after the beginning period of the analysis for a given type of structure.

The third row of each grouping, "Previous New Structures" (SP_{jt}) represents the status of structures built in succeeding years (post-1980 for drilled wells and post-1984 for all other types of structures). In each year, new structures are being built. It is assumed that each new structure remains functional

for one year after construction (it gets one year grace), but in the absence of a routine maintenance program, deteriorates at a rate ($1/U_j$) each year after that. For example, for urban drilled wells, there were 12 new wells drilled in 1984, and 81 "Previous New Wells" in 1984. Therefore, there are [12 + (.9 * 81)] = 85 urban drilled wells in the "Previous" row for the 1985 column.

The fourth row of each grouping, "Needed New or Rehabilitated Structures", SN_{jt}, represents the numbers of structures which must be built or rehabilitated in a given year to 1) keep pace with expanding consumption needs from all sources and 2) to replace or rehabilitate deteriorated structures (as calculated above). Specifically, they are calculated as the number of structures needed to make up the difference between "Needed Total Structures" and "Old Structures" plus "Previous new Structures":

$$SC_{jt} - (SO_{jt} + SP_{jt}) = SN_{jt}$$

For each grouping, the 1990 numbers of "Needed New or Rehabilitated Structures" have been used in the Level III submodel to calculate needed inputs.

I-8.4 Level III Submodel

The primary objective of this submodel is to provide a system which estimates the inputs of raw materials, labour and equipment required to build and maintain a water supply system with a given capacity. A major objective of this model is to serve as a basis for the development of a market study for Level III of the water industry to provide the private sector with a decision making tool.

This model can be regarded as a simplified Input/Output model based on current technology in Somalia. Inputs are the raw materials, labour and equipment involved in the construction and/or maintenance of the different water supply structures under

consideration. Outputs are defined as numbers and types of water supply structures which need to be "produced", that is, either constructed or rehabilitated or maintainted. (e.g. number of drilled wells to be constructed or number of burkeds to be maintained).

Technical coefficients, establishing the quantity of Input i required in order to produce (either drill/construct, rehabilitate, operate, or maintain) one unit of Output (structure) j are determined. (e.g., quantity of cement required for the construction of one burked).

For purposes of the Level III Submodel, drilled wells are divided into five categories:

- Urban Wells
- Rural Wells equipped with hand pumps;
- Rural Wells equipped with diesel pump;
- Irrigation Wells; and
- Non Production Wells, assumed to be in fixed proportion of rural wells.

The other structures are undivided.

Each of these structures is clearly defined in Section I-7; sources and estimating procedures are discussed in Section I-9. The framework has been designed in a way that allows more structures to be considered. Estimates have been made of the following:

- Technical coefficients of drilling/construction
- Technical coefficients of rehabilitation (drilled wells only)
- Technical coefficients of maintenance
- Technical coefficients of operation (drilled wells only)
- Useful Life

- Rehabilitation Period
- Maintenance Period.

The framework is designed in order to allow maximum flexibility in the estimates. Any of the values that have been assumed in the main framework can be easily modified.

Definitions:

APR_j = Annual Production Rate: indicates the number of new structures to be constructed in a given year for each type of structure j (= SN_j, Needed New Structures for Level II if there is no rehabilitation).

UL_j = Useful Life for structure j: represents the life expectancy of structure j, assuming that the structure is properly and regularly maintained.

MP_j = Maintenance Period: indicates the number of years between two consecutive maintenance services for structure j.

AMR_j = Annual Maintenance Rate for structure j: indicates the annual number of structures j to be maintained. AMR is defined as follows:

$$AMR_j = SC_j/MP_j$$

WRP_j = Rehabilitation Period: indicates the number of years between two consecutive rehabilitations of drilled wells.

$AWRR_j$ = Annual Wells Rehabilitation Rate for wellj: indicates the annual numbers of wells to be rehabilitated. The maximum $AWRR_j$ would be estimated as:

$$AWRR_{jt} = (SO_{jt} + SP_{jt}) - (SO_{jt-1} + SP_{jt-1})$$

In practice, the rehabilitation rate will be defined according to the program (or lack thereof) in effect at time j.

$AWOR_j$ = Annual Wells operation Rate for each well j: indicates the annual numbers of wells to be operated:

$$AWOR_j = SC_j$$

n = number of Inputs i (i=1, . . . n)
m = number of Outputs (structures) j (j=1, . . .m)

A_{ij} = Technical coefficient representing the quantity of Input i required to drill/construct one unit of Output j.

B_{ij} = Technical coefficient representing the quantity of Input i required for one rehabilitation service of one unit of j.

C_{ij} = Technical coefficient representing the quantity of Input i required for one maintenance service of one unit of j.

D_{ij} = Technical coefficient representing the quantity of Input i required for one day's operation of unit j.

W_{ij} = Total annual quantity of Input i to be supplied in order to drill/construct Output j.

X_{ij} = Total annual quantity of Input i to be supplied in order to rehabilitate Output j.

Y_{ij} = Total annual quantity of Input i to be supplied in order to maintain Output j.

Z_{ij} = Total annual quantity of Input i to be supplied in order to operate Output j.

W_i = Total annual quantity of Input i required for the drilling/construction of all water supply structures in a given year.

X_i = Total annual quantity of Input i required for the rehabilitation of all wells in a given year.

Y_i = Total annual quantity of Input i required for the maintenance of all water supply structures in a given year.

Z_i = Total annual quantity of Input i required for the operation of all wells in a given year.

Relationships:

The following relationships can be established:

$$W_{ij} = A_{ij} * APR_j$$

$$X_{ij} = B_{ij} * AWRR_j$$

$$Y_{ij} = C_{ij} * AMR_j$$

$$Z_{ij} = D_{ij} * AWOR_j$$

$$W_i = \sum_{j=1}^{m} W_{ij}$$

$$X_i = \sum_{j=1}^{m} X_{ij}$$

$$Y_i = \sum_{j=1}^{m} Y_{ij}$$

$$Z_i = \sum_{j=1}^{m} Z_{ij}$$

Finally, $W_i + X_i + Y_i + Z_i$ = the total annual quantity of Input i to be supplied to the water industry at Levels I and II for all purposes.

In addition, for the sake of calculating the direct costs of production in the well drilling industry, WISyMS provides unit costs (P_i, as CIF Mogadishu) for each type of input, in dollars. Then the total annual costs (PW_i) for each type of Input i for drilling/construction of drilled wells can be calculated as:

$$PW_i = P_i * W_i$$

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(Similarly for rehabilitation - PX_i; maintenance - PY_i; and operations PZ_i)

The total costs for drilling/constrution for drilled wells (PW) is then:

$$PW = \sum_{i=1}^{n} PW_i$$

(Similarly for rehabilitation - PX, maintenance - PY, and operation PZ)

WISyMS data output is presented in Annex I. Notes, sources, and estimating procedures are discussed in Section I-9, below.

