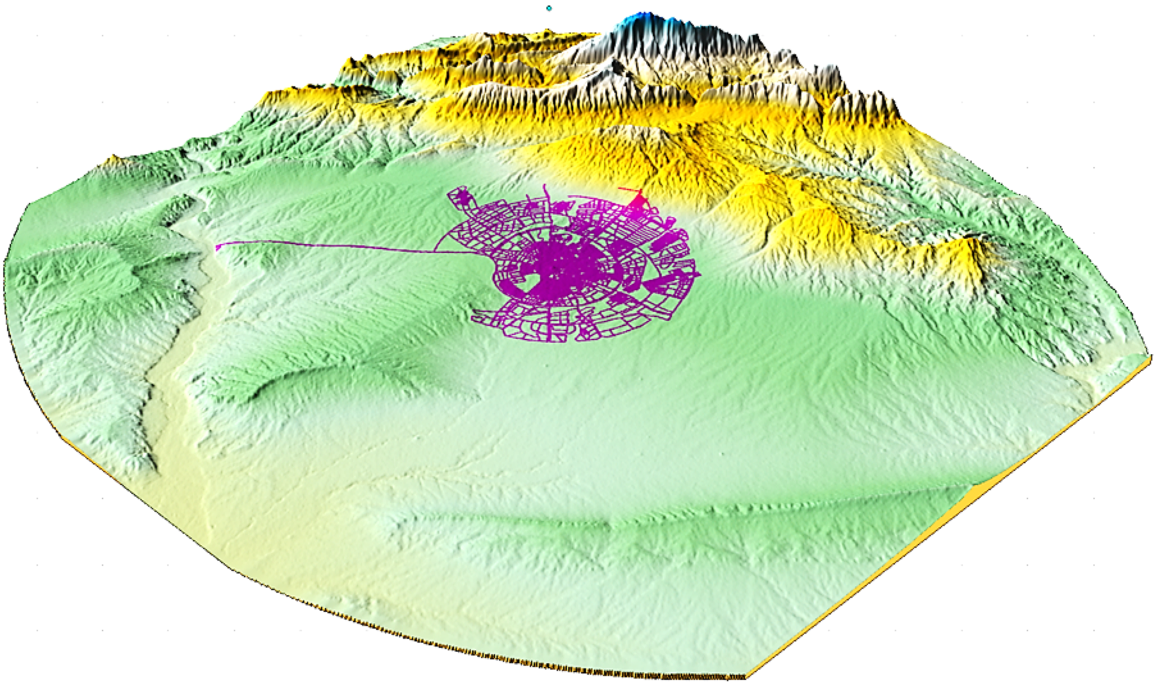
KURDISTAN REGIONAL GOVERNMENT - IRAQ

MINISTRY OF MUNICIPALITIES AND TOURISM

Kurdistan Region Infrastructure

Water Sector Master Plan

HYDRAULIC CALCULATION



WD - ERBIL

REPORT

HORIZON: 2035

JULY 2012

SETEC Engineering

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Asbestos cement
ADD	Average daily demand
ALC	Active leakage control
AMR	Automatic meter reading
ASCII	American standard code for information interchange
AWWA	American Water Works Association

BS	Booster station
CAD	Computer-aided design
CI	Cast iron
CIS	Customer information systems
DEM	Digital elevation model
DI	Ductile iron
DCI	Ductile cast iron
DMA	District metering area
DN	Diameter Nominal
DVGW	German Technical Association for Gas and Water. Deutsche Vereinigung des Gas- und Wasserfaches E.v. - Technisch-Wissenschaftlicher Verein
DWP	Dohuk Water Project (OHITAN)
DXF	Drawing Interchange File Format
EPANET	Hydraulic modelling software of the United States Environmental Protection Agency
GIS	Geographic information system
GPRS	General packet radio service
GPS	Global positioning system
GSM	Global system for mobile communications
GST	Galvanized steel
H	Head
HDPE	High Density Polyethylene
ID	Identification
IWA	International Water Association
JICA	Japan International Cooperation Agency
K&A	Khatib & Alami
KfW	German Credit bank for reconstruction Kreditanstalt für Wiederaufbau (German Development Bank)
l/c/d	Liter per capita per day
m^3/a	Cubic meters per year
m^3/h	Cubic meters per hour
MASL	Meters Above Sea Level
MDD	Maximum daily demand
MNF	Minimum night flow
MoP	Ministry of Planning
NDF	Night to day factor
NRW	Non-revenue water
O&M	Operation and maintenance

P	Pressure
pcs	Pieces
PE	Polyethylene
PHD	Peak hourly demand
PL	Pressure logger
PLC	Programmable logic control
PM	Pressure management
PMA	Pressure management area
PRV	Pressure reduction valve
PS	Pumping station
PVC	Polyvinyl chloride
Q	Flow
SA	Supply area
SCADA	System for Supervisory Control and Data Acquisition
SIV	System input value
ST	Steel
TM	Transmission pipeline
UFM	Ultra sonic flow meter
UFW	Unaccounted-for water
WDN	Water distribution network
WHO	World Health Organization
WLS	Water level sensor

1 INTRODUCTION

1.1 Content

This report covers the preparation and execution of the hydraulic calculation, calibration and analyses for the area of ERBIL, undertaken from June 2011 to July 2012 by SETEC Engineering under the project "CONSULTING SERVICES FOR KURDISTAN REGION INFRASTRUCTURE WATER SECTOR MASTER PLAN" financed by the Kurdistan Regional Government - Iraq / Ministry of Municipality.

The hydraulic model is intended to develop the Hydraulic Scenario for the year 2035 and to provide a guideline for detailed planning of IFRAZ IV new WTP, new transmission routing, new main reservoirs and their location and the design of supply areas as well as principal operation measures as required. The proposals are based on information received and calibration of the present situation.

Activities related to hydraulic analysis like data mining and mapping commenced in 2010 and included site investigations with field survey measurement. Calibration measurements were made in November 2011 in accordance with the Addendum No. 1 Terms of Reference.

The report shall assist in planning of a structured development of the extension and strengthening of the overall water system. This shall ensure a continuous supply to all consumers in an efficient and economical way at acceptable supply pressures.

1.2 Project Area

The project area corresponds to the area covered by the Urban City Masterplan developed by Dar al-Handasah covering the area inside a new green belt. This area has been included into the responsibility of WD ERBIL City.

The city develops at tremendous pace with housing projects especially in the east and north sectors. These areas need supply with water services. The results of this report provide the base to plan these extensions under consideration of the overall development.

Existing planning and considerations are incorporated in the establishment of the hydraulic model. These are:

- the Project IFRAZ IV envisaged in 2015,
- the on-going JICA water rehabilitation project inside of the 60meter road and quarters in the south west of Erbil city.

The Consultant's team consisted of the following technical experts: Faraedun Zada, Spear Zozik, Gabriele Weihrauch, Richard Dobrounig, Stephan Woelcher, the team leader Josef Just and project manager Wolfgang Charlet. Words of thanks must be given for good assistance and cooperation provided by WD Erbil management and WD Erbil technical staff in every necessary relation.

All maps and presentations of hydraulic results are attached in the Appendices. A soft copy of this report is also provided including all information, inclusive hydraulic model and other digital data, in electronic form.

1.3 Consultant's Scope of Works

The main items of the scope of works as per Terms of Reference are:

- Elaboration of operational hydraulic model from.
- Preparation of network maps,
- Preparing digital maps for the hydraulic model based on all available information,
- Establish a DEM,
- Undertake population and demand allocation, modelling and analysis of demand,
- Data transfer into and preparation of the hydraulic data base,
- Develop and deliver a hydraulic model based on the established hydraulic data base covering the existing situation and the scenario 2032,
- Supply of 15 No. pressure loggers (0 to 20 bars) and 1 Flow Meter as well as hydraulic software,
- Design the field investigation and measuring campaign, install the measuring devices and undertake the calibration measurements for 24 hours.
- Calibration and revision of input data, verification of hydraulic model.
- Steady state calculation of load cases, development of extended period simulation models from existing steady-state models.
- Elaboration of pressure zoning and operation of the distribution system, network re-zoning and operational efficiency.
- Network design for pipe routing and pipe sizing for new constructions and future network extensions.
- Guideline for required construction.
- Technical Report.

The hydraulic model may serve various purposes. In line with the Terms of Reference the focus was set on development of an accurate and reliable hydraulic model for calculating the primary distribution system. This forms base for a calibrated flow status for a set of present load cases. Such information is a requirement for proposals on improvements and extensions of the network and its components and the required pressure zoning to cover the situation in 2032.

The final model considers transmission and distribution mains from DN 200 and above. The detailed layout of distribution networks within supply areas must be subject to separate simulations after an existing layout is confirmed or a new area is to be designed. The demand requirements have been considered for each supply area at the nodes along the relevant supply mains.

Representatives of the WD ERBIL, working in close cooperation with the Consultant, were included in all steps of the process. This achieved maximum transparency and gave the opportunity to provide some on-the-job training. Problems and challenges encountered could thus be solved within a short period of time.

1.4 Data Provided by the Client

The Employer's input as defined in the contract is as follows

- Make available all digital information about the water supply network,
- Supply in digital form of geodetic heights or DEM of the supply area and for key assets like reservoirs and pumping stations,
- Indicate locations of intakes, water treatment plants, pump stations, reservoirs, pressure reducing valves and bulk meters marked in digitized form as well as information about their characteristics and specifications,
- Give detailed consumption data for the pipeline routes indicated by node points (consumption management),
- Determination of measurement point locations equally spread throughout the network for installation of pressure loggers,
- Determination of locations for installation of mobile ultrasonic flow meters,
- Precautions for protection of removable flow meters and loggers at locations where those are installed during the whole measurement period,
- Secondment of experienced engineers having network knowledge as well as operation.

WD Erbil provided required basic data for implementation of works to an extent as far as possible. This did not cover all contractual requirements and the consultant had to improvise or to locate other sources of information with assistance by the client.

Information and data supplied by the client are summarised in the following:

- Basic digital CAD maps of the Erbil quarters distribution network, including information about pipe material and diameter from WD Erbil GIS
- PDF copies of JICA/K& A project network maps
- GIS network maps of towns and villages elaborated for WD Erbil surrounding under MP.
- Erbil Urban City Masterplan by Dar al-Handasah
- Population projection based on Ministry of Planning's figures
- Data records, gathered from bulk meter readings throughout the new production and transmission system.
- Basic information about existing key assets like reservoirs, pump stations, booster stations, pressure reducing valves.

2 TECHNICAL BASICS AND GUIDELINES

2.1 Hydraulic Simulation

2.1.1 LOGICAL SEQUENCE OF NETWORK DESIGN AND ANALYSIS

The systematic sequence of design steps is illustrated below.

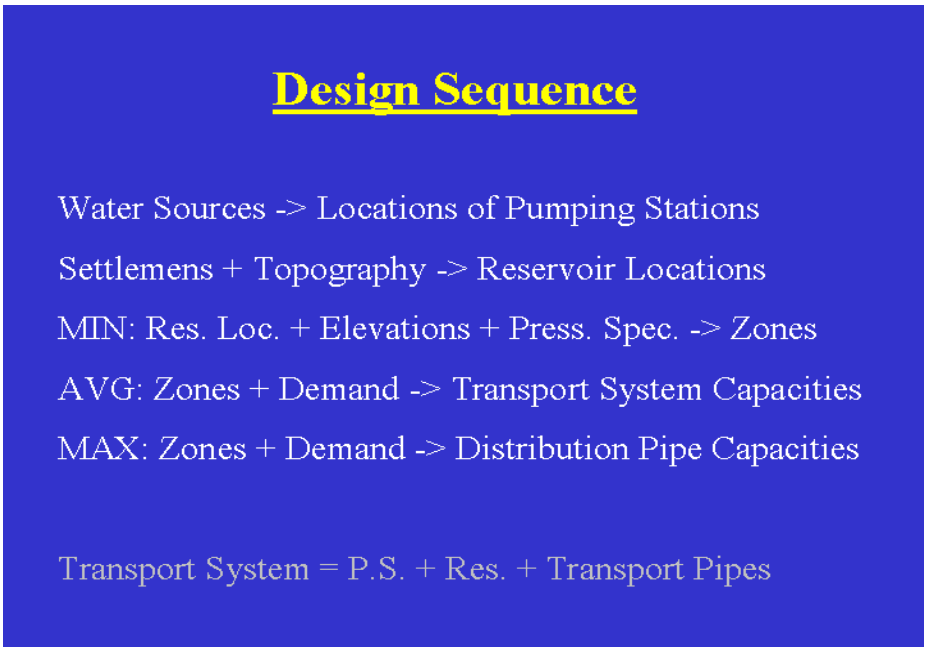


Figure 2-1: Sequence of Water Network Design

The purpose of a water supply system is, to bring water from where it may be found, the source, to the places where it is demanded by the population (transmission mains, storage, distribution system).

The **locations of water sources** are determined by the geological and hydrological properties of the landscape and are thus a natural general framework for the water supply system. The term “general framework” means that these conditions are to a large extent beyond the freedom of choice for the network designer.

The **locations of water demand** are given by the geographical distribution of the population in settlements and are thus a historic and cultural determining factor.

The purpose of the system of **transport mains** is to convey potable water in bulk quantities through large diameter pipe lines from the water sources to storage/ supply reservoirs near population centres.

The **distribution system** provides water from storage reservoirs to individual households by distribution mains and smaller diameter network pipes, preferably by natural gravity flow and not by pumping.

The designer has some freedom in choice of the locations of the supply reservoirs and the layout of the transport system may, based on experience and hydraulic simulation results.

2.1.2 SUPPLY/ PRESSURE ZONING

A **minimum demand load (or zero flow) case simulation of the distribution network**, together with elevation contour lines, will guide the design of supply zone boundaries. A supply zone is that part of the distribution system which is fed by a specific reservoir. Unless a reservoir is artificially elevated, it usually has to be situated outside (uphill) of its supply zone. A supply zone may have to be subdivided into several pressure zones, if the terrain is sloping and minimum and maximum supply pressure specifications have to be met. Due to the basic hydrostatic law, upper and lower pressure zone boundaries are preferably chosen along elevation contour lines and some pressure reducing or pressure breaking devices are needed at the interconnections between pressure zones.

This is illustrated in the figure below.

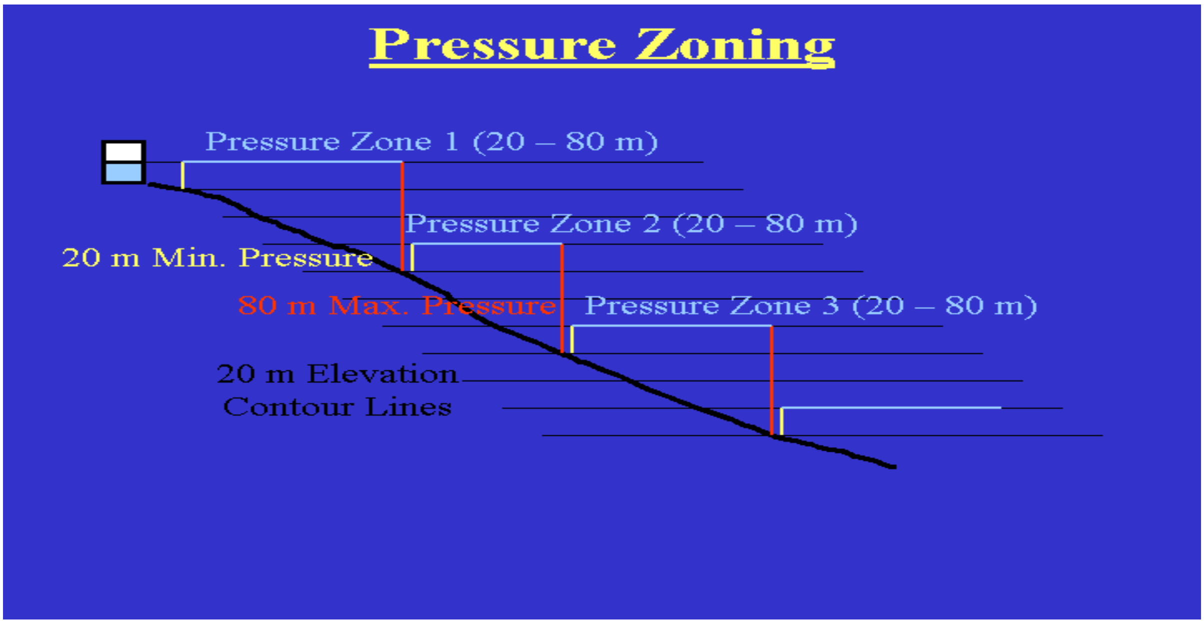


Figure 2-2: Pressure Zoning in Water Distribution Systems

Demands can be calculated after determination of the supply zones and be used for the design of the reservoirs, pumps (if required) and pipe lines.

2.1.3 LOAD CASES

The hydraulic modelling is done using three load cases:

- **average hourly demand**
  to dimension the main transport system
- **maximum (peak) hourly demand** and
- **minimum hourly demand.**

The maximum and minimum load cases are used to determine pressure zones and to dimension the distribution system. For detailed information refer to section 7.5.

2.2 Standards Used

As a basis for the parameters used and the hydraulic calculations made the following standards were used:

- DVGW Regelwerke (Bodies of Rules and Regulation from the German Association Gas and Water), in particular
  - DVGW-Worksheet GW 303: Hydraulic calculations on water supply systems.
  - DVGW-Data Sheet GW 110: Technical Units for Gas and Water
- DIN relevant standards, regulations and guidelines (German Industrial Standards)

2.3 Hydraulic Model NESEI

NESEI was used for the project and is a software package of programs, designed for the hydraulic simulation of water or gas distribution pipe networks. It is a tool which allows performing the hydraulic analysis, optimisation and design of complex distribution systems.