I-9 WISYMS NOTES AND SOURCES

I-9.1 Introduction

This appendix provides notes to accompany the presentation of WISyMS contained in Section I-8 (Methodology) and Annex I (Data). It discusses sources of data and estimates used in the various runs of the model which are presented in Annex I and also discusses some of the estimating procedures involved in building the model. This section is organized into four sets following the presentation of the data contained in Annex I:

- **1984 BASELINE ESTIMATES**
  Annex I-1 Middle Level Estimates
  Annex I-2 Low Estimates
  Annex I-3 High Estimates

- **1990 PROJECTIONS/FORECASTS**
  Annex I-4 Middle Level Projections
  Annex I-5 Low Projections
  Annex I-6 High Projections

- **1990 CONSTRAINT ANALYSIS OF NATIONAL OBJECTIVES**
  Annex I-7 National Consumption Objectives (full standards)
  Annex I-8 National Consumption Objectives (partial standards)

- **1995 PROJECTIONS OF NATIONAL OBJECTIVES AND SUPPLY SIDE ANALYSIS OF CONSULTANTS' RECOMMENDED PROGRAM**
  Annex I-9 National Consumption Objectives without Consultants' Recommended Program (Demand Side Analysis)
  Annex I-10 National Consumption Objectives with Consultants' Recommended Program (Supply Side Analysis)

Each exhibit presents a run of some or all of WISyMS three inter-related submodels under different assumptions. The Baseline Estimates present 1984 estimates of current system parameters on the basis of three alternative sets of demographic and economic data and of inventory estimates as to the stock of existing water supply structures. The 1990 Projections/Forecasts extrapolate from the three baseline exhibits based on three alternative sets of growth rates applied to the demographic and economic data. The 1990 Evaluations of National Objectives are based on Annex I-4, the middle range projections, and include specific national goals for per-capita water consumption, standards, and service. The 1995 projections are an extention of the middle range 1990 projections, with the national goals for per capita water consumption (full standards) included as a target for 1995. Annex I-9 examines these goals in the absence of the Consultants' Recommended Program; Annex I-10 uses a supply side analysis to show how the recommended program meets the need.

I-9.2 WISyMS 1984 Baseline Estimates

The data presented in the first model, Annex I-1, "Middle Level 1984 Estimates of Population, Rates of Consumption, and Existing Structures" represent the Consultants' baseline estimates for year-end 1984. Annex I-2 and Annex I-3 present, respectively, lower and higher estimates for most variables used in the model, in order to illustrate the range of available estimates on each of the categories examined. Definitions and sources are described below, organized as in Section I-3 of this appendix and in Section I-7, "Definitions". Sources indicated in <brackets> refer to the bibliography, attached. Figures for which specific sources are not mentioned are Consultant's estimates. All calculations are explained in Section I-8.

I-9.2.1 Consumption Units:

- **Total Human Population ("Subtotal 1"):** Ministry of National Planning (MNP) figures indicate a total population of around 5.35 million <1> as of end 1984. While these are the government's official estimates, many experts believe that the 1975 census on which those figures are based was not an accurate one and that there may have been significant double counting and/or missed areas. Annex I-2 presents the Consultant's estimate of the likely lowest end of the possible range of population, and estimates presented in Annex I-3 are from aerial reconnaissance and ground sampling techniques conducted by Resource Management and Research (RMR) of London, which estimated the total population at over 6,885,000 as of 1983/84 <2>.

- **Urban Population:** Urban population figures are based on MNP's estimate of 25% of total population. Surveys for the Mogadishu Second Water Supply Project <3> estimated that about 11 percent of Mogadishu households have private connections ("HC") and 89% have access only to standpipes ("SP"). Kismayo claims to have about 20% of its households connected. The figures presented represent the Consultant's estimate that about 8% of the total "urban population" has household connections.

- **Rural Settled And Nomadic:** The figures presented are in line with MNP and RMR estimates of the percentage of the total population in each category: approximately 29% and 46% respectively.

- **Livestock:** estimates for camels, cattle, sheep, and goats are from the MMWR <4>, RMR <2>, and MNP <1>, which are in close agreement. The estimate for "other animals" is strictly hypothetical. "LSU" is Livestock Units, where the average camel is counted as one LSU, cattle are .8 LSU and Sheep and Goats are .125 LSU.

- **Agriculture, (Hectares):** for Annex I-1 are from MNP <5> estimates for "current irrigated cropland", "current rainfed cropland" and "flood-fed cropland". Annex I-3 estimates are from RMR <6 & 7>, adjusted to take into account different definitions for the categories.

- **Government And Industry:** The MNP <8> lists about 300 industries with five or more employees, but admits that probably many companies were missed.

I-9.2.2 Per Unit Water Consumption Factors

- **Daily Use Factor:** is the estimated weighted average consumption of water per day for each type of consumption unit.

- **Human Consumption of Water:** the figures employed represent rough estimates of average consumption, based on a number of sources, including the Mogadishu Water Supply Project <3> for urban consumption and MMWR <4> and the National Range Agency (NRA) for rural consumption.

- **Livestock Consumption Estimates:** are based on a variety of sources, including MMWR <4>, and the National Range Agency (NRA).

- **Agricultural Water Consumption:** the 68 cubic meters per day for irrigated land was calculated from assumed absorption of rainfall plus information in MMWR <4> on agricultural demand for surface and groundwater, (however, these estimates are based on an assumed 45% efficiency of water use in irrigation, instead of the more likely 20% efficiency estimated by most experts). The consumption figures for "rainfed" and "flood" agriculture are heuristic approximations offered for illustrative purposes only.

- **Government and Industry:** The Mogadishu Water Supply Project <3> estimates that government institutions use over half of the water consumed in Mogadishu, and that industry uses another 3%. The Consultant's estimates are based on an extrapolation to all urban areas. "Average Daily Consumption" was derived from these figures and from estimated numbers of establishments.

- **Days per Year:** is for use of water. This is 365 days/year for humans and livestock, the average potential growing season for agriculture, and working days/year for government and industry.

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- **Conversion Factor:** translates liters into cubic meters of water for human and livestock water consumption.

- **Annual Consumption ("M^3*K/YR"):** for each type of consumption unit is the calculated total annual volume of water consumed in thousands of cubic meters per year.

I-9.2.3 Water Consumption/Intake Structure Flow Relationships

- **Structural Control Percentages:** refer to the percentage of water taken from nature with the use of man-made water supply structures or improvements to natural sources. Figures presented are the Consultant's estimates.

- **Structural Control Amount:** is then the calculated volume of water consumed through man-made water supply structures, in thousands of cubic meters per year.

- **No Structure Percentage:** percentage of water consumed directly from nature without the use of structures.

- **Percentage Distribution Across Structures:** A matrix illustrating the percentage distribution of consumption across the range of water supply structures, by type of consumption. Since there are no published data available on this subject, the figures employed represent the Consultant's estimates based on conversations at the Water Development Agency (WDA), NRA, and MNP. Further research will be conducted by the WDA Planning Department.