The mathematical solution of the steady state hydraulic equations for a complex pipe network must comply with three basic laws:

- The pressure loss formula for a straight cylindrical pipe (Darcy-Weisbach formula)
- The law of mass conservation (Kirchhoff's 1st law)
- The law of energy conservation (Kirchhoff's 2nd law)

All available experimental facts about the pressure loss are contained in the Darcy-Weisbach formula together with the Moody diagram of friction loss coefficients over a very wide range of Reynolds numbers. Various analytical formula (Prandtl, Kharmann, Colebrook, White, Nikuradse, Reynolds, Hagen, Poisseuilles, Hazen-Williams etc.) only get near to these experimental facts for different partial regions of the diagram.

NESEI uses numerical tables of the experimental facts (complete Moody diagram) and the Darcy-Weisenbach formula, while most other hydraulic programs use some analytical approximation, e.g. a power law, because some iteration methods yield an increase in computational speed for such a simple law.

2.3.1 ASSUMPTIONS

The hydraulic analysis of the water network was carried out with aid of the Knowledge Base Software NESEI V9.3

The head loss due to pipe resistance is calculated by the equation

H = f L/D. V2/2g

Where:

H = head loss (m)
L = length of pipe (m)
D = pipe diameter (m)
V = velocity (m/s)
g = gravitational acceleration
f = friction coefficient

The friction coefficient used in the D'Arcy-Weisbach is calculated from the Colebrook-White friction factor.

$1 / \sqrt{f} = -4.0 \log [2.51 / 2Re \sqrt{f} + k/3.7D]$

Where:

f = friction coefficient

D = the pipe diameter

k = the mean height of roughness in the pipe

Re = Reynold's number defined as:

$Re = \rho V D / F$

Where:

ρ = the liquid density

v = the velocity of flow

D = pipe diameter

F= the dynamic viscosity (see below)

An integral roughness (network roughness) of 0.1 mm was assumed for the reticulation network, also covering the hydraulic losses of fittings, appurtenances and construction imperfections.

The Colebrook-White friction coefficient is recalculated for each pipe after each iteration, to cater for the variation of the Reynold's number with fluid velocity.

The default value of Kinematic viscosity used in WATER is:

1.002 x 10-6 m2/s (water at 20˚C), and the default density is 1000kg/m³.

2.3.2 PRINCIPLES OF HYDRAULIC MODELLING

A model is a mathematical construct, which behaves in certain aspects like a real system. The basis for hydraulic models is derived from a systematic observation of nature with the help of experiments and the formulation of hydraulic laws with the help of a suitable scientific theory.

It is important to distinguish between hydrostatic situations (no flow), steady state or stationary situations (constant flow), quasi-dynamic sequences of steady states (extended period).

It is the responsibility of the hydraulic expert who operates the model, to know the limits of his model, to classify hydraulic situations as described above correctly and to recognise any unusual phenomena outside the range of the models applicability.

The following laws are relevant for the steady state and extended period simulation of a drinking water distribution network:

- The law of mass conservation, which requires, that all flows into and out of each node add up to zero.
- The law of energy conservation, which requires, that all pressure losses and pressure gains along any closed loop add up to zero.
- The law for the dynamic pressure loss due to friction within a cylindrical pipe.

If these laws are formulated for a large hydraulic network a huge set of non-linear equations is generated. Various methods of numerical mathematics are available to solve these equations for the general case and a number of commercial computer programs are available to solve these equations for a specific real distribution system by feeding the program with specific data.

A hydraulic network is first of all described by its topological connectivity and the dimensions and materials of its pipes and devices like reservoirs, pumps, valves and regulators. These network parameters are rather permanent as they may only be changed by construction work.

Input variables are the demands (consumption rates), the reservoir filling levels and operational device parameters like, pump speeds, valve and regulator settings, which may be changed easily.

The model computes from these data the output variables like flow rates and pressures for all pipes and nodes.

2.3.3 DESCRIPTION OF HYDRAULIC MODELLING PACKAGE

The software package NESEI for the simulation of large drinking water distribution networks integrates several top-of-the-line software products under a common user interface.

AutoCAD Map [from Autodesk]

This window is used for the visualisation of the general landscape, roads, buildings etc. and the pipe network as well as for interactive graphical data manipulation within a special NESEI menu.

SQL-Base [from GUPTA]

This is used for the save and crash proof storage of all input and output date of the simulation program.

NESEI [from SETEC]

This window is used for the tabular representation and manipulation of input and output data of the hydraulic simulation. The NESEI package includes several programs which are hidden from the user under a common user interface:

SUPERNET,

for the hydraulic simulation unlimited,

SUPERMIX,

for the simulation of water quality (propagation, mixing and decay of inert aan chemically reactive substances),

SURFER [from Golden Software]

This is a powerful contouring, gridding, and surface mapping package for scientists and engineers.

SUPERNET

uses a unique mathematical algorithm for the hydraulic analysis. Steady state, extended period (time step) and automatic pipe diameter optimisation simulations have been implemented.

SUPERMIX

can perform water quality analysis as a follow–up run after a SUPERNET hydraulic simulation.

Together the following simulation models are provided:

Steady state hydraulic simulation (SUPERNET)

Steady state inert propagation (SUPERNET)

Time step (extended period) hydraulic simulation (SUPERNET)

Time step reactive propagation (SUPERNET + SUPERMIX)

Automatic pipe dimensioning (SUPERNET)
Automatic pipe roughness calibration (SUPERNET)

Automatic pipe blockage detection (SUPERNET)

The following devices may be simulated:

Throttle (partially closed valve)
Flap (preventing back flow)
Closed valve
Flow control valve
Pressure reducing valve (forward; optional: flow corrected target pressure)
Pressure sustaining valve (backward)
Reservoir valve (bottom drain pipe with flap and overhead filling pipe)
Reservoirs overflow transfer to lower zone
Reservoir inlet float valve
Pump (ideal/real with quadratic characteristic)
Flow transfer / design pump
Pressure regulated pump
Speed regulated pump
Switches (up to 3 levels with hysteresis)
PLC controls
User defined devices as requested on short notice

Loads / consumption rates as well as leakage loss rates may specified for individual nodes but also as distributed (m^3/h per km pipe length) for quick approximate simulations without load assignment.

Leakage losses are simulated as pressure dependent with a specifiable exponent.

House storage tanks may be specified for individual nodes but also as distributed (m^3 per km pipe length).

For negative supply pressures demands and leakage losses are switched off automatically.

Simulations may proceed even beyond some reservoirs and pipes running dry, describing the gradual emptying of the network and its eventual refilling.

The “hydraulic backbone tree” of the network may be visualized graphically. This facilitates the optimal design of calibration runs, supply pressure zones, permanent and temporary leakage control zones and the topological leak location in temporary leakage control zones via selective valve closures.

3 ERBIL EXISTING WATER SUPPLY SYSTEM

3.1 Coverage

The water supply system of Erbil supplies customers within the area of Erbil city and newly surrounding municipalities like Kasnazan, Banslawa, Daratu as well as villages and settlements inside green belt area of official Urban City Masterplan.

3.2 Water Supply Network Characteristics

In 2011 approximately 770,000 people are supplied with potable water in the project area via house connections. A total length of about 1,450 km was imported into the hydraulic model database representing the existing transmission and distribution mains.

The city's water demand is currently supplied from Ifraz at Great Zab River about 25 km northeast from the city centre (the main source) and about 800 deep wells within the city.

The Ifraz water treatment facilities consist of:

- Ifraz I, built in 1968 with a capacity of 1,600 m³/h.
- Ifraz II, built in 1983 with a capacity of 2,880 m³/h and
- Ifraz III, built in 2006 with a capacity of 6,000 m³/h.

Water is pumped to the Dawajin reservoir with 24.000 m³ capacity.

The about 800 deep wells (in average each well has a capacity between 20 and 30 m³/h) operated by WD Erbil are spread over the entire city. These wells supply quarters, factories and hospitals, educational and technical institutions.

The current intermediated distribution of supply to divided supply zones and sectors is organized for manual water rationing by strategic valve operation. This allows delivery of minimum requirement for filling of roof tanks to satisfy customers. Some customers use small booster pumps to suck water from the network to get a supply.

Maps of main pipes, showing pipe materials and diameters, were updated by the consultant based on the knowledge of WD-Engineers. This process continued until acceptable degree of completeness of the main system was reached for modelling purposes. The following statistical information on the present network is neither complete nor confirmed in quality, especially for distribution pipes inside the sectors.

Service connections are not considered at all.

Dimension	Material and Length [m]											Total Length	
	DI	n/a	CI	DIK	DN	GRP	PE	PEK	PVC	ST	STg	[m]	[%]
50		1,310										**1,310**	**0.1**
65									50			**50**	**0.0**
75		2,024					124			93,647	10,917	**106,713**	**7.4**
90								981				**981**	**0.1**
100	277,875	46,573	3,733	19					4,047	246,088		**578,334**	**40.0**
110							65,140	259,540				**324,680**	**22.5**
150	35,779								841	74,553		**111,173**	**7.7**
160							12,376	46,330				**58,706**	**4.1**
200	214			42,166	471		2		5	32,870		**75,729**	**5.2**
250	3,773			970						20,719		**25,462**	**1.8**
300	176			3,556						5,589		**9,320**	**0.6**
400	139			4,393						2,416		**6,949**	**0.5**
450										140		**140**	**0.0**
500	19,522									20		**19,542**	**1.4**
600	1,640			703						270		**2,613**	**0.2**
700	49,512			243								**49,755**	**3.4**
800	8,053			1,101						26,982		**36,136**	**2.5**
900	44											**44**	**0.0**
1000				1,193								**1,193**	**0.1**
1200	4,374											**4,374**	**0.3**
1300										30		**30**	**0.0**
1500	50					32,038						**32,088**	**2.2**
Total [m]	**401,152**	**49,907**	**3,733**	**54,343**	**471**	**32,038**	**77,642**	**306,851**	**4,943**	**503,324**	**10,917**	**1,445,322**	
Length [%]	**27.8**	**3.5**	**0.3**	**3.8**	**0.0**	**2.2**	**5.4**	**21.2**	**0.3**	**34.8**	**0.8**		

Table 3-1: Pipe length by diameter and material

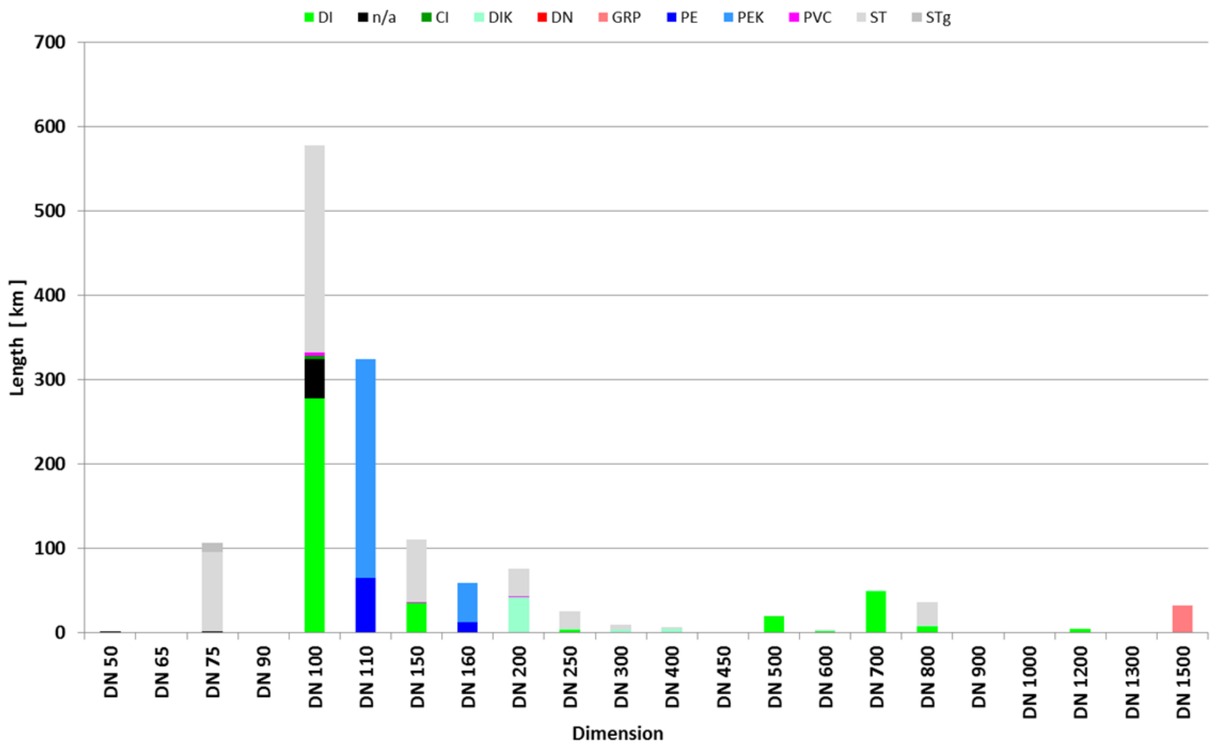


Figure 3-1: Pipe length by diameter and material

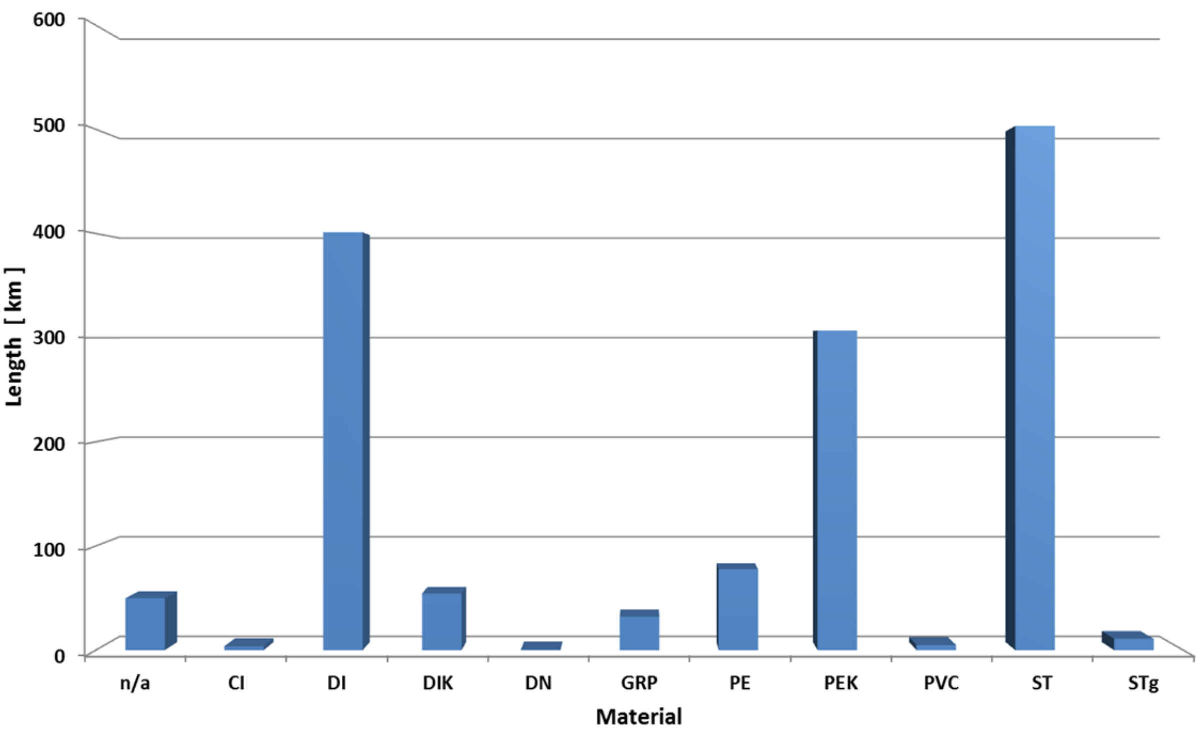


Figure 3-2: Pipe length by material

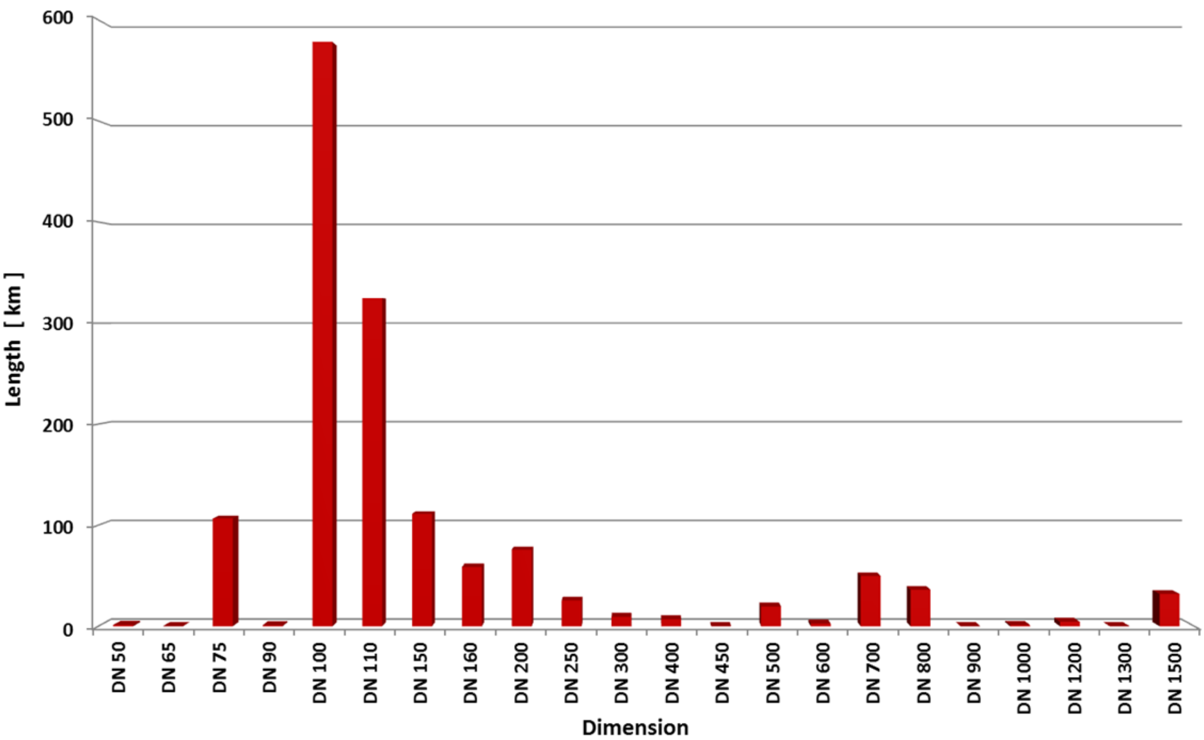


Figure 3-3: Pipe length by Diameter

Supply Area	Lenght [km]	Ratio [%]
BS Ifraz I	128.83	0.009
BS Ifraz II	109.85	0.008
BS Ifraz III	48.5	0.003
BS Maroda	71.68	0.005
SA Erbil	1359819.13	94.084
TM Ifraz I	25483.91	1.763
TM Ifraz II	27014.18	1.869
TM Ifraz III Part 1	20697.98	1.432
TM Ifraz III Part 2	11726.63	0.811
proposed / outofwork	221.12	0.015

Table 3-2: Pipe length by supply area

4 WATER SUPPLY KEY ASSETS

A general system overview is given in the map “WSS Erbil– Calibration Status 10 2011” attached in Appendix 3. It shows the primary distribution system, other key assets, and pressure and supply zones.

The following figure gives a general overview.

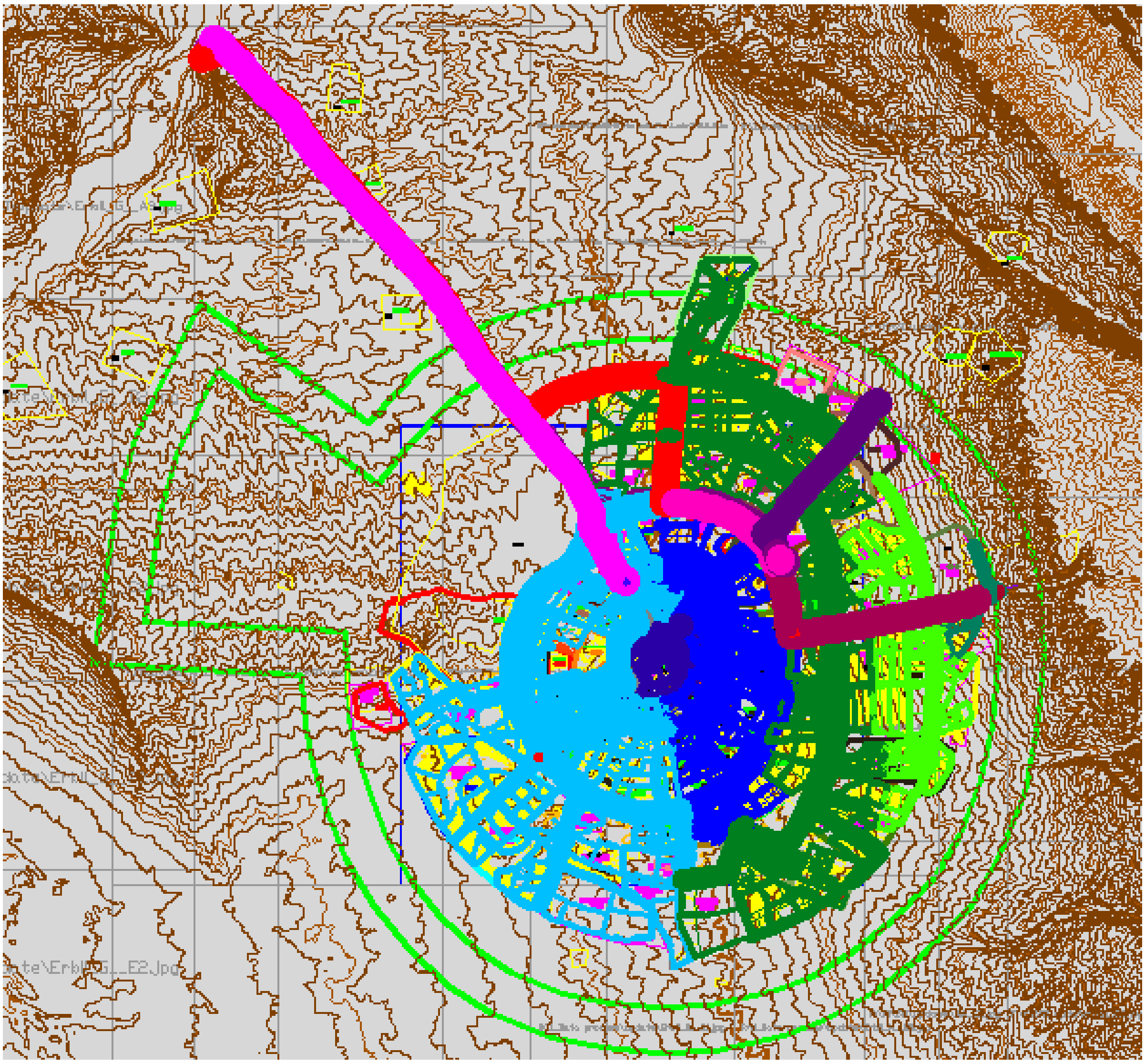


Figure 4-1: General overview water supply Erbil 2035

The following chapters list the system’s key assets, namely production, storage and pump stations, together with a short description.

4.1 Production

4.1.1 SOURCES

The Great Zab River (originating from Turkey) is the only surface water source available for supply of drinking water. The intake for the town's water supply is located about 29 km in the north-west of Erbil on the Great Zab river. The river water is of good quality.

Groundwater is available in the greater Erbil basin (see report 'Water Balance and Management Report') consisting of recent alluvial deposits of more than 200 m thickness. The aquifer is extensively over-exploited by a great number of private, official and unofficial wells used for irrigation and water supply. The ground water level is constantly falling and well capacities decrease. It is recommended not to rely further on groundwater resources but to use the Great Zab river as a reliable source.

Network extensions presently under construction are designed to rely also on ground water. This should be revised and considered an interim solution only.

4.1.2 INTAKES AND WTP'S

In 1968/69 IFRAZ I intake structure was constructed at the east bank of the Great Zab river at Ifraz village (Old Ifraz Water Project). From there the water is pumped to a treatment plant and then to Erbil. Few years later, a second intake structure was constructed at the same site to increase the water supply bringing the existing transport main to a nominal capacity of 1,600 m^3/h (38,400 m^3/d). Due to inadequate maintenance and wear of pumps the present capacity is only 1,331 m^3/h (31,949 m^3/d).

In 1983 IFRAZ II new intake (New Ifraz Water Project) was constructed at the same site and raw water is pumped to the new water treatment plant in Erbil-Ainkawa. The treatment plant has a design capacity of 2,880 m^3/h (69,120 m^3/d). Due to unknown reasons the present capacity of the treatment plant is only 1,787 m^3/h (42,892 m^3/d). The consultant was informed that the design capacity was never reached. Resent upgrade of the intake chamber and exchange of pumps was insufficient to reach the design capacity. The taken measures increased the capacity only from 1,787 m^3/h to 1,909 m^3/h.

In 2006 IFRAZ III WTP and transmission main DN 1500 were constructed to supply water to the New Dawajin reservoir (24.000 m^3) in the north east of Erbil city to improve the supply conditions. The treatment plant has a current capacity of 6,000 m^3/h (140,000 m^3/d). Restriction in funds did not allow the construction all components to reach the original design capacity of 10,000 m^3/h. An upgrade of IFRAZ III WTP, pump station and intermediate booster station to reach design capacity is in planning stage by WD Erbil.

4.1.3 DEEP WELLS

About more than 800 deep wells operated by WD Erbil spread all over the supply area. These are not considered for the hydraulic scenarios of the master planning. This was agreed between the consultant and WD Erbil due to the increasing risk of contamination and over-exploitation of the aquifer. The ground water abstraction shall be gradually phased out.

Functioning deep wells may be used for non-potable water supply or in case of emergency only for local supply demand of drinking water.

The average capacity of the wells is about 30 to 50 m³/h. The present time of use and quantities are not recorded. Water from these wells is treated by chlorination and pumped directly to the distribution network.

4.2 Storage

4.2.1 DAWAJIN RESERVOIR

In the east of Erbil city center the new Dawajin Reservoir (24,000 m³), supplied by the Ifraz III transmission pipe, was constructed. The input pipe from Ifraz Intake is a DN 1,500 GRP pipe (present capacity 6,000 m³/h, proposed final design capacity 10,000 m³/h); the feeding pipes to Erbil are DN 1,200 (to Erbil city – 60 Meter Road) and DN 1200 (to the south of Erbil). These two outgoing pipes are gravity pipes which are also pressure reduced in areas of low elevations.

4.2.2 HAWLER RESERVOIR

In the east of Erbil City center the Hawlery reservoir (1,640 m³) is serving some city quarters. The Hawlery reservoir is supplied by a DN 700 from Dawajin reservoir. The outlet pipe DN 300 to Erbil city works by gravity.

4.2.3 KASANAZAN RESERVOIR

In the east of Kasnazan town center the new built 5,000 m³ reservoir, connected like a terminal, is in operation for the town. The incoming DN 100 pipes are from deep wells around the reservoir. An outgoing DN 200 pipe supplies Kasnazan town by gravity.

4.2.4 OTHER RESERVOIRS

Inside the city of Erbil there are 7 other storage tanks of sizes between 300 and 4,500 m³, mostly made of steel. Only two ground tanks of 900 m³ capacity exist. All 7 storage tanks were originally connected to the distribution system, serving as balancing tanks for the supply of the adjacent city quarters.

The deteriorating supply situation between 1980 and 2000, characterized by decreasing pressure in the network, did not allow the filling of the elevated reservoirs anymore even in night time. As a consequence some of the elevated tanks have been connected to wells; others were disconnected, by-passed or abandoned. At present 5 larger elevated tanks in the city are not operational and empty, 2 tanks are fed by wells, only the two ground tanks and the one elevated tank at Qualat Hill which are connected to the distribution system.

The following table list the storage tanks with a short description.

	Name of Reservoir	Location	Capacity [m³]	Supply from	Supply to	Elevation [m]	Remarks
1	Al Qualla Tanks	Qualat Hill City Centre	2 x 450 GT 1 x 300 ET	Ifraz I&II and deep wells	Al-Arab QuarterAl-Tajeel Quarter Al-Qualla	+12.00 & 430 masl	built in 1924 Operational
2	Al-Mustafi Tank	Tayrawa Quarter	1 x 500 ET	Ifraz I&II	Al-Mustawi, Tayrawa Quarter	+15.00 + 410 masl	built in 1959, not operational
3	Saidawa Tank	Saidawa Quarter City Center SW	1 x 1,000 ET	Ifraz I&II Project	Saidawa Quarter	+16.00 + 415 masl	built in 1960, not operational
4	Stadium Tank	Stadium, City Center South	1 x 1,500 ET	Deep well under tank	Stadium	+16.00 + 410 masl	built in 1967, operational
5	Setaqan Tank	Setaqan Quarter	1 x 1,500 ET	Well under tank	Setaqan Quarter	+16.00 + 420 masl	built in 1960 not operational
6	Tayrawa Tank	Salahadin Quarter	1 x 4,500 ET	Ifraz Project	Salahaddin Quarter	+16.90 + 410 masl	built in 1984, not operational
7	Saylo Tank	Saylo Quarter	1 x 4,500 ET	Ifraz Project	Saylo, Kuran	+16.90 + 401 masl	Erected in1984, Not operational
Total Storage Capacity			Appr. 15,000 m³				

Note: GT = ground tank; ET = elevated tank

Figure 4-2: Old Reservoirs

The total storage capacity of these tanks is about 15,000 m³, which is very inadequate to serve as a buffer to regulate daily peak demands for the city.

There are some minor existing reservoirs (40- 200 m³) in the system. Their impact for future zoning and scenarios for the overall approach is of no importance. However, a complete list and GPS elevation survey of existing reservoirs is promised to be done by WD Erbil GIS department.

4.3 Existing Pumping Stations

Pump characteristics have been collected and entered into the hydraulic model database. As a minimum the pump name and two operating points (head [m] and flow rate [m³/h]) are needed.

DWP supplied information on existing new pumps like the pump characteristics and specific pump curves provided from pump producers. Pump curves are a graphic representation of the performance of a pump in relation to the rate of flow against the total head, with the efficiency of the pump shown for the points along the curve.

Other information was taken from the internet based on the information from the pumps' label.

4.3.1 IFRAZ I

IFRAZ I Intake and WTP facility were built in 1969 at Great Zap River. The Intake elevation is about 290 masl. The water is conveyed to Erbil by a booster with 2 + 4 high lift pumps and the transmission main DN 700 . Currently one out of the 4 pumps is out of order.

- 4 no. high lift pumps: Q 426 m³/h x H 200 m x 1,460 rpm x 320 kW
- 2 no. high lift extension pumps Q 300 m³/h x H 220 m x 1,475 rpm x 400 kW

The design capacity is 38,400 m³/d (1,600 m³/h).

4.3.2 IFRAZ II

IFRAZ II Facility was built in 1983. The Intake is located at Great Zap River 290 masl and raw water is pumped to the WTP in Ainkawa through a DN 800 transmission main. The clear water tank elevation is 411 masl. From Ainkawa 3 booster pumps supply the Saylo network and other 3 pumps supply the Tayrava quarters. Design capacity is 69,000 m³/d (2,880 m³/h).

- Pump station at Ifraz II Intake
- 6 x high lift pumps Q 720 m³/h x H 210 x 1,490 rpm x 585 kW
- 4 x high lift extension pumps Q 300 m³/h x H 220 x 1,460 rpm x 250 kW
- Pump station at Ainkawa WTP
- 3 x Saylo line pumps Q 690 m³/h x H 35 x 1,480 rpm x 95 kW
- 3 x Tayrawa line pumps Q 690 m³/h x H 30 x 1,480 rpm x 78.1 kW

4.3.3 IFRAZ III

The IFRAZ III intake at Great Zap River at 290 masl includes a 35 km transmission main DN 1500, interrupted by Maroda intermediate booster station, to Dawajin reservoir built in 2006. The clear water tank (6,400 m³) elevation is 292 masl. The reservoir at the Maroda intermediate booster station (6,400 m³) is about 389 masl. Dawajin reservoir (24.000 m³) is located in the north-east of Erbil at 490 masl.

The design capacity is 144,000 m³/d (6,000 m³/h). An additional 96,000 m³/d (4,000 m³/h) extension is planned by WD Erbil. Details were not available during the master plan survey.

- IFRAZ III intake 4 high lift pumps
  - - Q 426 m³/h x H 200 x 3 pumps
  - - Q 300 m³/h x H 220 x 1 pump
- Maroda Intermediate pump station 411 masl 4 high lift pumps
  - - Q 426 m³/h x H 200 x 3 pumps
  - - Q 300 m³/h x H 220 x 1 pump

A 4 km long gravity main DN 1200 supplies Erbil city centre quarters from Dawajin reservoir and a DN700 to the South.

5 HYDRAULIC MODEL PREPARATION

5.1 Accuracy of the Hydraulic Model

The quality of the base data available, such as an actual map of the water supply network and an accurate elevation model, do have a major influence on the quality of the output of hydraulic modelling. Other data like the production and consumption figures do not have such a strong influence. The influence of the type of modelling software is also minor.

Therefore attention was focused to carry out the necessary and required network map update in close cooperation with O&M network engineers of WD Erbil.

5.2 Mapping, Pipe Network Digitizing

WD Erbil GiS department started operation in 2010 with support of the JICA financed rehabilitation project. WD Erbil started to use an ArC GIS based system but it is still under construction and not fully operational. No substantial GiS Database is available concerning pipes and network assets and huge efforts are needed to reach acceptable or even international GiS standards.

The consultant performed time-consuming surveys to confirm and add information to upgrade the network data having a focus on quality. Only correct system information will allow meaningful hydraulic modelling.

Information for the update of the base map on the water supply network was collected from satellite topographic images. Vector based cadastral maps are not available.

Some CAD Network data, organized by quarters, were obtained from WD Erbil during the engagement of the Consultant. The consultant also received general system data like maps in PDF-format showing the JICA Erbil Water Project. The rest of the network was digitised together with the support of DW engineers having knowledge and sketches about their supply areas and pipe layout.

All these different data were transformed and combined and integrated into an updated base map for the supply area of Erbil to be covered by the project. The data were crosschecked by the Consultant, corrected and updated in cooperation with the WD engineers, complemented with details and missing key assets like routes, connections, diameters and materials. This process continued until the overall information was acceptable for hydraulic modelling purpose.

Though the resulting updated network base map in digital form meets the requirement for hydraulic modelling this is not a standard of mapping as required for network operation and documentation. The consultant strongly recommends that WD Erbil organizes the established GiS department to achieve the urgent needed improvement in documentation quality.

5.3 Conversion of Digitized Map Data to the Hydraulic Data Base Model

The updated digital map of the existing primary distribution system has been created in an AutoCAD drawing file (DXF format). Pipes and their attributes, like diameter and material, are contained in separate layers of this map and shown as labels along most pipes. Assets like reservoirs, pumping stations and valves were indicated by symbols. In the interest of map legibility, in crowded situations around reservoirs and pumping stations, pipe connections and devices had sometimes to be drawn schematically, which means not in their exact position. These data were imported in stages into the hydraulic data base using an import algorithm.

Hydraulic nodes are required at all pipe junctions, pipe ends and at all dimensional or material changes along a pipe. The assignment of nodes at all individual pipe ends and pipe property changes was done automatically by the import algorithm of the hydraulic software.

A topological, logical entity called “network” was assembled by AutoCAD/MAP by merging all nodes of separate pipes, if they were sufficiently close to each other within a specifiable tolerance limit, and the result was written into a SQL data base. After this operation the complete digital description of the AutoCAD/MAP representation of the network is stored within the relational data base. Depending on the quality of original data of the resulting data base needs manual check and verification to various degrees.

The final correct data base is the digital representation of the network and forms the base for the generation of all further hydraulic calculations.