I-9.2.4 Volumes of Water Provided Through Supply Structures

- **Total Consumption of Water by Type of Consumption and by Type of Structure:** A matrix calculated from the Structural Volumes for each type of consumption, and the Percentage Distribution Across Supply Structures: each cell of the matrix specifies the volume of water used for each particular use and supplied by a particular type of structure.

- **Structural Supply Volumes:** are the volumes of water consumed for all uses for each type of structure, summed down each column of the above-described matrix.

- **Volume Output, M^3*K/STR/YR:** is the weighted average volume, in thousands of cubic meters, of water consumed per single supply structure per year and is calculated in Figures 1 - 3 as "structural supply volumes" divided by the "numbers of water supply structures".

- **Days/Year:** is the weighted average number of days per year each type of structure is in use.

- **M^3/STR/DAY:** calculated volume of output in cubic meters per single supply structure per day.

I-9.2.5 Numbers of Water Supply Structures

- **Numbers of Water Supply Structures:** are estimates on the numbers of each type of water supply structure which were operational and in use as of end-1984. Numbers of drilled wells are Consultant's estimates based on known drilling activity over the past five years, and on the numbers of older wells assumed to be still operational. Estimates of the numbers of dug wells, uars, and ballehs are based on RMR data <7, 10 & 11>, along with standard errors, which were used for the numbers of supply structures presented in Annex I-2 and I-3. Figures presented on intakes from rivers and streams, burkeds, and dams are rough estimates, as there are no published comprehensive data on these structures.

- **Commercial Scale Structures:** are the subsets of operational supply structures the construction of which involve some capital input and at least the potential for construction on a commercial basis. In other words, they have been selected on the basis that their construction and/or maintenance require minimum inputs of raw materials, labor, fuel and equipment that can justify the involvement of "Level III" (water industry inputs) industries. Structures built on a self-help scheme and natural water sources are not included.

I-9.2.6 Detailed Descriptions of Water Supply Structures

- **Drilled Wells:** All drilled wells are considered commercial scale structures. Drilled wells are either urban, rural equipped with a hand-pump or a diesel pump, or irrigation wells. (Wind mill and solar pumps are being seriously considered for the future but at this stage, their number is too marginal to be taken into account in the context of our framework).

  Both **urban** and **rural diesel pump wells** have an average depth of 120 meters. Most wells are completed with a 12" or 14" diameter surface casing and 8" steel or plastic casing and screen. Hand pump and irrigation wells are assumed to be an average of 80 meters deep.

Diesel pumped wells serving rural areas are equipped with a diesel generator and pump unit that is capable of yields from 8 cubic meters per hour. Water is stored in an above ground concrete storage tank with a capacity of 45,000 liters which supplies one human water point and two animal water points by gravitation. It is assumed that about 70% of all rural drilled wells are equipped with a diesel pump, as are all urban and irrigation wells.

Hand pump wells are equipped with a lift pump which is manually operated and yields approximately 10 liters/minute. A sloped concrete pad is built around the well in order to drain spoil water. It is assumed that about 30% of all rural drilled wells are equipped with a hand pump.

Drilled wells are further classified as **"production"** or **"non-production wells"**. **Production wells** are completed operational structures, equipped with a pump and "producing" water. **Non-production wells** are test boreholes abandoned after it has been determined that water quantity and/or quality is not suitable. It is assumed that the number of non-production wells in a given year averages 30% of the number of rural production wells.

- **Hand Dug Wells:** Less than 15% of hand dug wells are in the Commerical Scale category. Depending on the kind of layers encountered while digging the well, well depth and lining requirements will vary. Wells dug entirely through soft layers of unconsolidated materials will require lining over the full height of the well, wells dug partly through consolidated materials will only require lining in the portions of the well which are unconsolidated. Therefore, it is realistically impossible to give one clear definition of a hand dug well. For the purpose of our analysis, an average commercial scale well is defined, which is a combination of the three types of wells described above. This well has a depth of 15 meters, is lined over 55% of its height and is covered in 20% of the cases.

- **Intakes From Rivers:** All intakes are considered commercial scale. Intakes consist of a pipe immersed into a river and connected to a diesel powered pump with a generator. In some cases, a concrete pump house is built in order to protect the diesel engine from the rain. For irrigation, water is then distributed through hand dug distribution channels.

- **Uars:** The Consultant estimates that about 4% of all uars are commercial scale. The commerical scale uars considred in the model are defined as those mechanically excavated with bulldozer or draglines. Their average size is of 50 m x 25 m at the top X 4 m days and of trapezoid vertical cross-section (this shape has been used by the National Range Agency in order to avoid degration). Their average volume is 2500 cubic meters. It is estimated that they are lined with plastic sheets in 10% of the cases.

- **Improved Ballehs:** The Consultant estimates that only about 2% of ballehs are commercial scale. For a commercial scale balleh, the natural balleh's shape is improved by earth moving with heavy equipment such as bulldozers. Then plastic sheets are installed in the bottom and on the sides in order to reduce seepage of the water. These balleh's holding capacity range from 10,000 to over 50,000 cubic meters, with an average of perhaps 30,000 cubic meters. The commercial scale ballehs considered in the model are assumed to be 1.5 meters deep, 300 meters long and 100 meters wide. They are also assumed to be lined with plastic sheet in 10% of the cases.

- **Burkeds:** All burkeds are considered to be commercial scale. The range of holding capacities is extremely wide, 10 to over 100 cubic meters in the Central Rangelands and South. In the North, where they originated, they may be as large as 600 cubic meters. The average holding capacity is assumed to be 60 cubic meters. They are sometimes roofed with materials such as corrugated metal sheeting, concrete, plastic sheet or simply shaded with small bushes suspended over the tank in nets.

- **Diversion Dams:** The Consultant estimates that about 2% of diversion dams are commercial scale structures. The average commerical scale diversion dam is assumed to be 120 meters long, of trapezoid shape, up to 4 meters high above channel invert with a top width of 2 meters. The side slopes of the earth section are 3 to 1 (average). Diversion Dams are constructed across water channels and are made of earth, stones, (the stones may be contained in gabions - wire cages), or concrete.

- **Average Useful Life:** for each type of structure are consultant's estimates. Actual lifespans for each type of structure will vary widely. The figures presented take into account the conditions and levels of maintenance currently prevailing in Somalia.

- **Annual Replacement Rates:** calculation gives a rough indication of the number of new structures needed solely to replace the ones likely to fail in a given year. For the 1984 middle-level estimates (Annex I-1), these replacement rates were introduced directly into the Level III submodel to illustrate the quantities of inputs required solely for replacement purposes. Notes of the Level III submodel follow the discussion of the 1990 forecasts and the Level II submodel, below.