5.4 Digital Elevation Data

A digital elevation model (DEM) is required to assign altitudes to node points in the model in case there are no terrestrial survey data available. The data from the DEM need to be very close to those in reality to achieve an acceptable modelling accuracy. Referring to the standards applied in DVGW Worksheet GW 303, elevations of hydraulic nodes shall be within the range of ± 1 m for ordinary nodes.

No terrestrial survey or original DEM could be gathered from the client. In order to establish a DEM of the supply area a plan in DXF format from a Korea study, containing elevation contour lines, was handed over to the consultant. The elevation data, based on contour line vectors, have been extracted and used to set-up the DEM for the hydraulic model. It turned out to be accurate enough and could be used. The areas outside the city area were covered using data from a KRG wide ArcGiS data file. Although these elevation data have a lower quality they were found suitable and were used for the transmission pipes.

5.5 Demand Allocation

The hydraulic load of a water supply system is the demand which is normally registered by water meters. The readings are usually taken regularly by the administration and collected for accounting. There is no water meter reading available and therefor no also no information on consumption.

The base for the demand estimation for 2011 was elaborated by the other parts of the Consultant's services giving the per capita consumption values as agreed upon. The other basis for the calculation of the (household) demands was a list containing the number of population per quarter. The consumption for each street could be determined and was proportionally allocated to the hydraulic nodes.

In reality the loads are located along the pipes. Following well established practice demands were assigned to the nearest node of the primary distribution system. This process is called "Demand Allocation". In general the geographic nearest node is taken as the withdrawal point for the areas's consumption.

As these demand figures are only used to provide weight factors for a distribution of the total consumption value, as discussed and defined for each load case, it does not matter which nominal per capita consumption value is used at this stage.

Special demands and their withdrawal points were not provided for major water consumers.

5.6 Pipe Diameter and Materials

A hydraulic node with a unique sequential ID was assigned to every important pipe junction, change of pipe diameter or material and to every extraction point. A unique sequential ID was also given to every pipe segment between to hydraulic nodes. The ID's can be assigned arbitrary.

As pipe diameter and material labels were present within the network drawing most of them could be automatically assigned to the proper database fields. Pipes were marked in red for which no material / dimension are found. Pipes were marked in yellow if they had more than one possible assignment. These incidences required manual confirmation and correction.

5.7 Existing Network Zones

Network zones are hydraulically isolated or only weakly connected parts of the whole network which may be simulated independently of each other. They are usually identical with so called pressure zones.

There is no base zoning of the whole network existing which may be operated independent of each other. Common usual practice is water rationing by operating strategic valves and deep well operation into living quarter. A seperation is organized in quarters connected to its source like Ifraz I, Ifraz II and Ifraz III having also interconnection in case of emergency.

The borders of existing supply areas are not clearly defined and not known as there is no complete network map available at WD Erbil GIS department.

Furthermore there are about 800 deep wells in intermittent operation and hence there are no clear supply area boundaries in the existing system.

6 POPULATION PROJECTION AND WATER DEMAND

6.1 Population Projection

6.1.1 POPULATION AND GROWTH RATE

The Erbil city's population 2009 was 725,620 according to Kurdistan Region Statistical Office (KRSO) data in the year 2009. The consultant has used the official growth rate of 3.2 % to calculate the population within the master plan area up to the target year 2035. The population would therefore be 772.800 in 2011. The WD Erbil and others are of the opinion that this figure is to low and that it should be in the range of 1,000,000. The actual population development might deviate depending on the actual conditions governing the growth rate and an accurate number of inhabitants for the base value.

6.1.2 URBAN DEVELOPMENT

Dar Al-Handasah's Urban City Masterplan shows the proposed urban development for the year 2030. It proposes development for of various uses like residential quarters, industrial areas and University etc. Population density figures had to be established for the new quarters jointly by the Consultant and DW according to their experience and best judgment.

The development plan assumes development within the planned area surrounded by the Green Belt.

6.1.3 POPULATION DISTRIBUTION

The actual development of the population's distribution dependents on availability of accommodation for the additional people. Quarters, which have already a high population density, cannot increase their population in ration to the population growth. The growth in population needs to be distributed according to planned new residential areas and using a reasonable increase in density for existing residential area.

The consultant, in close cooperation with WD Erbil, distributed the increase in population according the development plan and more detailed planning (Bayos maps) and by an increase in population in existing areas. The KRSO provided information for the present built-up area giving a distribution of areas (Mahallas) with their present population.

6.1.4 POPULATION PROJECTION

The future population was calculated using a combination of methods.

Firstly, the KRSO figure was extrapolated to the year 2035. This results in a total population of 1,658,956 for the year 2035. It was assumed that 50% of the future total population can be housed in the existing built up area (or Mahalla). The remaining 50% must be accommodated in the new residential areas.

Secondly, the size of the new residential areas was determined. The population able to live in this area was calculated using the area and a density of 4,000 people per square kilometre. This gave a total of people which can be accommodated.

The figure resulting from the second calculation should be equal or larger than the 50% overspill to be distributed according to the first calculation.

Thirdly, the existing built up areas, outside of Erbil town but within the extent of the Erbil Master Plan, were considered as in existence with their present population.

The resulting total population for the year 2035 and its distribution is given in the following summary table.

ID No	Greater Area	Population	
		2011	2035
1	Overall population and projection with a rate of 3.2%	772,803	1,658,956
2	Mahallas in presently built up areas	772,803	931,208
3	New residential areas to be developed per Master Plan	0	913,152
4	Overspill from presently built up areas [2] to be housed in new residential areas = smaller than [3] = OK	0	727,748
5	Population within the built up area outside Erbil town	65,035	102,380
6	**Total Population after using combination method [2 + 3 + 5]**	**837,838**	**1,946,740**

Table 6-1: Summary of population estimate

The above table shows that the actually calculated population for 2035 of about 1.95 million corresponds to a present population of near to 1.0 million based on a growth rate of 3.2%.

The following tables show in detail the distribution of population per Mahalla and new areas. The figures were discussed and agreed upon with the WD Erbil.

The first table shows the Mahallas in the built up area, their present population, theoretical total capacity in 2035 and allocation of this number to the area and as overspill into new residential areas.

Erbil City Mahalla areas as per KRSO	Population in 2009	Population in 2011	Population in 2035	Mahalla built up in 2011	Final Population Estimate	
					Maximum Inside built up Area 2032	Portion to be Housed in New Residential Areas
Aenda 1	801	853	1.817			1.817
Aenda 2	4	4	9			9
Andazyaran	4.435	4.723	10.059	X	5.030	5.030
Arab	2.649	2.821	6.008		6.008	
Azadi 1	15.331	16.328	34.773	X	17.387	17.387
Azadi 2	4.220	4.494	9.572	X	4.786	4.786
Babagurgur (Zhyan)	5.592	5.956	12.684		12.684	
Badawa	16.621	17.702	37.699	X	18.849	18.849
Bahar	19.029	20.266	43.161	X	21.580	21.580
Bakhteyare	10.241	10.907	23.228	X	11.614	11.614
Bazar	303	323	687		687	

Erbil City Mahalla areas as per KRSO	Population in 2009	Population in 2011	Population in 2035	Mahalla built up in 2011	Final Population Estimate	
					Maximum Inside built up Area 2032	Portion to be Housed in New Residential Areas
Berkot	3.368	3.587	7.639		7.639	
Brayate	17.409	18.541	39.486	X	19.743	19.743
Chnar	14.659	15.612	33.249	X	16.624	16.624
Chwar Chra	36.084	38.430	81.844	X	40.922	40.922
Empire village est.			3.575		3.575	
Italien village est.			1.589		1.589	
English village est.			7.976		7.976	
Galauezh	8.832	9.406	20.032		10.016	10.016
Grupi Andazyaran	716	763	1.624			1.624
Gulan 1	13.299	14.164	30.164	X	15.082	15.082
Gulan 2	10.822	11.526	24.546	X	12.273	12.273
Hamreen	10.779	11.480	24.448	X	12.224	12.224
Havalan	5.324	5.670	12.076	X	6.038	6.038
Hawleri New	4.692	4.997	10.642	30	10.642	
Hiran City	127	135	288			288
Ieskan	8.187	8.719	18.569	X	9.285	9.285
Kani	25.741	27.415	58.384	X	29.192	29.192
Karezan	23.793	25.340	53.966	X	26.983	26.983
Khabat	23.527	25.057	53.363	X	26.681	26.681
Khanaqa	5.574	5.936	12.643	X	6.321	6.321
Khanzad	20.075	21.380	45.533	X	22.767	22.767
Komare	2.714	2.890	6.156	X	6.156	
Kuestan	13.855	14.756	31.425	X	15.713	15.713
Kurani Ankawa	12.592	13.411	28.561	X	14.280	14.280
Kurdistan	31.386	33.427	71.188	X	35.594	35.594
Mahabad	11.520	12.269	26.129	X	13.065	13.065
Majidawa	1.102	1.174	2.500		2.500	
Mamostayan 1	3.333	3.550	7.560	X	3.780	3.780
Mamostayan 2	7.483	7.970	16.973	X	8.486	8.486
Manara	6.703	7.139	15.203	X	7.602	7.602
Mantikawa	8.432	8.980	19.125	X	9.563	9.563
Marewan	129	137	293			293
Media	946	1.008	2.146			2.146
Mstaufe	6.620	7.050	15.015		15.015	
Mufte	14.307	15.237	32.450	X	16.225	16.225
Nauroz	40.577	43.215	92.035	X	46.017	46.017
Naz	2.987	3.181	6.775		6.775	

Erbil City Mahalla areas as per KRSO	Population in 2009	Population in 2011	Population in 2035	Mahalla built up in 2011	Final Population Estimate	
					Maximum Inside built up Area 2032	Portion to be Housed in New Residential Areas
Nishtiman	14.646	15.598	33.219	X	16.610	16.610
Parlaman	586	624	1.329		1.329	
Qalat	40	43	91		91	
Rapareen	12.405	13.212	28.136	X	14.068	14.068
Raste	8.897	9.476	20.180	X	10.090	10.090
Rizgari 1	12.639	13.461	28.667	X	14.334	14.334
Rizgari 2	14.149	15.069	32.092	X	16.046	16.046
Roshnbery	2.752	2.931	6.242		6.242	
Runaky	5.021	5.347	11.388		11.388	
Saedawa	13.369	14.238	30.323	X	15.161	15.161
Safeen 1	1.560	1.661	3.538		3.538	
Safeen 2	501	534	1.136		1.136	
Safeen 3	1.505	1.603	3.414		3.414	
Salahadin	24.991	26.616	56.683	X	28.342	28.342
Sarbaste	1.457	1.552	3.305			3.305
Sarwaran	3.409	3.631	7.732		7.732	
Sebardan	3.743	3.986	8.490			8.490
Setaqan	12.975	13.819	29.429	X	14.715	14.715
Shade	22.166	23.607	50.276	X	25.138	25.138
Shaed Same Park	524	558	1.189		1.189	
Sharawane	6.517	6.941	14.782	X	14.782	
Share Andazyaran	221	235	501			501
Share Khawn	736	784	1.669		1.669	
Shary Ashty	32	34	73			73
Shary Lawan	687	732	1.558			1.558
Shorsh	12.185	12.977	27.637	X	13.819	13.819
South industrial	1.312	1.397	2.976		2.976	
South graveyard	32	34	73		73	
Tahjeel	4.027	4.289	9.134		9.134	
Tayrawa	15.565	16.577	35.304	X	17.652	17.652
Zagros 2	1.081	1.151	2.452		2.452	
Zagros	10	11	23		23	
Zanayan	7.229	7.699	16.396		16.396	
Zanko 1	15.827	16.856	35.898	X	17.949	17.949
Zanko 2	3.585	3.818	8.131		8.131	
Zanyare	5.565	5.927	12.622		12.622	
Zelan	16.754	17.843	38.001		38.001	

Erbil City Mahalla areas as per KRSO	Population in 2009	Population in 2011	Population in 2035	Mahalla built up in 2011	Final Population Estimate	
					Maximum Inside built up Area 2032	Portion to be Housed in New Residential Areas
TOTAL	**725.620**	**772.803**	**1.658.956**		**931.208**	**727.748**

Table 6-2: Population distribution between existing and new residential areas

The following table gives the result of calculation the population figures in the new residential areas based on planned size and the average population density.

New Residential Areas Outside the Built Up Area	Bayo CMP sqkm	Population 2035
Note: Average density used: 4,000 people/ sqkm		
Meriwan	12,0	48126,7
Shary & Hiran	4,7	18748,1
Kasnazan	6,8	27091,8
Sebardan	9,5	37939,3
Hawlere new II	7,5	29920,8
Ainkawa North	6,6	26541,1
Ainkawa East	2,1	8294,3
Airport city south	4,7	18880,6
Airport city	19,0	76167,7
Pirzen	8,1	32306,3
Business District Banslawa South	8,5	34073,6
University	10,7	42666,7
Torak west	2,5	9958,2
Torak quarter	2,3	9385,8
Torak village	9,0	35969,3
Airport south	3,8	15109,9
Pirzeen south	3,9	15560,0
Birkot new	5,7	22950,2
Shawes	5,0	20054,3
Banslawa	8,4	33558,7
Daratu	12,9	51701,6
University	6,7	26878,3
Ware house	3,3	13383,5
Plan Expansion I Mamzawa	13,7	54991,5
Mamzawa Business	1,2	4712,2

New Residential Areas Outside the Built Up Area	Bayo CMP sqkm	Population 2035
Plan Expansion II	11,8	47301,0
Baba Gor Gor South	1,1	4426,5
Kasnazan North	6,2	24950,3
Pirzeen North I	3,9	15785,3
Pirzeen North II	3,6	14352,1
Ankava center	4,2	50038,0
Share Andazyaran	4,2	16637,1
Shawes North	6,2	24691,2
Erbil City "Bayos" outside Ringway 4		913.152

Table 6-3: Population projection for new residential areas

The following table gives the present and estimated future population for areas outside Erbil town but within the new boarders for Erbil as per the Master Plan.

Existing villages outside Erbil but within area of Master Plan	Population Figures		
	2009	2011	2032
Arab Kand	766	816	1.737
Baghamra Shahab	209	223	474
Baharka	27996	29.816	63.499
Gazna	3028	3.225	6.868
Haza	781	832	1.771
Kani Qirzhala	2773	2.953	6.290
Kani Garni Harki	245	261	556
Qalachoqhan	883	940	2.003
Qalatga	445	474	1.009
Qara chnaqa	88	94	200
Qareatagh	88	94	200
Qareatagh Harki	88	94	200
Qupa Qran	209	223	474
Quritani Jukel	1769	1.884	4.012
Seberan	3835	4.084	8.698
Seberane Bchuk	278	296	631
Shekha Shel	876	933	1.987
Sherawa	161	171	365
Temari Gawra	620	660	1.406
TOTAL	**53.060**	**65.053**	**102.380**

Table 6-4: Erbil Population Figures

6.2 Projected Water Demand

There was no documentation made available to the consultant covering the dimensioning of the Ifraz water treatment plants. The projection of the water demand is therefore based on the agreed upon average specific water demand of 270 l/c/d and the estimated population for the target year. The Peak Day Demand is calculated using a factor of between 1.36 and 1.75, depending on the size of the supply area.

The following tables give the water demands per supply area and for various demand conditions.

Supply Area	Population	Average Demand			Peak Day Demand		
		l/(Inh.*d)	m³/d	m³/a	Faktor	l/(Inh.*d)	m³/d
SA Kasnasan Town	32,133	270.0	8,676	3,166,714	1.75	472.5	15,183
SA Kasnasan	154,509	270.0	41,717	15,226,821	1.51	407.7	62,993
SA Pirzeen+Bahrka	490,429	270.0	132,416	48,331,787	1.40	378.0	185,382
SA Dawajin	616,900	270.0	166,563	60,795,495	1.36	367.2	226,526
SA Berkot	627,272	270.0	169,363	61,817,654	1.36	366.9	230,165

Table 6-5: Population, Average Demand and Peak Day Demand per Supply Area

Supply Area	Population	Peak Day Demand	Peak hourly Demand		Minimum hourly Demand		Average hourly Demand	
		m³/d	%	m³/h	%	m³/h	%	m³/h
SA Kasnasan Town	32,133	15,183	7.2	1,093.2	1.1	167.0	4.2	632.6
SA Kasnasan	154,509	62,993	6.1	3,842.6	1.8	1,133.9	4.2	2,624.7
SA Pirzeen+Bahrka	490,429	185,382	5.5	10,196.0	1.8	3,336.9	4.2	7,724.3
SA Dawajin	616,900	226,526	5.0	11,326.3	2.5	5,663.1	4.2	9,438.6
SA Berkot	627,272	230,165	5.0	11,508.2	2.5	5,754.1	4.2	9,590.2

Table 6-6: Peak Demands for each SA

7 DESIGN PARAMETER

7.1 Key Figures

The main aim of the Kurdistan Regional Infrastructure Water Sector Master Plan Erbil is to establish key-values in order to estimate investment costs for WD Erbil as required for establishment of a system of major transmission mains, main distribution system and proper zoning. The established model is based on a water supply from the Ifraz source also in the future and the use of existing assests.

The administrative responsibility of WD Erbil has been greatly extended from the present coverage of the town of Erbil to coverage of the greater Erbil region as defined by the Erbil Master Plan. This is an enormous enlargement of the supply area and responsibilities. There is presently no general concept how to construct and manage the water supply within the extent of the new boarders. The concept and model developed under this master planning provides a proposal to serve the Master Plan area with a backbone of transmission mains supplying reservoirs for dedicated supply areas and pressure zones.

The hydraulic survey and modeling by SETEC is precise enough to provide sufficient details for decision making on design principals and to make realistic cost estimations. Final detail designs will require additional work i.e. detailed topographic and network survey (precise position for pipe routing and land acquisition and precise elevation of pumps/reservoirs). The layout and details of the existing and proposed distribution systems inside supply zones will need to be established and recorded in a GIS system. All changes and extensions need to be documented and also be recorded in the GIS system.