I-9.3 WISyMS 1990 Projections/Forecasts

The next step in the simulation, presented in Annex I-4 through I-6, was to make a set of projections by applying different possible growth rates to the three sets of baseline (1984) estimates. Annex I-4 contains the middle-level projections for 1990, using middle-level growth rates applied to Annex I-1's middle-level base line estimates for each of the key variables. Annex I-5 contains the low-level projections for 1990, using low-level growth rates applied to Annex I-2's low-level baseline estimates. Annex I-6 contains the high-level projections for 1990, using high-level growth rates applied to Annex I-3's high-level baseline estimates. This gives us the largest possible range of projections for 1990 for each of the variables.

I-9.3.1 Level I Submodel

- **Population Projections:** for Annex I-4 assume a total annual average population growth of 2.9%. This figure is a weighted average of urban population growth (4.5% p.a.), rural settled growth (3.0% p.a.) and nomadic population growth (1.9% p.a.). The MNP calculates a net natural increase of 3.1% <2>, but indicates that net emmigration would bring the actual population growth rate to just below 3% p.a. We also assume that the percentage of urban households with private connections increases to 10%. Annex I-5 assumes a total annual average growth rate of 2.5%; with a 4% p.a. increase in urban population, of which 9% will have household connections by 1990. Annex I-6 assumes a total annual average population growth of 3.1%; with a 5% p.a. increase for urban population, of which 12% will have household connections by 1990.

- **Livestock Population Projections:** for Annex I-4 employ the MNP's estimate of about 1% for annual average net increase <12>. Annex I-5 uses 0.5% and Annex I-6 uses 2% net increase per anum.

- **Agricultural Projections:** Annex I-4 assumes a growth rate of 2.5% per anum for hectares under irrigated cultivation; and 5% per anum growth for hectares under rain-fed and flood-fed cultivation. Annex I-5

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assumes 1.1%, 2.5% and 2.5% growth rates p.a. respectively for the three categories; and Annex I-6 assumes 5%, 6% and 6% growth rates p.a.

- **Government and Industry Projections:** All three 1990 forecast Annexes assume no growth in water consumption for governmental institutions. Annex I-4 assumes the number of private commercial establishments will increase by 6.5% per anum, and that per-establishment consumption will increase by 8% per anum. Annex I-5 assumes the number of establishments will also increase by 5% per anum, and that per-establishment consumption will increase by 5% per anum. Annex I-6 assumes the number of establishments will increase by 7.3 per anum, and that per-establishment consumption will increase by 9.8% per anum.

- **Human Consumption Projections:** are the Consultant's estimates which indicate the likely range of figures on per capita consumption as of 1990.

- **Livestock Consumption Projections:** assume some growth for cattle and camel, but not for sheep and goats (except for Annex I-5, which assumes some growth from Annex I-2).

- **Agricultural Consumption Projections:** Per hectare consumption is assumed not to increase; for although crops could usefully consume more water, this should come about as a result of increased efficiency in water use, and not through greater quantities of water diverted to agriculture.

- **Structural Control Percentage Projections:** All three annexes assume that there will be increased reliance on water from structures in general, increasing "Structural Control Percentage" by up to five percentage points for each category of use.

- **Groundwater Percentage Projections:** All three annexes assume that there will be increased reliance on groundwater (water from drilled wells and hand dug wells) in particular, changing the percentage distribution in favor of drilled wells and hand dug wells by up to 5 percentage points, at the expense of surface water facilities.

The combined effects of human, livestock, agricultural, and industrial growth, plus growth of per-capita, per-head, per-hectare, and per-establishment consumption of water are significant. Annex I-4 indicates an increase of 4.3% per anum for total water consumption through all structural control facilities. Annex I-5 and Annex I-6 indicate a possible range of 1.6 to 6.6% per anum.

- **Numbers of Water Supply Structures:** For the sake of projecting the numbers of water supply structures for 1990, the Consultant assumed that output per supply structure per year would remain constant; and calculated the number of supply structures needed in 1990 to satisfy the projected growth in water consumption.

- **Commercial Scale Structures:** are assumed to remain as a constant proportion of total water supply structures for each type of facilitiy.

- **Useful Life:** is assumed to be unchanged.

These projections, together with the baseline estimates of the numbers of each type of supply structure in existence as of end-1984, are used to project the numbers of **new** supply structures needed to (a) replace old deteriorated structures and (b) to keep pace with growing water consumption needs. The procedure used by the Consultant is described in more detail in Section I-8.

I-9.3.2 Level II Submodel

- **Needed Total Drilled Wells:** from 1980-1984, numbers of drilled wells are Consultant's estimates based on known drilling activity over the past five years, and on the numbers of older wells still assumed to be operational; from 1985 through 1990 they are the projected requirements of numbers of wells needed to maintain existing (end-1984) volume of output per operational drilled well, keeping pace with growth in consumption from all sources.

- **Old Wells:** are Consultants' estimates on the number of operational drilled wells which had been in existence as of 1980. At that point, they would have had varied ages, and if their life expectancy is ten years, we can assume that about 10% of them would fail each year. By 1990, we could not expect any of them to be functional.

- **Previously Drilled "New" Wells:** are wells drilled since the beginning of 1980 but before the current year of the column. For the sake of analysis, the consultant assumes that all drilled production wells will last at least one year, and will then begin to fail at a rate of 10% per year.

- **Needed New Wells:** for years 1980-1984 are estimates of the numbers of wells actually drilled each year, based on known drilling activity. (Annex I-5 assumes we were double-counting or counting nonproduction wells, and Annex I-6 assumes we missed some drilling activity.) For 1985 through 1990, they are calculated

as the number of wells that need to be drilled or rehabilitated to make up the difference between "needed total wells" and "old wells" plus "previously drilled new wells".

A similar procedure is used for each of the other types of structures, although data are not available for past rates of construction.

I-9.3.3 Level III Submodel, Input-Output Technical Coeffiecients for Construction (A_{ij})

Note that all "inputs" used in the input-output model represent averages currently prevailing in the country. These averages are heavily influenced by work taking place under foreign auspices which is relatively more capital intensive than average, and by work taking place under governmental force account, which involves larger payroll than is perhaps necessary. Work undertaken by the private sector, (whose inputs are described in Section Three of the main body of the report and in Appendix D), may make more economical use of labor and capital, but are also currently restricted in their well depths and in the formations through which they can drill.

Raw Materials Inputs:

The list of raw materials inputs does not presume to include every single item involved in water supply structures construction. The purpose of this exercise is not to give a detailed bill of materials for each structure, but rather to estimate the potential impact of an increase in the number of structures on the Level III industries. Hence, the raw materials inputs have been selected on the basis that they are likely to influence Level III entrepreneurs' decision-making. More precisely, these are either raw materials used in substantive quantities or materials that are relatively expensive.

- **Cement, stone, gravel and sand** are used for well construction and for civil works. Gravel for packing of wells is used on a limited basis, and is not included in calculations. In the context of this model, gravel refers to crushed stones, used to make aggregate. Input coefficients have been assumed to be 20% higher than standard civil engineering coefficients, to allow for lost and damaged materials. The relatively high coefficients associated with rural and urban wells equipped with diesel pumps are due to the large storage tanks incorporated into the civil works. (See Definitions of the Structures in Section I-7).

- **Steel casing, screen and conductor casing** are used exclusively in drilled wells. Technical coefficient for production wells have been selected on the basis that the average well depth for urban and rural diesel pumped wells is of 120 meters. For irrigation and hand pumbed wells, the average depth is assumed to be 80 meters. Coefficients estimates were provided by CGDP experts.

- **Shelter:** The following structures are estimated to have a shelter:

  (i) All urban and rural drilled well equipped with a diesel pump
  (ii) 20% of irrigation wells and rural wells equipped with a hand pump
  (iii) 10% of the Hand dug wells
  (iv) 50% of the burkeds

- **Pipes** include plumbing and fittings in addition to the pipe itself. Technically, pipes are not part of the structures, but rather a link between different structures (e.g., from a well to a storage tank) or from a structure to the water end-user. (e.g., from a river intake to an irrigated field). Pipe requirements are substantial however and will increase as development of water distribution systems increases. We exclude from this analysis the piped distribution systems of municipal and irrigation water works.

- **Drilling Fluid (Bentonite):** is used at the rate of 20 sacks per 100 meters drilled.

- **Drill Bits:** are used at the rate of one per 1000 meters.

- **Hand Pumps and Diesel Pumps:** CGDP experts estimate that hand pumps are used in 20% of the hand dug wells and 30% of the rural drilled wells. In drilled wells, the choice between a hand pump versus a diesel pump is usually determined by the production rate of the well. Diesel pumps are generally utilised for needed production rates greater than 40 liters per minute. Clearly, other factors, when choosing between hand and diesel pumps, such as the location of the well, its accessibility to fuel and maintenance services, the identification of water users and the rate of utilisation of the well, are taken into account.

  In low population density areas, where wells are used primarily by the nomadic population as a source of water for human and animal consumption, wells are

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sometimes equipped with hand pumps. These areas are often remote areas, thus not easily accessible for maintenance and fuel services, another reason to decide in favor of hand pumps. Solar or wind pumps are also alternatives.

In high population density areas, urban areas, or intensive agriculture areas, where substantial quantities of water are needed, wells are usually equipped with diesel pumps. These areas are also usually easily accessible for maintenance and fuel services, a necessary condition to meet when opting for diesel pumps.

Intakes from rivers are equipped with diesel pumps. Clearly intakes are to yield substantial quantities of water, mainly for irrigation purposes, and therefore must be equipped with diesel pumps.

- **Rebars and Wood:** Rebars (reinforcement steel bars) are used in limited quantities in order to improve the tensile strength in masonry such as service tanks at well-heads and burkeds. Wood is used for concrete forms.

- **Plastic Sheets:** Plastic sheets are used to line some of the ballehs and uars to prevent seepage through the bottom and sides. The consultants estimate that around 10% of the ballehs and uars are lined with plastic sheets. Since a uar's average holding capacity is estimated to be about 2500 cubic meters (trapazoidal: 50 x 125 top x 4 depth), plastic sheet requirement per uar is 1,043 square meters. A similar estimate of plastic requirements per balleh (300 x 100 x 1.5) can be made and yields to approximately 15,000 square meters.

Labor Inputs

Labor inputs are measured in man-days and classified as skilled or unskilled. Note that these are current average labor inputs and reflect the large amount of WDA force-account labor and labor in foreign aided projects executed on behalf of the WDA.

- **Drilling Labour Inputs:** includes all labour involved in the borehole test drilling, log taking, hole reaming, well development, casing and screen installation. In the case of rural diesel pump production wells, drilling is estimated to be performed by a team of 13 people. These include 3 skilled workers: chief driller, assistant driller, and hydrogeologist plus a crew of 10 unskilled workers. The team is assumed to spend 24 days on the

well site. Drilling labor for shallower irrigation and hand pump wells is corresponsingly lower. In the case of non production/exploratory wells, the same size team will be present on the site but for a time period of 15 days.

- **Excavation Labour Inputs** relates to hand digging and/or earth moving with heavy equipment such as bulldozers. Diggers are unskilled whereas bulldozer operators are assumed to be skilled. Completion of hand dug wells are estimated at the rate of 3 men-hours per meter, 7 hours per day and an average well depth of 15 meters. Thus excavation labour input coefficients per hand dug well is:

  $$(3 \times 15)/7 = 6.43 \text{ men-days}$$

  Uars are assumed to be excavated with bulldozers and graders (uars hand dug on a self-help scheme by villagers are not included in this analysis since they are not commercial scale and do not require the involvement of "Level III" industries). It is estimated that an average uar with 2500 cubic meter capacity can be excavated with one bulldozer in 10 days. Ballehs are also excavated with bulldozers and graders. It is estimated that a balleh with a 30,000 cubic meter capacity will require 10 equipment-days. Burkeds are hand dug at the rate of 0.5 men-days per cubic meter of capacity, thus (0.5 x 60) = 30 men-days for the average burked of 60 cubic meters capacity. Diversion dams are dug with bulldozers and/or draglines. These are estimated to hold 7,500 cubic meters in average, hence will require approximately 15 equipment days.

- **Civil Works Labour Inputs:** CGDP experts estimate that a team of 9 people (1 skilled civil work supervisor assisted by 2 skilled workers and 6 unskilled crew members) will work for 6 days in the case of rural hand pumped wells and 36 days in the case of rural diesel pumped wells. Urban wells require somewhat more time, and irrigation wells somewhat less. The considerable amount of civil work associated with wells equipped with diesel pumps is due to the number and size of structures provided.

  In the case of hand dug wells, civil work consists principally in lining the well. The amount of work involved is directly related to the structure of the layers encountered. In soft layers, chances that soil will cave in the hole are high, thus lining is required over the full height of the well. Wells dug in hard layers may not require any lining. On average, 55% of the wells need to be lined and 1.2 men-days are

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necessary per meter of well lining. Thus, total civil works labout input requirement amounts to: (15 meters x 55% x 1.2 men-days/meter)=10 men-days which are practically split between one skilled mason and his assistant (unskilled).

In most instances (80%), intakes from rivers do not involve civil works. Intakes usually consist of a bare pump and an intake pipe immersed into the river. There are however some intakes that involve the construction of a concrete block structure, such as a pump house. It is estimated that for those intakes that require some civil work, 1 mason and an unskilled assistant will be working for 5 days. Thus, technical coefficients for both skilled and unskilled labour are: (10 men-days x 20%) = 2 men-days.

Uars and ballehs involve minimal civil works such as masonry work, but in those uars and ballehs lined with plastic sheets, labour inputs are required. These are classified under civil work for practical purpose. It is estimated that the installation of pastic sheets takes 1 man-day per 100 square meters, thus input technical coefficients for uars and ballehs are respectively of 1.5 men-days and 15 men-days.