7.1.1 AVERAGE DAY DEMAND

The calculation of the water demand for the year 2032 is based on the population forecast per quarter, the 270 l/p/c/d design parameter of average day demand (ADD) (see Table 6-5: Population, Average Demand and Peak Day Demand per Supply Area

7.1.2 PEAK DAY DEMAND

An appropriate peak day demand factor is chosen for each supply zone corresponding to the size of the supply area. Therefor the peak day demand factor varies between 1.36 and 1.75 (for big SA and respectively for the smallest SA – refer to Table 6-5: Population, Average Demand and Peak Day Demand per Supply Area

The overall peak day demand divided through the average day demand results in the average peak day demand factor which is 1.39 in average for Erbil. The result is a specific peak day demand of 375 l/c/d.

The peak day demand is the base on which the following components are designed: transmission mains, reservoirs, booster pumps, etc.

7.1.3 PEAK HOURLY DEMAND

Water requirements change during the day from times of low demand to peak hour flows. In order to consider this fact the peak hourly demand is used for pipe sizing in the distribution network to ensure supply under the "worst case scenario". The peak hourly demand is given in percentage of the peak day demand and is also depending on the size of the SA. The values are between 5.0% and 7.2% of the peak day demand (see Table 6-6: Peak Demands for each SA

7.1.4 MINIMUM HOURLY DEMAND

For determination of the highest pressure in the SA the minimum hourly demand (or no flow condition) is required. It is calculated through the minimum hourly demand factor which is also given in percentage of the peak day demand. These range from 1.1% to 2.5% (see Table 6-6: Peak Demands for each SA

7.1.5 OTHER DESIGN PARAMETERS

The following table gives an overview of additional design parameters used for hydraulic calculation and system optimization.

Description	Value
Design horizon / year	2032 / 20 years.
Hydraulic Peak Faktor HPF (>300,000 - <2.000,000)	1.39
Velocity $V_{max.}$	1.8 m/sec.
Velocity V_{min}	0.3 m/sec.
Pressure $P_{max.}$	6.0 bar
Pressure$P_{min.}$	1.5 bar
Fire fighting	48 m^3/h per hydrant, pressure minimum 1.5 bar.

Table 7-1: Other design parameters

7.2 Storage Requirements

The storage volumes were estimated to be about 30 % of the Peak Day Demand. This serves the buffering during daily demand variations and the uninterrupted supply in case of power cut or technical failure as well as firefighting.

7.3 Fire Fighting

The design will be based on the German standard, ensuring that water for fire fighting is available as follows:

- at a volume of 48 m^3/h for middle fire risk level in rural areas and
- a volume of 96 m^3/h for higher fire risk level for central areas of town).

Fire fighting requirements according to German Standards are presented in the following table:

<table>
<tr><th colspan="2">Type of settlement</th><th>Rural areas</th><th colspan="2">Private living quarters</th><th colspan="2">Central areas of town</th><th>Industrial Areas</th></tr>
<tr><td colspan="2">No. of storeys</td><td>2</td><td>3</td><td>Larger 3</td><td>1</td><td>Larger 1</td><td></td></tr>
<tr><td colspan="8">Demand for fire fighting in m³/hour – minimum 2 hours</td></tr>
<tr><td rowspan="3">Fire risk level</td><td>Small</td><td>24</td><td>48</td><td colspan="2">96</td><td colspan="2">96</td></tr>
<tr><td>Middle</td><td>48</td><td>96</td><td colspan="2">96</td><td colspan="2">96</td></tr>
<tr><td>High</td><td>96</td><td>96</td><td colspan="2">192</td><td colspan="2">192</td></tr>
</table>

Table 7-2: German Standards for Fire-Fighting

To simulate the scenario of fire-fighting, the load case Maximum Daily Demand was superimposed with a hydrant discharging the design fire flow of 48 m³/h to 200 m³/h.

7.4 Roughness and Velocities

The pipe roughness was taken as 0.4 mm for old DCI and old Steel pipes and 0.1 mm for new pipes. During the calibration the roughness was adjusted for the transport mains to actual values to match the pressures at the node points.

In order to avoid water stagnation and associated health risk, the pipelines were dimensioned to ensure also a reasonable velocity during average daily demand (ADD). The design tries to avoid dead ends. The consultant attempted to reach a minimum velocity of 0.3 m/sec in the pipelines where possible. This value is required for a regular flushing of pipes. In Load Cases

7.5 Load Cases

The digital model was analysed with the following load cases:

- Average Hourly Demand
  sizing of transmission mains
- Minimum Hourly Demand
  maximum pressure levels, boarder of pressure zones
- Peak Hourly Demand
  minimum supply pressure, boarder of pressure zones, reservoir volumes
- Fire Fighting Demand

The design results for the load cases mentioned above as well for the fire-fighting load cases are listed below.

Results for the Node analysis include

Elevation – in meters above mean sea level
Head - in meters above sea level
Pressure – in bar
Discharge – in m³ per hour [m³/h]

Results for the pipe analysis include

Flow – in m^3 per hour [m^3/h]

Velocity – in meter per second [m/s]

Head Loss – in meter [m]

Pressure Loss Gradient – in meter per kilometer [m/km]

The results for the load cases Minimum Hourly Demand and Peak Hourly Demand are given graphically in Appendix 1.

8 HANDLING OF HYDRAULIC MASTER DATA

8.1 General

Relevant physical properties were collected from devices like reservoirs, pumps and valves etc. which can be changed only by construction work. These data are identical for all load cases. Existing as well as proposed future device data were entered into the respective tables of the hydraulic model data base. These data are shortly described in the following chapters of this section.

The hydraulic model master data base is part of the digital project data submitted to the client.

8.2 Reservoirs

The reservoir name and its storage capacity [m³] were entered for maximal three relative filling levels [m] for each reservoir.

- Absolute elevation of its invert level (bottom of reservoir)
- Maximum water level
- Inlet level

8.3 Pumps

The pump name and at least two operating points (head [m] and flow rate [m³/h]) were entered for all pumps. If only one operating point was available the second operating point was assumed to be the maximum flow rate point with double the operating point flow rate and near zero pump head or the maximum pump head equal to 1.33 times the operating head at near zero flow rate.

If no second operating point is entered the software generates it automatically.

If a pumping station had several pumps, each pump can be individually assigned within an array of parallel pipes, in order to accommodate the possibility of more than one pump operating at the same time. Terrestrial elevation values for pump shafts were obtained, to allow accurate evaluation of pump pressure readings if required.

8.4 Pipe Materials and Roughness Values

For operational friction standard values where used in the first step (see section 7.4). The real roughness of single materials where entered as a result of calibration.

8.5 Real Pipe Diameters

No hydraulic significant differences are expected between nominal diameters and real inside diameters, because of the dominant effect of the roughness value in the calculation. Nominal diameter is an approximate measurement of the diameter of a pipe. Although the nominal diameter is used to describe the size or diameter of a pipe, it is usually not the exact inside diameter of the pipe. The inside diameter of a pipe changes with the class of pipe and wall thickness of material, but all pipes near a certain diameter are referred to as that size of pipe.

9 HYDRAULIC CALCULATION

9.1 Hydraulic Model

The existing network documentation (Drawings, AutoCAD and GIS files) had to be transferred into a digital form suitable to be used for the hydraulic calculations, the hydraulic model. This is a data base storing all information in relation to pipe location, hydraulic nodes, dimensions and material of pipes. Furthermore it stores the hydraulic relevant information on important devices such as reservoirs, wells and pumping stations. Using this data base a hydraulic map can be produced for each load case and printed out using graphical programs like AutoCAD, GIS or Surfer.

The hydraulic model is a representation of the real network. The network and the digital model are identical. In order to prepare quality network mapping additional information needs to be available like a layer showing elevation contour lines and satellite images or cadastral background mapping.

The MP team, in close cooperation with the DW staff, has collected all available paper and digital mapping and other information like K&A design under construction and transferred it into an updated AutoCAD network map. Missing and questionable information was checked and corrected as far as possible. Emphasize was given to transmission mains as well as main pipes inside quarters and their connections, to reservoirs (new and existing) as well as to the delineation of supply areas connected to a reservoir or pump station.

This resulted in an up-to-date map of the network and it's appurtenances within the urban city Master Plan Erbil delineated by the Green Belt area.

These data were imported into the hydraulic model.

The established new mapping of the system has to be transferred into a GIS system and needs permanent update to record correct actual conditions, any modifications, changes and extensions. This task is very important especially as there are extensive construction activities ongoing.

9.2 Hydraulic Scenarios

SETEC established a fully operational hydraulic model covering the primary system, key assets, reservoirs and future pressure zones and corresponding operation for the distribution system. Design of supply areas and zoning considers the elevation of contour lines taking into consideration the new established reservoirs, transmissions and existing mains. The result is the identification of logical Supply-Pressure-Areas corresponding to the existing or future needed demand and to the corresponding reservoirs and booster stations. Hydraulic load-cases were calculated to size important mains supplying pressure zones including DMAs. These calculations assist also how to establish connection to existing systems. The results, based on a sound engineering practice, shall be used for detailed planning and construction.

SETEC analyzed the K&A design covering the area inside 60 meter road area. The project was incorporated into the general operational idea of logical pressure zones for the entire system. Additional connection points are proposed to supply water from proposed future important transmission mains.

Together with future demand and pressure zoning, the location and operation of reservoirs and booster sizing is established by min./max. load-case scenarios, discussed and agreed with WD Erbil. All technical principals and scenarios were approved and confirmed by WD Erbil management followed by detailed modeling for pipes and key assets described in this technical report. The soft copy of the fully working model is attached in digital form covering all scenarios and can be used by WD Erbil engineers for further simulations.

The results of the hydraulic models under this MP are a guideline for layout, dimensioning and operation of:

- proposed intake and WTP location for ERBIL IV system
- future back bone transmission mains,
- boosters,
- sizing and location of reservoirs,
- corresponding pressure zoning,
- preparations for establishment of DMAs by ring mains and position of inflow points
- time-step simulation of entire operation.

The proposed list of rehabilitation measures, based on high quality facts, and their cost of implementation is needed to allocate future funds and undertake budget planning by WD and GWD management and the governorate administration (see Section 14).

10 CALIBRATION MEASUREMENT

10.1 General Description

The actual measurements in the field are essential for the correct function and calibration of the hydraulic model. These measurements enable the check of the correctness of the pipe connections and zoning, the pipe diameters, the specific roughness of the pipes and the elevations used. The measurements include flow, water levels and pressure using digital recording. The actual operation of pumps and the situation in the network and other parts of the supply system are recorded as a base for interpretation and calibration.

The measurements took place in November 2011. The points of installation for the recording devices are shown in maps in Annex 3 (see excerpt in Figure 10-1: Location of measuring points). Records taken and the map were handed over to the WD Erbil in digital form after completion of the field work. They are also attached as Appendix 2 to this report.

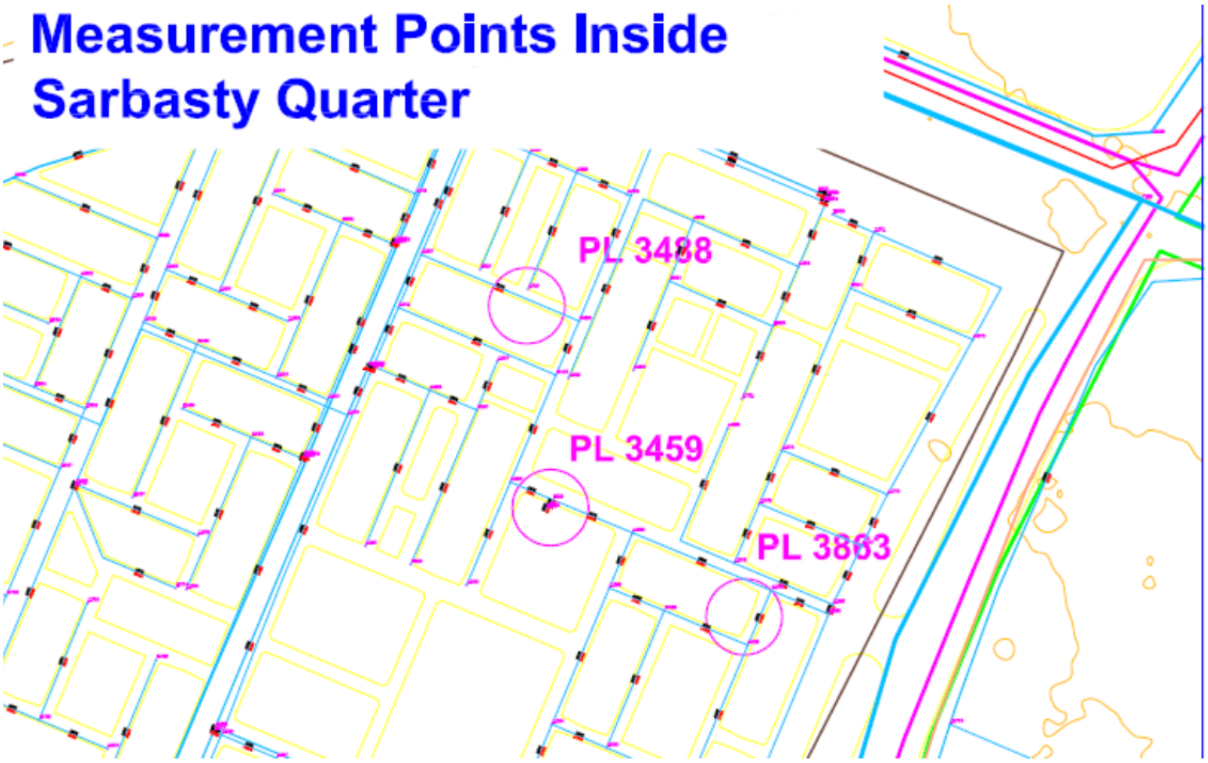


Figure 10-1: Location of measuring points

The operation was done using:

- up to 40 pressure loggers (PL),
- 4 water level sensors (WLS) to monitor the water level of reservoirs and
- 5 mobile ultrasonic flow meters (UFM) for the individual supply areas.

The equipment was installed to record simultaneously. Suitable access and measuring points had to be defined based on the actual situation in the network as established earlier. Programming, installation on site, and read out of records was carried out by two teams operating together with WD staff.

Altogether the following records are available:

- about 40 pressure measurements with positive information records,
- 15 flow meter records and
- 10 different water level sensor records.

Suitable access and measuring points had to be defined to install the equipment with support of WD Erbil.

The following chapters describe shortly the methodology used for the three types of measurements: flow, level and pressure. The programming, installation on site, and read out of records was carried out by a measuring engineer. The measurements focused on the transmission main system and were done in cooperation with WD staff. Some sample measurements of well production and connected pipes was carried out for supply areas of the distribution network. Due to the fact of intermediate supply, supply mix of deep wells and Ifraz bulk supply in combination with low pressure made calibration measurement for the supply area impractical.

The consultant performed measurements and calibration of the important parts of the network including the backbone of the Erbil water network IFRAZ I, II and III.

10.2 Flow Measurement

The input to the system was measured by mobile ultrasonic flow meters at the following locations:

- main pumping stations in Ifraz (for Ifraz I & III),
- at WTP Ainkawa (for Ifraz II),
- at the intermediate booster station Maroda of Ifraz III and
- in front of the Dawajin reservoir.

The measurement equipment was installed for at least 2 days to get meaningful results.

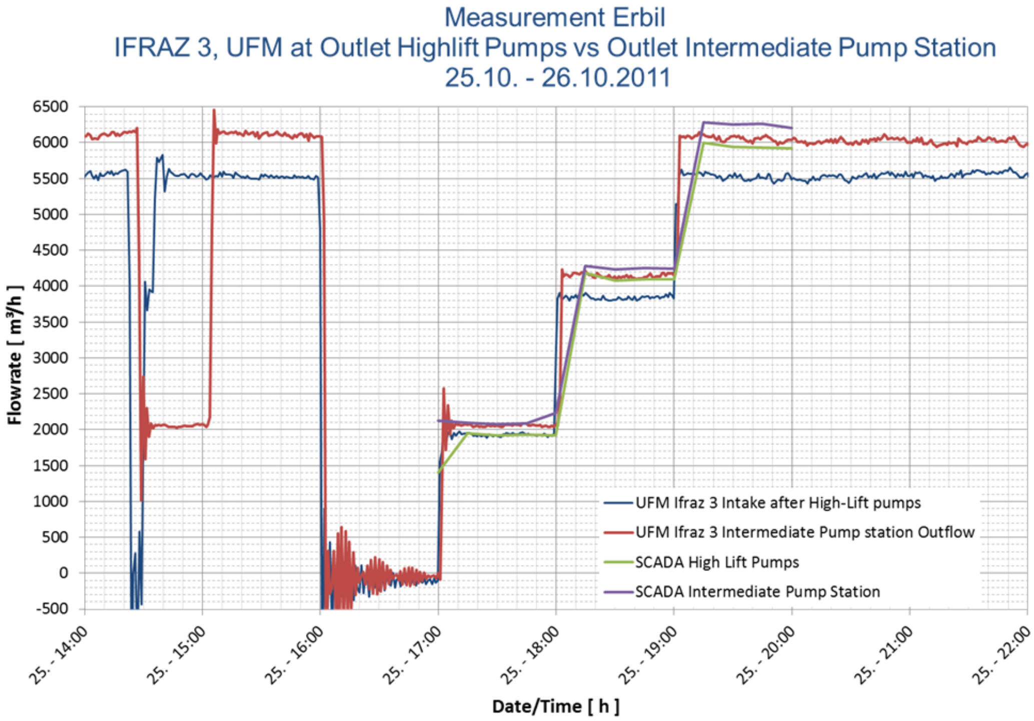


Figure 10-2: Results of Flow Measurements IFRAZ III

The records made are attached in Appendix 2.

10.3 Water Level Measurement

The inflow (or outflow) rate of a reservoir can be calculated by measuring the change of the water level over time, using the known surface are. Cross checks can be done with other measurements, especially in cases of large flows and with multiple chambers. The change in water level was recorded in at least one chamber of a reservoir where flow measurements took place during the period of flow recording.