Dams, for the purpose of this study, are structures usually made of stones and earth, thus requiring civil works. It is estimated that 6 skilled men-days, and 10 unskilled men-days are sufficient for the construction of an average sized dam.

- **Mechanical Labour Inputs:** Under mechanical labour inputs are grouped all labour inputs that involve some mechanical, plumbing or electrical work, such as installation of the pumps, pipes and fittings, generators, etc.

  In irrigation wells and rural drilled wells equipped with hand pumps, mechanical works consist mainly in the pump installation. The pump crew is composed of one skilled supervisor and 4 unskilled crew members who will be working for 3 days. Note that the pump installation itself can be completed within 1 day but it is reasonable to add 2 other days for deployment to and from site.

  In rural drilled wells equipped with a diesel pump, pump installation labour requirements are comparable to those of hand pumped wells; but mechanical work also involves the installation of pipes and fittings between the various structures attached to the well. It is assumed that 7 men-days will be necessary to complete the additional mechanical (plumbing) works.

Thus, the technical input coefficients for mechanical labour per drilled well with diesel pump are (a) skilled: (1 pump crew supervisor x 3 days + 7 plumbers-days) = 10 men-days and (b) unskilled: (4 °crew members x 3 days) = 12 men-days. For urban wells, these co-efficients should be 67% higher.

As for those hand dug wells equipped with a hand pump, mechanical labour inputs are similar to those required for drilled wells, technical coefficients are (a) skilled:
(1 men x 3 days x 20%)= 0.6 men-days and (b) unskilled:
(6 men x 3 days x 20%)= 3.6 men-days.

Intakes from rivers equipped with diesel pumps require mechanical labour inputs. As previously stated, in 80% of the cases intakes merely consist of piping from the river to the pump. Mechanical labour inputs are 3 skilled men-days and 12 unskilled men-days. In the remaining 20% more sophisticated structures, pipes and fittings are installed, requiring about 2 additional skilled men-days. Thus technical input coefficients are (a) skilled:
(3 men-days + (2 men-days x 20%)) = 3.4 men-days, and (b) unskilled: 12 men-days.

Neither uars, nor ballehs require any kind of mechanical labour inputs, thus coefficients are nil.

Burkeds require a minimum of plumbing work which is assumed to take 3 men-days of skilled labour and 6 men-days of unskilled labour.

In the case of dams, technical mechanical labour coefficients are assumed to be nil.

Equipment Inputs

Equipment Inputs are measured in equipment-days of utilization of drill rigs, pump rigs, heavy vehicles and light vehicles. Minor equipment items such as chisels and trowels have been neglected in order to simplify this analysis. Note that these are current average equipment inputs and reflect the relatively high capital intensity of work on foreign aid projects and WDA force account work.

- **Drill Rigs:** Drill Rigs are used exclusively for the construction of drilled wells. Drilling is performed with a rotary rig using a tricone drill bit. (or with a cable tool rig using a hammer bit). The drill rig input coefficient is estimated to be 30 days for urban wells, 24 days for rural diesel pump wells, 20 days

for rural hand pump wells, and 18 days for irrigation wells. These figures may appear a little high (under normal circumstances, this coefficient would be about 7 equipment-days), but it reflects a real situation where drilling progress is slowed down because of logistics such as lack of fuel, and difficult site accessibility. These amounts of time include 50% for drilling and 50% for down-time.

In the case of non-producing exploratory wells, drilling is stopped as soon as it has been determined that the site is not appropriate for well completion. The input-output coefficient is assumed to be 10 equipment-days.

- **Pump Rigs:** Pump rigs are used for the installation of the pump in drilled wells. The pump installation should not take longer than one day. One or two additional days are needed to move the pump rig to and from the site. Thus, the input coefficient is 2-3 equipment-days.

- **Heavy Vehicles:** include a wide range of vehicles, such as water tankers, fuel tankers, flatbed trucks, trailers and bulldozers.

  In the case of drilled wells equipped with hand pump, equipment requirements are as follows:

  1 Flatbed truck x 25 days
  1 Water truck x 20 days
  1 Fuel Tanker x 5 days
  1 Crane Truck x 20 days

  Thus the input coefficient is 70 equipment-days.

  Coefficients for irrigation wells should be about 33% lower.

  In the case of drilled wells equipped with diesel pump, additional equipment inputs are needed to support the civil works involved in the construction of the water storage and distribution structures. These additional requirements are as follows:

  Flatbed truck x 30 days
  1 Water Tanker x 30 days
  1 Fuel Tanker x 8 days
  1 Dump truck x 30 days

  Thus additional requirements are for 98 equipment-days so the input coefficient is: (70 + 98) = 168 equipment-days.

Coefficients for urban wells should be about 33% higher.

Hand dug wells require the use of two heavy vehicles for 5 days, thus the coefficient is 10 equipment-days.

Non production wells require the following heavy vehicles:

1 Flatbed x 12 days
1 Water Truck x 10 days
1 crane truck x 10 days
1 Fuel tanker x 3 days

The coefficient is 35 equipment-days of heavy vehicle per non-production well.

Intakes from rivers require heavy equipment inputs. It is estimated that 2 equipment days are sufficient for the pump installation and basic civil works.

As previously stated (see Excavation Labour Inputs), uars and ballehs require respectively 10 and 62 heavy earth moving equipment-days.

Burkeds can be completed with 2 heavy vehicles in four days.

As previously stated, diversion dams require 25 days of heavy earth moving equipment-days.

- **Light Equipment Inputs:** Light vehicles are used principally for passenger transportation; estimates of equipment-days are based on number of people and number of days on the site.

- **Fuel Inputs:** Fuel inputs are calculated as follows: (Estimated daily fuel consumption x Number of Equipment days).

  Estimates of Daily Fuel Consumption are as follows:

  Drill Riggs: 300 liters
  Pump Rig: 112 liters
  Heavy Equipment: 40 liters
  Light Vehicles: 30 liters

I-9.3.4 Level III Submodel, Input-Output Technical Coefficients for Rehabilitation (B_{ij})

Currently in Somalia, there are no functioning rehabilitation programs, and even simple pump replacements have not been performed. In the absence of a program of well/pump maintenance and repair (see below), well rehabilitation and/or

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pump replacement may be called for as often as once every three years, instead of the ten years which should be available for a routinely maintained well and pump. In many cases in the past in Somalia, wells with a pump in need of simple repair have been abandoned, and a whole new well eventually drilled to replace the old. This alternative is usually three times as expensive as pump replacement (including the cost of the new pump) or six to ten times the cost of pump repair.