One result of such observation can be the determination, whether installed non-return valves are working properly in each chamber. This would be indicated by varying water levels in the chambers.

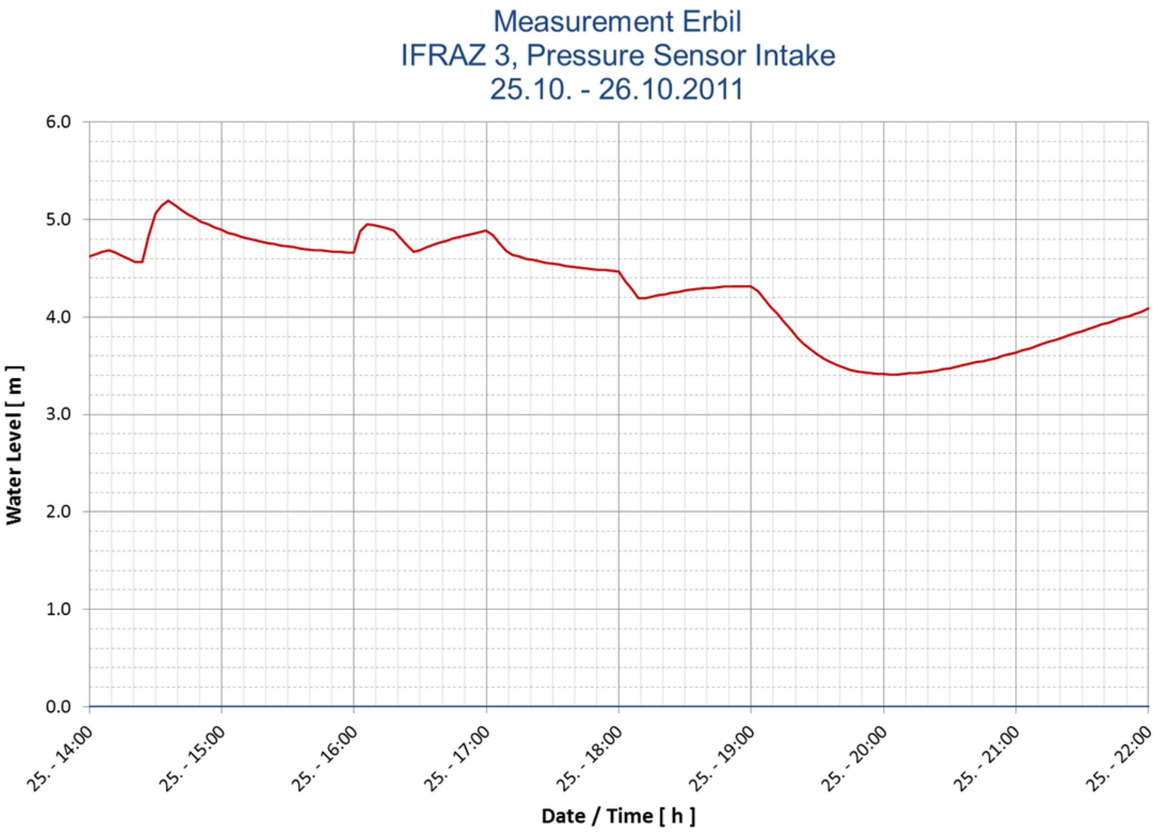


Figure 10-3: Record on water level measurement

Copies of the results are attached in Appendix 2.

10.4 Pressure Measurement

Pressure loggers (PL) were used to record the pressure conditions in the water supply network zones and on the IFRAZ main pipelines. They were connected to available access points at pumping stations or on house connections close to the main pipes.

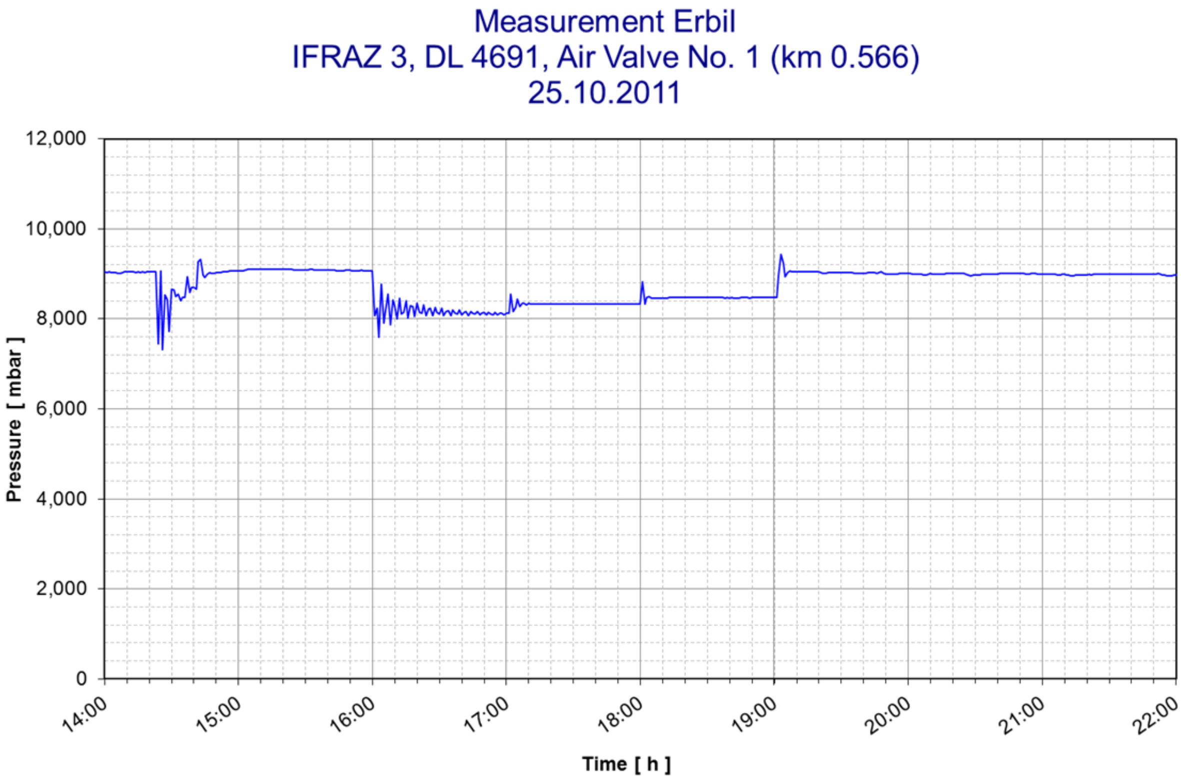


Figure 10-4: Record of pressure measurement

The complete records are attached in Appendix 2.

10.5 Calibration Measurement campaign

The flow and pressure measurement campaign was performed during November 2011 for the Ifraz transmission mains and sample supply areas inside Erbil city. About 40 No. pressure measurements with positive information records, 15 No. flow meter records and 10 No. different water level sensor records have been compiled from raw data to diagram curves for calibration and easy interpretation.

Details to each measurement point including diagrams are attached in the Appendix 2.

10.6 Location of Measurement points

For each installed Pressure Logger (PL) the location is given in the in Appendix 3. The location of the measuring devices is given in the following tables.

No.	Name	No. of Measurement Devices			Location		
		UFM	WLS	PL	UFM	WLS	PL
1	TM Ifraz I	2	1	4	R Outlet DN 700, close Airport[1)]	Ifraz, reciever R	along TM
2	TM Ifraz II	2	2	9	manhole after Ifraz R Outlet, manhole before Inlet Ainkawa WTP R	Sedimentation Tank in Ifraz, Splitting Chamber in Ainkawa	manholes P1, P2, P4, P5, P6, P7, P8 along TM[2)], Ainkawa before and after Venturi-Meter[3)]
3	TM Ifraz III Part 1	1	1	6	first chamber after Outlet DN 900[5) 6)]	chamber before pumps in Ifraz	1x directly after pumps, 1x at collector pipe, 4x along TM[4)]
4	TM Ifraz III Part 2	1	2	4	first chamber after Outlet DN 900[5) 7)]	chamber before pumps in Marooda, Dawajin R	1x directly after pumps, 1x at collector pipe, 2x along TM[4)]
5	TM Ifraz II Saylo Line	1	1	3	manhole 20 m outside pumphouse DN 600	Fresh Water Tank before Pumps	1x before pump, 1x after pump, 1x manhole 20 m outside pumphouse
6	TM Ifraz II Tayvara Line	1	1	3	manhole 20 m outside pumphouse DN 600	Fresh Water Tank before Pumps	1x before pump, 1x after pump, 1x manhole 20 m outside pumphouse

Remarks:

1) therefore the pipe had to be excavated

2) Installation of pressure loggers along the second half of the transmission pipeline towards Ainkawa was not possible since no isolation valves were installed in this section

3) With the help of these two loggers the pressure loss produced by the Venturi-Meter was determined

4) The placing of the PLs was a time consuming procedure, since the chambers needed to be opened by a crane and some fittings needed to be installed first to get the right connection of the PLs

5) In the same chamber the flow rate was measured by the SCADA-system.

6) The installing of this UFM emerged to be difficult because at that time the whole chamber was current-carrying. Therefore the whole Ifraz III pump station had to be stopped for the installation of the UFM

7) The measured flow rate was also compared to the flow rate given by the SCADA-system (handwritten document, since the SCADA is not recording data).

Table 10-1: Location of measuring devices on TM

No.	Name	No. of Measurement Devices			Location		
		UFM	WLS	PL	UFM	WLS	PL
1	SA Dawajin	3	1	-	1x manhole about 1 km west of Dawajin R, manholes in Pirmam Street (1x close to Gulan Street, 1x at 60 Meter Road	west chamber of Dawajin R	no connection available
2	SA Sarbasty	-	2	9	at different wells in SA[1)]	-	spread iside SA
3	Wells[2)]	3	4	5	different well locations	different well locations	outflow wells

Remarks:

1) SA was only supplied by two wells

2) Due to some wrong information the ground level pressure sensor was only able to measure groundwater levels to a maximum of 100 m (it was assumed that the ground water level is about 50 – 70 meters). Since most wells dynamic water level was below 100 m, only a few wells were measured. The corresponding diagrams are attached in Appendix 2.

Table 10-2: Location of measuring devices in SA

10.7 Measurement Campaign Interpretation

10.7.1 OVERVIEW

The following table gives an overview about the measurement results and their interpretation. The result for the SA Dawajin is given in the following sections.

Location	Nos. of Pumps in operation	Flow Rate [m^3/h]	Pressure at Pump [bar]	Remarks
TM Ifraz I	0	0	12.0	Pressure at end of TM (at old Ifraz 1 PS) was 0.25 bar (0 pumps) and 2.2 bar (4 pumps) Design capacity: 1,600 m3/h (flow is 94%)
	1	550	13.2	
	4	1,500	18.0	
TM Ifraz II	1	700	14.0	Pressure at and of TM (Venturi meter at Ainkawa WTP) was 0.6 bar (1 pump) and 1.1 bar (4 pumps). Design capacity: 2,800 m^3/h (flow is 64%).
	2	1,300		
	3	1600		
	4	1,850	19.5	
SA Ifraz II Sylo line	1	750	3.5	
SA Ifraz II Tayrava line	1	750	1.5	
	2	1,450		
TM Ifraz III - 1 from WTP Ifraz to BS Dawajin	0	0	9.6	Water hammer was observed upon pump shut down with oscillating pressuring in 2 minutes interval.
	1	1,950	9.9	
	2	3,800	10.1	
	3	5,600	10.7	
TM Ifraz III - 2 from BS Dawajin to Dawajin reservoir	0	0	9.4	The capacity of the booster pump station is larger than the pumps at the WTP – danger of draining the reservoir at the BS. Measured flow is less than SCADA records
	1	2,050	9.6	
	2	4,150	9.8	
	3	6,100	10.3	
SA Dawajin				See text below

Table 10-3: Interpretation of measurement campaign

10.7.2 SA DAWAJIN

The measurement at the Dawajin main pipe to the city included flow measurement at three different positions (manholes). The measurement in the first manhole (DN 1200) didn't give useful information due to the bad measurement conditions. The UFM was installed right after a valve and therefor the measured flow rate (about 2,400 m³/h) was not accurate.

Therefore, the flow rate at the outlet of the Dawajin was calculated based on the difference of the water level in one chamber and the flow rate form IFRAZ III to the same chamber. The outflow rate was 4,200 m³/h in average.

The flow rate in the 2nd manhole at Gulan / Pirmam Street was about 1,750 m³/h. The measuring point was after the branching of two other lines. One pipe DN 800 ductile iron branched to the Kuestan area and another DN 800 ductile iron branched to the south of Erbil through the Gulan Street.

The last flow measurement was carried out in the manhole close to the 60 meter street. There 1,500 m³/h were measured. For the Dawajin main pipe no pressure measurements were done since there were no connections for installing the PLs available.

10.8 Actual Water Production 2012– Outlook 2032

10.8.1 WATER PRODUCTION

At WTP Ifraz III pumping station a permanent PLC record is available to monitor the supply from Ifraz III to the city. Flows at Ifraz I and II are also measured but not recorded digitally.

Intermediated supply to the quarter's is regulated by individual valve operation. This practice eables to serve all customers in WD Erbil supply area. No metering or monitoring devices exist in the present distribution supply system.

The situation in water supply is as follows:

Source	Design Capacity [m³/h]	Measured Performance [m³/h]	Actual in per cent [%]
Ifraz I	1,600	1,500	94%
Ifraz II	2,880	1,850	64%
Ifraz III	6,000	5,600	93%
Sub-Total	**10,480**	**8,950**	**85%**
Wells	800 * 30 = 2,400	Estimated at 50% = 1,200	
Specific consumption exclusive of wells	324 l/c/d	279 l/c/d	

Table 10-4: Actual water production

The specific consumption is calculated using a total population of 770,000 people.

10.8.2 OUTLOOK & RECOMMENDATIONS

The following points give a general overview about future steps required:

- New IFRAZ IV water supply project with a capacity of about 20.000 m^3/h
- Upgrade of Ifraz III to a capacity of 10.000 m^3/h
- shut down of deep wells with a selection of wells kept operational for emergency
- Major rehabilitation is required to keep Ifraz I & II fully productive also in coming decades. Ifraz I (1968) is 44 years old and Ifraz II (1983) is 29 years old. For the hydraulic model 2032 this two facilities are considered to also supply the new established Berkot Zone by direct pumping to the distribution network.
- Consider the future overall supply area and its demand on the distribution system in all projects for smaller areas.
- The proposed system of transmission mains and reservoirs should be implemented to feed into the various supply areas.
- Follow the proposed division in supply areas and pressure zoning.

WD-Erbil has to reduce the overall water consumption and losses. Necessary steps are listed below:

- First measures should be the set-up of metering and billing system to avoid wastage.
- Construction of house connections should be under the responsibility and control of WD. Consumer must use correct materials and construction methods. This will avoid poor workmanship unmetered connections as well as leaks at house connection pipes.
- Replace old weak pipes and keep the new main pipes also inside quarters in good condition (pressure testing) in general with acceptable leakage rate.
- Undertake continuous water loss monitoring by control of minimum night flow to zones and district meter areas by permanent bulk-meters or mobile ultrasonic flow metering.
- Undertake dedicated leak detection based on night flow observation.
- Repair reported leaks as soon as possible.

11 MODEL CALIBRATION

The calibration of the backbone transmission mains was carried out using the data of the field measurement. In each case two load cases have been calculated. All load cases are part of the generation “Calibration”.

LC 1 – Load cases with Minimum Flow (or no flow)

LC 2 – Load cases with Peak Flow

The result of the calculation is compared to the measured values at the specific point. The comparison error is the difference between measured and calculated pressure head at hydraulic node points.

The load case 1 is used to eliminate systematic errors in the elevations and load case 2 determines the specific pipe roughness and punctual pressure losses in the network like closed or throttled valves.

Additional load cases can be considered e.g. to show the situation of in case of one, two, three or more pumps in operation.

11.1 Calibration of the Hydraulic Model

11.1.1 GENERAL

The verification of the hydraulic model was performed by comparing the different load cases and measured pressures with the computed ones. The observed discrepancies between measured and computed pressure values can be separated into systematic errors and random errors and are explained in following Section.

The results of the calibration exercises for various load cases are presented in the "Calibration Map". Black decimal numbers indicate the difference between measured and calculated hydraulic grades. The number “-0.2” means that the calculated hydraulic grade is 0.2 m higher than the measured value. The comparison of measured and calculated flow rates is displayed as purple numbers. The first value describes the measured quantity, the second the deviation in percentage.

11.1.2 TYPES OF CALIBRATION ERRORS

Systematic Errors

Systematic errors are of no significance for the performance of the hydraulic model because all flow rates depend on differences in pressure between hydraulic nodes only. Therefore, the absolute pressure at the reference node can be chosen as an arbitrary constant in the solution of the mathematical equation. The observed systematic error just indicates e.g. that an unmeasured water level in a reservoir was not estimated correctly. This error disappears after a corresponding correction of the reference pressure.

Random Errors

Only random errors are relevant for the quality of the hydraulic model. If differences at individual nodes exceed a range of ± 1 m the causes have to be identified and the model to be corrected.

11.2 Calibration Transmission Mains

11.2.1 TM IFRAZ I

The measurement results used for calibration of the TM-Ifraz three PL are given in the following table.

			LOAD CASE 2.1	LOAD CASE 2.2	LOAD CASE 2.3	LOAD CASE 2.4
Date	01.11.2011	Time	11:50 - 11:55	12:25 - 12:30	12:50 - 12:55	13:20 - 13:25
average Flow: [m3/h]						
TM Ifraz I	Node		557,6	942,8	1.267,6	1.505,9

Table 11-1: TM Ifraz I Flow

Pressure Measure Points :												
					LC 2.1				**LC 2.2**			
L=Pressure Logger R=Pressure Recorder		**Node Nr.**	**Geod. Level [m]**	**Korr. [m]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**
SR Ifraz I		7377	283,60	0,0	1,66	7377	285,26	-0,75	1,58	7377	285,18	-0,83
DL	3863	11154	286,50	0,0	132,96	11154	419,46	11,72	146,70	11154	433,20	25,46
DL	4673	7440	286,50	0,0	135,50	7440	422,00	12,69	149,22	7440	435,72	26,42
DL	4676	7480	405,50	0,0	8,69	7480	414,19	6,22	11,76	7480	417,27	9,29

Table 11-2: TM Ifraz I Pressure 1

Pressure Measure Points :												
					LC 2.3				**LC 2.4**			
L=Pressure Logger R=Pressure Recorder		**Node Nr.**	**Geod. Level [m]**	**Korr. [m]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**
SR Ifraz I		7377	283,60	0,0	1,87	7377	285,47	-0,54	1,81	7377	285,41	-0,60
DL	3863	11154	286,50	0,0	165,59	11154	452,09	44,36	182,95	11154	469,45	61,71
DL	4673	7440	286,50	0,0	167,72	7440	454,22	44,91	185,63	7440	472,13	62,83
DL	4676	7480	405,50	0,0	17,15	7480	422,66	14,69	22,40	7480	427,90	19,93

Table 11-3: TM Ifraz I Pressure 2

The high lift pumps were integrated in the hydraulic model with all details including pump characteristics and efficiencies. Currently pump No. 3 is out of order.

Please see the following figure for a layout of the pumping station.

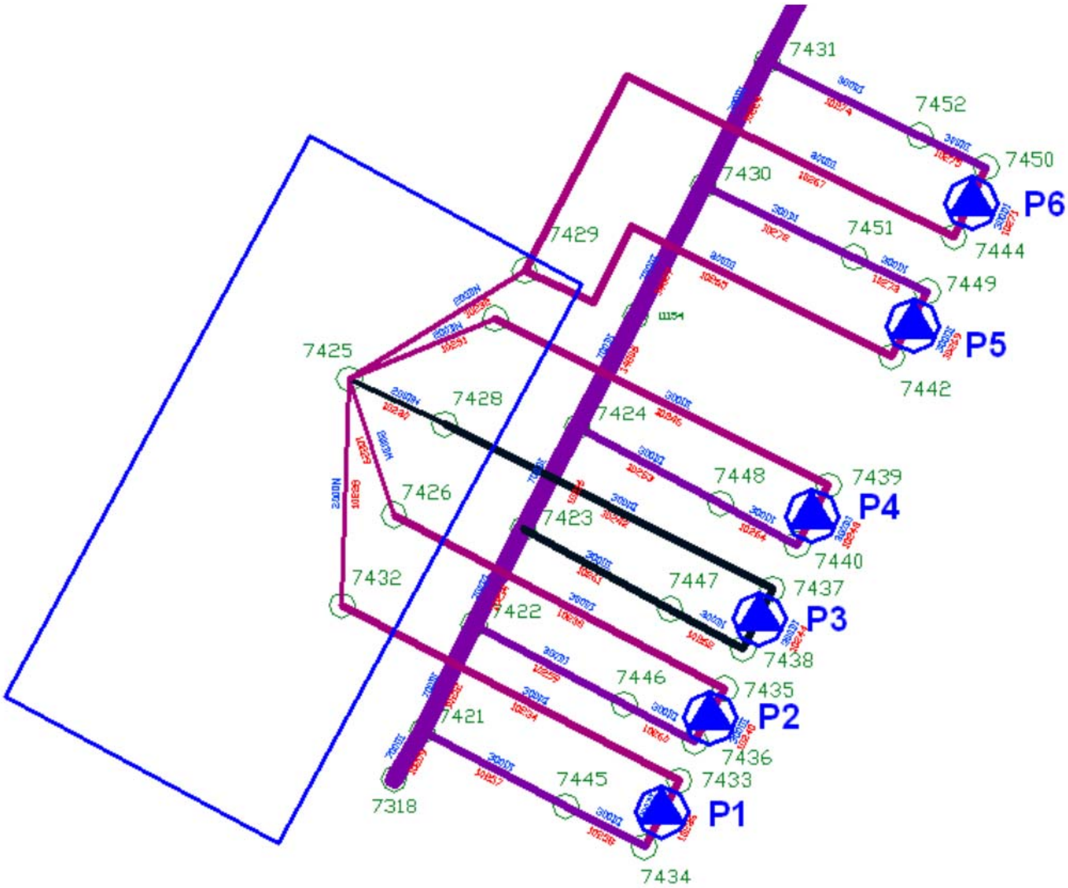


Figure 11-1: TM Ifraz I High Lift pumps

The calibration was accomplished by using 4 different load cases with flow rates between 560 m³/h and 1,500 m³/h. The corresponding pressure difference between load case 1 and load case 4 was about 6.2 m.

The best match between measured and calculated pressure was achieved by using an integrated roughness of 0.5 mm in all load cases. The ROSS valve right after the pumps is throttling the flow rate and therefore the input power is constrained. The specific resistance for the valves was gained by the calibration calculations. Without these resistances a compliance with the measured values is not possible. The graphical presentation in Appendix 1 pages 2-5 shows the results of the final calibrated model.

11.2.2 TM IFRAZ II – WTP AINKAWA

The table below shows the measured flow values used for calibration of the DN 800 TM to the Ainkawa WTP and for evaluating the pumps.

					LOAD CASE 1	LOAD CASE 2
Date	18.07.2011		Time		12:50 - 12:55	15:50 - 15:55
average Flow: [m3/h]						
TM Ifraz II		Node	4		737,4	1.909,4

Table 11-4: TM Ifraz II Flow

Table 11-5 shows the measured pressure values, the Pressure logger number and the corresponding node.

Pressure Measure Points :					**5,0 mm**		Final				
					LC 1			**LC 2**			
L=Pressure Logger R=Pressure Recorder		**Node Nr.**	**Geod. Level [m]**	**Korr. [m]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**
TP Ainkawa		11925	408,90	0,0	6,77	11925	415,67	6,87	11925	415,77	0,10
DL	4684	11922	410,00	0,0	6,30	11922	416,30	10,76	11922	420,76	4,46
DL	4680	11921	410,00	-0,5	6,85	11921	416,35	11,68	11921	421,18	4,83
DL	4675	11918	358,35	4,0	59,65	11918	422,00	94,93	11918	457,28	35,28
DL	4691	11917	373,95	7,0	42,18	11917	423,13	85,54	11917	466,49	43,36
DL	4673	11916	375,95	6,0	42,46	11916	424,41	91,32	11916	473,27	48,86
DL	4676	11914	362,43	5,0	56,89	11914	424,32	107,84	11914	475,27	50,95
DL	4682	11913	352,50	8,0	64,27	11913	424,77	116,54	11913	477,04	52,27
DL	4689	11911	346,13	2,0	76,80	11911	424,93	130,14	11911	478,27	53,34
DL	4679	11910	330,27	-3,0	97,70	11910	424,97	151,99	11910	479,26	54,29
DL	4672	7317	285,10	-0,5	141,03	7317	425,63	197,78	7317	482,38	56,75
						FLOW	m³/h		FLOW	m³/h	
						15779	737,40		10208	1909,40	

Table 11-5: TM Ifraz II Pressure

The design capacity of the WTP Ainkawa is 2,880 m³/h. The pumps at the Ifraz II intake are designed for this flow rate; nevertheless the design capacity was never reached. To increase the flow rate a new grid chamber with low lift pumps was constructed as a receiver tank. Even with the support of this grid chamber the flow rate could be raised about 10 % to 2,000 m³/h only. This was leading to the assumption of a local resistance somewhere at the pipe. Therefor a calibration measurement on Ifraz II transmission main was carried out. To isolate the location of the resistance pressure loggers were installed. It was only possible to install the pressure loggers in places of air valves at the first half of the transport main. The calibration was implemented with two load cases whereas the difference in flow rate should be as big as possible. The load case with the small flow rate (LC 1) was used to eliminate systematical errors like wrong elevations. The calculated correction values of the LC1 have to be used for all other load cases. The following calibration calculations are accomplished with the corrected elevations. The difference in pressure between load case 1 and load case 2 accounts to 56 m.

The initial value for the integral roughness of the pipe was assumed to be 0.1 mm. The difference between the calculated and the measured pressure decreased along the whole pipe to Ainkawa for both load cases. In LC2 the deviation of water level was almost 40 meters. (Appendix 1, page 14)

To get better match of measured and calculated values the integral roughness was raised first to 2.0 mm, then to 4.0 and finally to 5.0 mm. Only the calculation with 5.0 mm showed the same deviations of pressure at almost all points of the pipe. That means that there is no local resistance in the pipe.

The only punctual resistant is in Ainkawa at the inflow to the WTP. This resistance is depended on the flow rate and accounts to 1.0 m for LC 1 and 4.5 m for LC 2. For the graphical presentation the resistance was integrated in the calculation. (Appendix 1, page 11 and 18)

The cause of this pressure loss is probably the sedimentation at the inflow area to the WTP. Another possibility is a throttled valve at the inlet in Ainkawa.

The calculation was performed with a pipe diameter of 800 mm. A smaller diameter would lead to bigger flow losses and therefor to a smaller roughness of the pipe. A calculation was performed as reference using a diameter of 700 mm. The integral roughness decreased to 0.3 mm. (Appendix 1, pages 12 and 19). Nevertheless it was verified that the pipe diameter is DN 800 at all measured locations.

A high roughness as result of the calculation could also be caused by the quality of the raw water transported. If there was a big amount of suspended sediment in the raw water, the density of the water would increase and this would result in higher friction losses and thus in higher energy costs.

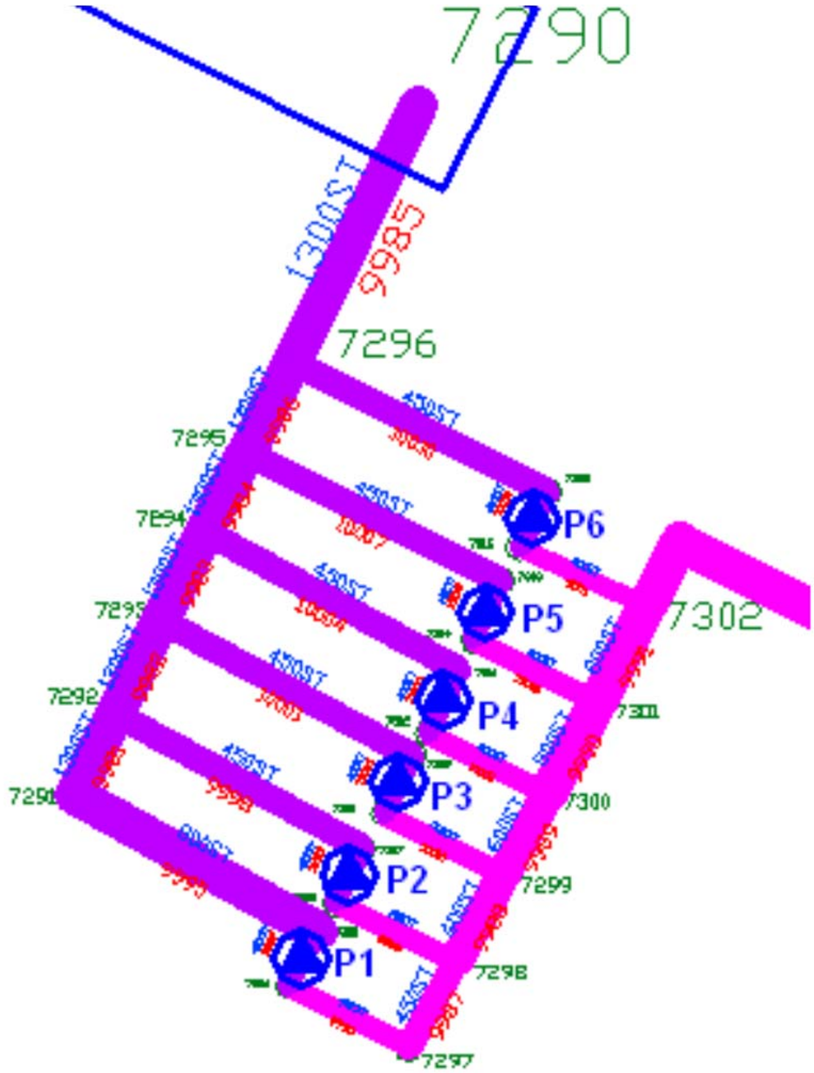
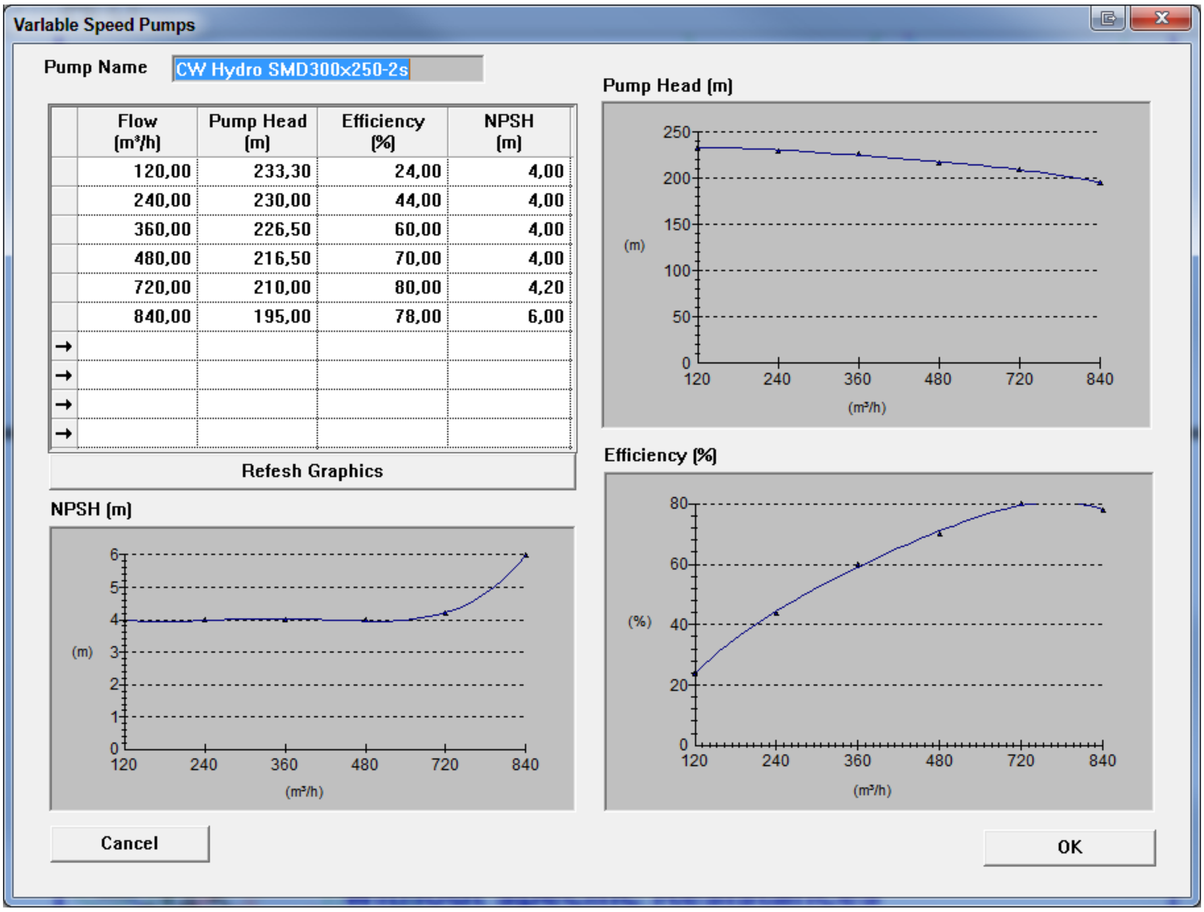


Figure 11-2: Booster Station Ifraz II High Lift Pumps

After establishment of the pipelines characteristic various load cases can be simulated after incorporation of the number and characteristics of the pumps and the new grid chamber.