If a program of routine pump maintenance and repair is in place for a diesel pump well, it should be rehabilitated once every ten years. The rehabilitation procedure will involve cleaning the well of the sand and other impurities that prevent the passage of water. In some cases, it could involve drilling the well deeper. At this stage, no rehabilitation procedures involving casing or screen repairs are envisioned. Such procedures require sophisticated equipment and skills which are not available in Somalia, and wells in need of such extensive service should be replaced with a new well.

Technical coefficients for rehabilitation are LBII/RMC estimates, and since future rehabilitation is assumed to take place on a contract basis, the inputs match those contained in Annex A-10 (Finanical Model of Contract Well Rehabilitation Activities) for labor and equipment utilization in the rehabilitation of rural diesel pump wells. Material inputs per rehabilitation procedure are as follows:

Material Inputs

- **Cement, Gravel, Sand, Pipes and Fittings, and Rebars and Wood:** 30% of the original construction requirements for each type of drilled well.
- **Diesel and Hand Pumps:** one per rehabilitation.

Labor Inputs

- **Pump Rig Operator and Skilled Construction Labor:** 12 to 18 days each, depending on type of well.
- **Rig and Construction Assistants:** three and two workers, respectively, times 12 to 18 days.
- **Drivers (Other Unskilled):** two workers times 12 - 18 days.

Equipment Inputs

- **Cable Tool or Pump Rig, Flat Bed and Pickup Truck:** 12 to 18 days each.

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Fuel Inputs

- **Cable Tool or Pump Rig:** 50 liters per day,
- **Flat Bed Truck:** 35 liters per day,
- **Pickup Truck:** 20 liters per day.

I-9.3.5 Level III Submodel, Input Output Technical Coefficients for Maintenance (C_{ij})

Currently in Somalia, little attention is paid to maintenance of water supply facilities; there are no functioning maintenance programs, so whatever maintenance there is takes place on an ad hoc basis if at all. Thus repairs are needed frequently. The repairs are also made only sporadically, so that communities may be without a functioning well for considerable periods of time.

A functioning, routine maintenance program would reduce the overall annual construction, rehabilitation, and repair costs, would ensure a reliable water supply, would ensure that financial resources are directed to the construction of net additions to stock (thus increasing the water supply), and would ensure regular demand for goods and services provided by "Level III" industries.

The following coefficients are estimates based on a contract maintenance program which could be followed in the immediate future, as described in Section Two of the main body of the Draft Final Report. This program involves only materials, skills and equipment which are either locally available or can be procured at reasonable cost and within a reasonable period of time. A brief description of the proposed maintenance program and the calculation of input coefficients is given based on the finanical model of contract maintenance activities presented in Annex A-12 of the Draft Final.

Maintenance of Drilled Wells Equipped with Diesel Pumps

These wells should be serviced at least once every three months for maintenance of the pump and every year for maintenance of the well and attached structures.

The routine maintenance procedures for the diesel driven pumps are as follows:

- Decarburize if the engine shows loss of compression or blow-by past the piston;
- Adjust valve clearances;
- Clean Cylinders

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- Check conditions of all belts and pulleys
- Clean the restrictor banjo union at the top end of the lubricating oil feel pipe to each cylinder head;
- Renew fuel filter elements
- Make any necessary repairs to pump and/or generator.

The maintenance procedures for the well, storage tank, human and animal water points are as follows:

- Sample the well, conduct chemical and bacteriological analysis, and disinfect
- Clean thoroughly the human and animal water distribution points
- Repair cracks in cement structures.

Maintenance and Rehabilitation of Drilled Wells Equipped with Hand Pumps

These wells should be serviced at least once a year and the following maintenance procedures should be followed:

- Remove, clean and make necessary repairs to hand pump,
- Pump the well with engine-driven pump to clean it, removing all dirt and organic materials,
- Disinfect the well with bleaching powder, and
- Repair cracks in cement base.

The following inputs for drilled wells are required:

Material Inputs

- **Pipes and Fittings:** one half meter per maintenance service for all diesel pumped drilled wells.
- **Spare Parts for Diesel Pump:** about 30% of all pump/generator units will need repairs each year (or 7.5% per quarter); each repair is estimated to involve an average spare parts requirements equal to 30% of the value of the original pump/generator set.

Labor Inputs

- **Supervisor:** one day per maintenance and one day for each repair job

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- **Mechanics:** two workers for three days for each maintenance and three days for each repair

- **Assistants:** two workers for three days for each maintenance and three days for each repair.

Equipment Inputs

- **Pump Rigs:** one day per pump repair,

- **Pickup Truck:** three days per maintenance service and three days per repair.

Fuel Inputs

- **Pump Rigs:** 50 liters per day.

- **Pickup Trucks:** 20 liters per day.

Maintenance of Hand Dug Wells:

Hand dug wells which are not equipped with a hand pump require less maintenance than drilled wells. The following items should be checked on hand dug well:

- Inspect well for signs of collapse in the walls,
- Inspect ground facilities for any unsafe conditions, unsanitary conditions, cracks in cement structure, and for a proper well cover.
- Disinfect well.
- Make checks of water depth and turbidity.

The following inputs are required:

Cement, stones, sand and gravel: 10% of construction requirements
Civil work labour: 10% of construction requirements

Hand dug well equipped with a hand pump are subject to the same maintenance requirements as drilled wells equipped with hand pumps. Diesel pumps for intakes from rivers require the same efforts as for diesel pumped wells.

Maintenance of Other Structures

Yearly Coefficients for maintenance of other structures are roughly estimated to be 10% of the construction coefficients for these structures.

I-9.3.6 Level III Submodel, Input-Output Technical Coefficients for Drilled Well Operation and Revenue Collection (D_{ij})

Operation of drilled wells is relatively simple, and requires a responsible individual, though not necessarily someone with extensive technical skills. For drilled wells providing drinking water to the public, the well operator may also function as a fee-collector. For other wells, it is not necessary for the "operator" to be present at the well at all times, but he or she would be responsible for the day-to-day functioning of the well, turning it on and off as needed, checking the meter and the fuel supply, and calling for the repair/maintenance service contractors if necessary.

The following inputs are involved in the operation of each drilled well:

- **Well Operator:** One person per well per day of operation for each type of well.
- **Diesel Pump:** Operating as many days as cited in the Level I submodel. Unit cost is calculated as the CIF price, amortized over the useful life, divided by the number of days in operation.
- **Fuel:** for urban wells, 36 liters per day (weighted average of municipal wells and private/industrial wells); for rural diesel pump wells, 15 liters per day; for irrigation wells, 25 liters per day.

I-9.4 WISyMS Constraint Analysis of National Objectives to 1990

Two sets of projections for 1990 have been made on the basis of the national goals with regard to human water consumption: specifically, the goals established by the MMWR in the Plan for the Drinking Water Supply and Sanitation Decade <4>. These are presented in Annex I-7 and I-8. Most of these figures are based on the demographic assumptions contained in Annex I-4, the middle level projections to 1990, with the following significant changes:

- **Human Population:** The percentage breakdown between urban families with household connections (HC) and those with access only to Standpipes (SP) was made on the basis of the Plan's Service Level goals of 80% of the urban population "served" (i.e., having a private connection or being within 200 meters of a standpipe), of which 40-50% have a private connection and consume 130 lcd, and 50-60% are within 200 meters of a standpipe and consume 50 lcd, while the remainder (20% of the urban population, all of whom are served by standpipe) are at a distance of over 200 meters from a standpipe and consume about 25 lcd.

- **Rural Population:** Consumption estimates are based on the Plan's service level goals of 60% of the rural population being "served" (i.e., being within 500 meters of a public standpipe) and consuming 30 lcd, and the remaining 40% of the rural population being beyond 500 meters from a public standpipe and consuming 20 lcd. The Plan further assumes that rural settled and nomadic patterns of consumption will be "similar".

- **Percentage Distribution Across Supply Structures:** Implicit in the stated goals of the Plan is an increased reliance on "safe, permanent" groundwater resources and in drilled well water supplies in particular, although the Plan did not explicitly link the growth in this type of consumption with the quantities of needed new drilled wells.

  For Annex I-7, the Consultant assumes that reliance on drilled wells in urban areas increases to 80%, and in rural areas to 30% (60% served by groundwater resources; about half each by drilled wells and hand dug wells). Once new water supplies are in place, it must also be assumed that they will be used by industrial firms in urban areas, and by livestock in rural areas, increasing these categories' reliance on drilled well water supplies along with human consumption's.

  Annex I-8 makes use of a more modest set of goals found in the planning document. The second set of goals implies less of an attempt to develop groundwater resources and a relatively heavier emphasis on surface water resources and catchments to serve its target populations. The distribution for rural areas in this run is: 15% for drilled wells, 30% for hand dug wells, and the rest distributed across the range of surface/catchment supply structures.

- **Numbers of Water Supply Structures:** These numbers increase greatly, solely due to the increased per capita consumption of water assumed in the national goals. The Consultant allowed WISyMS to show other structures to be used as a source to make up the needed growth in consumption, (even though many of these are surface water and catchment structures and therefore not necessarily "permanent and safe").

I-9.5 1995 Projections of National Objectives and Supply Side Analysis of Consultant's Recommended Program

Finally, we include two WISyMS projections through 1995, based in the middle level projections to 1990, continuing with the same growth rates for populations and economic activity (i.e., for consumption units), used for Annex I-4, and including the full national objectives for per capita consumption as targets for 1995, as described for Annex I-8, above.

Annex I-9 makes a straight forward WISyMS analysis as described above for Annexes I-4 and I-8. Annex I-10, on the other hand, assumes that the Consultants' Recommended Program with regard to well drilling, rehabilitation, maintenance, and operations has been in effect for the ten year period 1986 through 1995. The following assumptions are affected as described below:

I-9.5.1 Level I Submodel

- **Numbers of Water Supply Structures:** For the sake of projecting the numbers of water supply structures for 1995, the Consultants assumed that a program of contract operations and routine maintenance on 40% to 45% of about 1500 non-irrigation wells should have the effect of increasing the annual volume of water output from each well involved by about 33%; and thus increasing the average annual volume of water output from the entire stock of drilled wells by about 14%. This would correspondingly reduce the need for the number of wells needed to satisfy the projected volume of water required for 1995.

I-9.5.2 Level II Submodel

In place of the usual WISyMS demand side analysis for non-irrigation well drilling for Level II, Annex I-10 presents the Consultants' "with program" supply side projections of drilling and rehabilitation (as outlined above in Section I-5.5.4). These projections are summed for the section labled "TOTAL NON-IRRIGATION," described in further detail immediately below.

- **Old Wells:** deteriorate as described for Annex I-4, above.

- **Previously Drilled "New" Wells:** All new and newly rehabilitated wells, after the start of the Consultants' Recommended Program, are expected to be included in a program of contract routine maintenance and repair. These wells should not "fail" for ten years after their construction/rehabilitation. Thus the only deterioration in the stock of wells will be from the old (pre 1986) wells, which will continue to fail at a rate of 10% of the original (1986 stock) per annum.

- **Needed Rehabilitation:** This row highlights the numbers of wells which fail (as described immediately above) in a given year.

- **Rehabilitated Wells:** The well rehabilitation portion of the Consultants' Recommended Program covers some, but not all, failed structures each year.

- **New Drilling:** is the sum of all non-irrigation drilling projected by the Consultant, assuming implementation of the Consultants' Recommended Program.

- **New Stock:** For this supply side analysis is the sum, in any given year, of old plus "previous" plus rehabilitated plus newly drilled wells.

I-9.5.3 Level III Submodel, Input-Output Technical Coefficients for Constructon (A_{ij})

Inputs for the Level III submodel of Annex I-10 represent estimated averages of drilling being undertaken by local government agencies, foreign firms, and local private firms, assuming implementation of the Consultants' Recommended Program. In 1995, about three quarters of all wells drilled are expected to be drilled by local private firms (90% of all rural wells, half of all urban wells, and 67% of irrigation wells) with a substantially smaller complement of labor and equipment, and taking much less time than has been required, on avaerage, in the past. Direct costs for rural diesel pump wells drilled by local private contractors would involve the following level of inputs, based on the financial models for contract well drilling presented in Annex A-14:

Material Inputs

Same as described for Annex I-4 above.

Non-production wells: assumed to be 25% of all rural production wells.

Labor Inputs

- **Supervisor/Chief Engineer:** 15 days per production well; 10 days per non-production well;

- **Chief Driller/Assistant Engineer:** 15 days per production well; 10 days per non-production well;

- **Civil Works Engineer:** 15 days per production well;

- **Mechanical Engineer:** 10 days per production well;

- **Carpenter:** 2 days per production well;
- **Drilling technicians and semi-skilled assistants:** 3 each for 10 days per production well and 5 days per non-production well;
- **Construction Laborers:** 5 laborers for 10 days;
- **Mechanic Assistants:** 1 person for eight days;
- **Other Unskilled:** 2 workers, each 10 days per production well and 5 days per non-production well.

Equipment Inputs

- **Drill Rig:** 15 days per production well and 10 per non-production well, of which 9 and 4 days respectively, actually spent drilling;
- **Pump Rig (pump tripod on pickup truck or cable tool rig):** 3 days per production well;
- **Pickup Truck:** 22 days per production well and 13 days per non-production well;
- **Other Light Vehicle:** 30 days per production well and 13 days per non-production well;

Fuel Consumption

- **Drill Rig:** 250 liters per day (50 if a cable tool rig is used, although time spent per well of given depth is longer);
- **Pickup Truck:** 35 liters per day
- **Light Vehicle:** 20 liters per day (petrol)

I-9.6 **Final Note**

The Consultant's interpretation of WISyMS data output from all three levels and for all three functions forms an important basis for the analyses contained in the main body of the report and in the Executive Summary.

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