Without throttling the valves right after the pumps the flow rate would be about 11.5 % higher than the measured ones. (Appendix 1, page 21). By considering a specific resistance of the valves right after the pumps (like throttling) the measured flow and pressure conditions can be matched in the simulation. (Appendix 1, pages 20 and 22)



Flow (m³/h)	Pump Head (m)	Efficiency (%)	NPSH (m)
120,00	233,30	24,00	4,00
240,00	230,00	44,00	4,00
360,00	226,50	60,00	4,00
480,00	216,50	70,00	4,00
720,00	210,00	80,00	4,20
840,00	195,00	78,00	6,00

Figure 11-3: Pump Characteristic BS Ifraz II High Lift Pumps

11.2.3 TM IFRAZ III PART 1 (WTP IFRAZ III TO BOOSTER STATION MARODA)

The measured values are as follows:

				LOAD CASE 1.0	LOAD CASE 2.1	LOAD CASE 2.2	LOAD CASE 2.3
Date	25.10.2011	Time		16:55 - 17:00	17:55 - 18:00	18:55 - 19:00	19:55 - 20:00
average Flow: [m3/h]							
TM Ifraz III Part I	Node			0,0	1.904,0	4.160,0	6.056,0

Table 11-6: TM Ifraz III part 1 Flow

Pressure Measure Points :											
					LC 1			LC 2.1			
L=Pressure Logger R=Pressure Recorder		Node Nr.	Geod. Level [m]	Korr. [m]	rel. Press. [mWL]	Node Nr.	abs. Press. kor. [mWL]	rel. Press. [mWL]	Node Nr.	abs. Press. kor. [mWL]	Div. Press. [mWL]
SR Ifraz III		7377	291,80	0,0	4,88	7377	296,68	4,47	7377	296,27	-0,41
DL	4672	7336	300,83	0,0	0,07	7336	300,90	0,10	7336	300,93	0,03
DL	4676	7327	296,60	-3,5	98,61	7327	391,71	100,91	7327	394,01	2,31
DL	4691	7304	305,85	3,0	82,79	7304	391,63	84,99	7304	393,84	2,21
DL	4682	7351	386,88	1,5	3,30	7351	391,68	5,27	7351	393,65	1,97
DL	4690	7352	355,17	1,5	34,91	7352	391,58	35,37	7352	392,04	0,46
DL	4679	7401	361,46	3,5	26,70	7401	391,66	26,81	7401	391,77	0,11
DL	4666	7353	384,27	0,0	7,11	7353	391,38	6,88	7353	391,14	-0,24
SR Maroda		7377	388,80	0,0	2,77	7377	391,57	2,48	7377	391,28	-0,29

Table 11-7: TM Ifraz III Part 1 Pressure 1

Pressure Measure Points :												
					LC 2.2				LC 2.3			
L=Pressure Logger R=Pressure Recorder		Node Nr.	Geod. Level [m]	Korr. [m]	rel. Press. [mWL]	Node Nr.	abs. Press. kor. [mWL]	Div. Press. [mWL]	rel. Press. [mWL]	Node Nr.	abs. Press. kor. [mWL]	Div. Press. [mWL]
SR Ifraz III		7377	291,80	0,0	4,31	7377	296,11	-0,57	3,41	7377	295,21	-1,47
DL	4672	7336	300,83	0,0	0,11	7336	300,94	0,04	107,90	7336	408,73	107,83
DL	4676	7327	296,60	-3,5	102,76	7327	395,86	4,15	108,84	7327	401,94	10,23
DL	4691	7304	305,85	3,0	86,41	7304	395,26	3,62	91,89	7304	400,74	9,10
DL	4682	7351	386,88	1,5	5,82	7351	394,20	2,52	10,12	7351	398,50	6,82
DL	4690	7352	355,17	1,5	37,30	7352	393,97	2,39	40,08	7352	396,75	5,17
DL	4679	7401	361,46	3,5	27,69	7401	392,65	0,99	28,98	7401	393,94	2,28
DL	4666	7353	384,27	0,0	6,74	7353	391,01	-0,38	6,59	7353	390,86	-0,52
SR Maroda		7377	388,80	0,0	2,19	7377	390,99	-0,58	1,83	7377	390,63	-0,94

Table 11-8: TM Ifraz III Part 1 Pressure 2

The planned capacity of the finished Ifraz III WTP is 10,000 m^3/h. In the first stage Ifraz III WTP has a capacity of 6,000 m^3/h. The design capacity can be reached after completion of the second construction stage which is in planning.

Currently 4 of the planned 7 high lift pumps are installed and in operation. This are pump No. 1, 3, 5 and 7.

The layout is shown in the following figure.

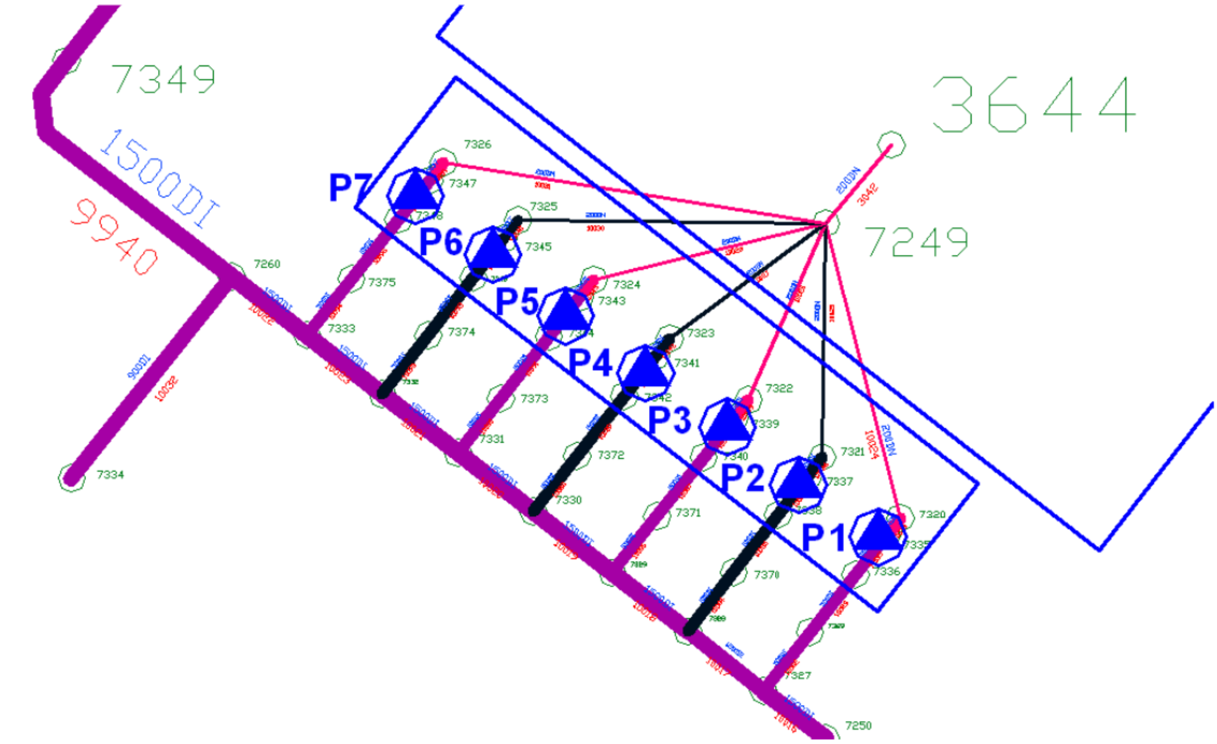


Figure 11-4: Ifraz III High Lift Pumps WTP

The calibration of the Ifraz III was performed using 4 different load cases. Since it was possible to stop all pumps, with the aid of load case 1 using a flow rate of zero all systematic errors were eliminated. (Appendix 1, page 23)

The best compliance between measured and calculated pressure was obtained by using a roughness of 1.0 mm. The ROSS valves right after each pump limits the input power of the pumps. The calculation used the nominal diameter instead of the inner diameter. The check of the actual diameter on a not buried piece showed that the inner diameter is marginally smaller than the nominal diameter.

In load case 2.12, after stopping all pumps one pump is in operation again, the consistence between measured and calculated pressure could be reached by using a local resistance at the highest elevation of the pipe layout. (Appendix 1, pages 25 and 26) At this point an air bubble is formed which is dispersed when two pumps are running. (Appendix 1, page 26).

In the load case in which three pumps are in operation the pressure measuring point between pump and ROSS valve is available. Without throttling the pumps the calculated pressure right after the pumps is 3.8 m too low. (Appendix 1, page 29, blue number) By integration of the resistance for the ROSS valve compliance between measured and calculated pressure is reached.

11.2.4 TM IFRAZ III PART 2 (MARODA BOOSTER STATION TO DAWAJIN RESERVOIR)

In the following table please find the measurements done at the TM-Ifraz III Part 2.

			LOAD CASE 1.0	LOAD CASE 2.1	LOAD CASE 2.2	LOAD CASE 2.3
Date	25.10.2011	Time	16:55 - 17:00	17:55 - 18:00	18:55 - 19:00	19:55 - 20:00
average Flow: [m3/h]						
TM Ifraz III Part I	Node		0,0	2.088,0	4.296,0	6.220,0

Table 11-9: TM Ifraz III Part 2 Flo

Pressure Measure Points :											
					LC 1			**LC 2.1**			
L=Pressure Logger R=Pressure Recorder		**Node Nr.**	**Geod. Level [m]**	**Korr. [m]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**
SR Maroda		7377	388,80	0,0	2,77	7377	391,57	2,48	7377	391,28	-0,29
DL	4673	7386	397,83	0,0	-0,02	7386	397,81	-0,01	7386	397,82	0,01
DL	4675	7362	393,60	0,0	96,86	7362	490,46	97,81	7362	491,41	0,95
DL	4671	7402	479,34	0,0	11,39	7402	490,73	11,59	7402	490,93	0,20
R Dawajin		3647	489,50	1,0	0,19	3647	490,69	0,29	3647	490,79	0,10

Table 11-10: TM Ifraz III Part 2 Pressure 1

Pressure Measure Points :												
					LC 2.2				**LC 2.3**			
L=Pressure Logger R=Pressure Recorder		**Node Nr.**	**Geod. Level [m]**	**Korr. [m]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**	**rel. Press. [mWL]**	**Node Nr.**	**abs. Press. kor. [mWL]**	**Div. Press. [mWL]**
SR Maroda		7377	388,80	0,0	2,19	7377	390,99	-0,58	1,83	7377	390,63	-0,94
DL	4673	7386	397,83	0,0	-0,01	7386	397,82	0,00	104,29	7386	502,12	104,31
DL	4675	7362	393,60	0,0	100,53	7362	494,13	3,66	104,70	7362	498,30	7,84
DL	4671	7402	479,34	0,0	11,87	7402	491,20	0,47	12,41	7402	491,75	1,02
R Dawajin		3647	489,50	1,0	0,49	3647	490,99	0,30	0,91	3647	491,41	0,72

Table 11-11: Figure 11-5: TM Ifraz III Part 2 Pressure 2

The high lift pumps were integrated in the hydraulic model with all details including pump characteristics and efficiencies. Currently 4 of the planned 7 pumps are installed and in operation. This includes pump No. 1, 3, 5 and 7.

A sketch is shown in the following about the pump layout in the Maroda booster station.

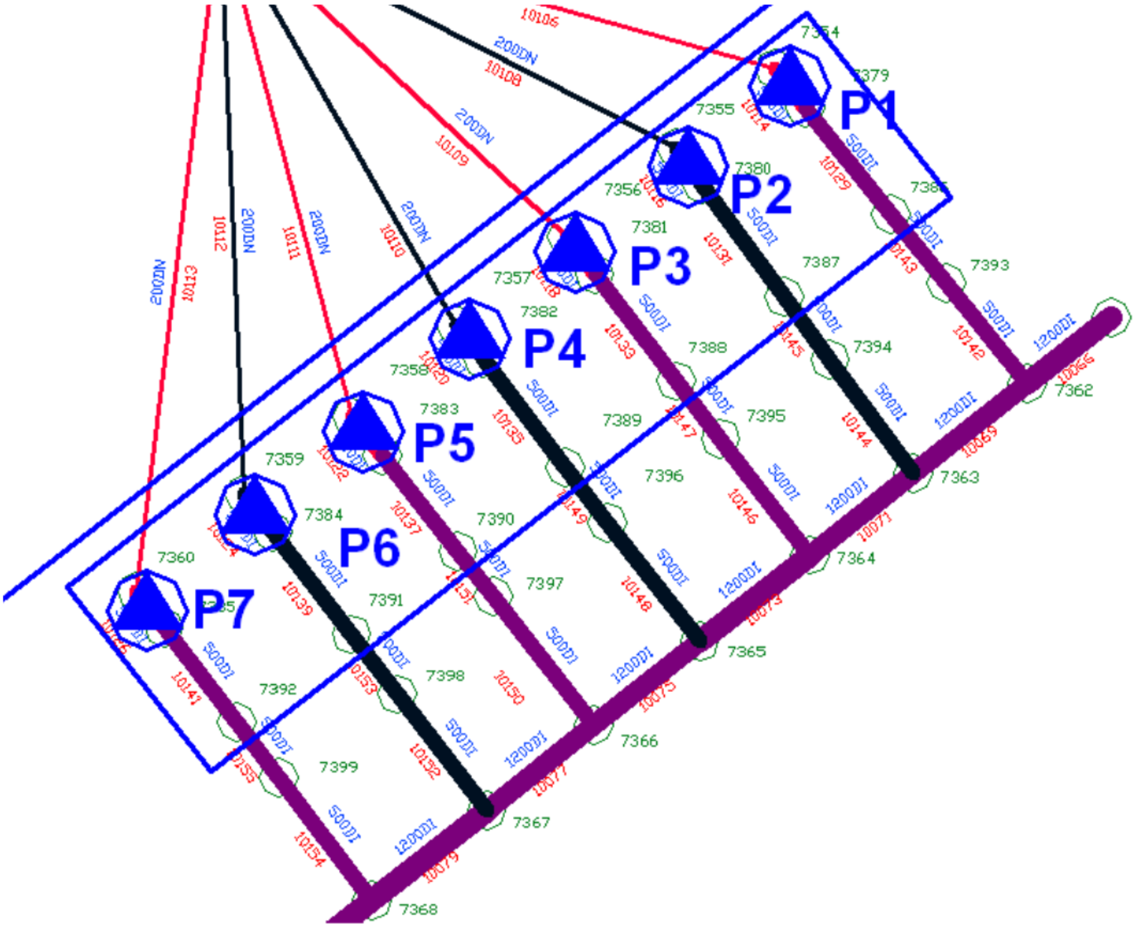


Figure 11-6 TM Ifraz III Part 2 Booster Station Maroda

The calibration of the Ifraz III part 2 was performed using 4 different load cases. Since it was possible to stop all pumps, with the aid of load case 1 using a flow rate of zero all systematic errors were eliminated. (Appendix 1, page 31)

The best compliance between measured and calculated pressure was obtained by using a roughness of 1.0 mm. The ROSS valves right after each pump limits the input power of the pumps. The calculation used the nominal diameter instead of the inner diameter. The check of the actual diameter on a not buried piece showed that the inner diameter is marginally smaller than the nominal diameter.

In the load case in which three pumps are in operation the pressure measuring point between pump and ROSS valve is available. Without throttling the pumps the calculated pressure right after the pumps is 2.4 m too low. (Appendix 1, page 36, blue number) By integration of the resistance for the ROSS valve compliance between measured and calculated pressure is reached.

11.3 Calibration existing Supply areas

The calibration of the existing distribution pipes inside the supply areas and sectors was impossible due to lack of a steady state condition. Also the absence of detailed maps about old pipes, their unknown connections, zoning, unknown boundaries and intermediate supply as well as unknown leakage rate would lead to unrealistic results.

However performed pressure logger and flow measurements provide sources to understand the system operation and to identify critical sectors. These facts are considered in design set-up for hydraulic new zoning.

Details of all pressure and flow measurements are attached in Appendix 2.

12 ESTABLISHED ACTUAL CONDITIONS

The hydraulic model was established using the data of the existing water network which were updated as much as possible to represent the actual today's situation.

All new transport mains were imported on basis of "As build"-drawings and calibrated with the corresponding pressure and flow rate measurements. The transport mains are the backbone of the system and therefore they were integrated as accurately as possible into the hydraulic model.

The existing supply network was included in the hydraulic model by digital data (e.g. GIS maps) and the JICA/K& A project.

The current main pipe system established and analysed by hydraulic calculations has a length of 1,450 km. The calibrated transport main pipes are about 85.0 km. The project of K& A, integrated into the model, accounts to 361 km and is divided into 38 DMAs.

12.1 Transmission Mains

Following the calibration of each TM some additional investigations were done to document the lowest and highest pressure and flow conditions. Load cases were calculated as follows:

- without pumps running (load case 1) and
- one or more load cases with pumps in operation.

The system pressure is represented as contour lines with different colors in the graphic presentations in Appendix 1, Actual Conditions. The colors represent areas of different pressure at intervals of 20 meters.

The input power of the pumps was recorded and specified in the graphic presentation. The efficiency of the motors was not included.

The following table gives an overview about the conditions established for the transmission mains.

No.	Transmission Main	Static Pressure at pump	High Elevation Point [bar / km]	No. of Pumps	Operation Status	Flow Rate	Pressure bar	Power Input [kW]	Design Flow Rate	Graphic Presentation, Appendix 1
1	Ifraz I	12,6	2.4 bars / 5.5 km	5	4 (2, 4, 5 and 6)	1 520	18,0	1 240	1 583	Actual Conditions, pages 39-40
2	Ifraz II	14,4	2.7 bars / 5.5 km	6	4	1 920	20,0	1 650	2 880	Actual Conditions, pages 41-42
3	Ifraz III Part 1	9,3	2.7 bars / 5.5 km	4	3	6 000	10,4	2 400	6 000	Actual Conditions, pages 45-46
4	Ifraz III Part 2	9,5	-	4	3	6 100	10,3	2 400	6 000	Actual Conditions, pages 47-48

Legend:
Static Pressure no pump in operation
High elevation Poir static pressure after X km after the Inflow point
Power Input kW for all motors together

Table 12-1: Condition of Transmission Mains

Due to the high integral roughness of the pipe for reaching the design capacity a pump head of 28.3 bars would be necessary. That would lead to a complete rehabilitation of the pump station because the current pressure range cannot exceed 25 bars. The input power including an overall efficiency of 80 % would account to ca. 2,850 kW. (Appendix 1, pages 43 and 44)

The necessary investments for this rehabilitation are in no relation to the benefits (supply is increased about 800 m³/h), as the additional water demand for Erbil is much bigger.

12.2 Supply Areas

The currently available resources of Ifraz I, II and III are not sufficient. To supplement the surface water source about 800 deep wells are used with an average capacity of 30 m³/h and spread in the supply area of Erbil city.

Since the supply area is divided into many small district areas and there are also a lot of connections between different areas, the precise record of these areas is not absolutely necessary for the future design of the water network system.

Additionally the scope of the work was modified in agreement between client and contractor. Since WD Erbil is now also responsible for the supply of the whole area within the Green Belt, the scope of the work was changed by GDWS to establish a concept for this extended area.

13 DESIGN SCENARIO 2035

Future investment projects (IFRAZ IV and possible supporting projects) have to cover a range of measures to meet the water supply requirements at the end of the design period, the year 2035. These are as follows:

- Water treatment plant WTP,
- Main pumping station
- Booster pumps
- Reservoirs
- Transmission mains
- Supply areas, pressure zoning
- Establishment of DMAs with monitoring facilities
- SCADA and PLC systems
- Replacement and installation of distribution pipes

13.1 Basic Considerations

The design scenario 2035 develops the measures required to ensure the future continuous supply for the water network of the master plan area within the Green Belt.

The basis of the hydraulic calculations is the peak daily demand of 375 liters per capita and day (see Section 6.2). These numbers were agreed with the WD Erbil. Currently the average specific demand of some supply areas with 24 h supply is much higher. Therefor it is imperative to implement measures to reduce water consumption.

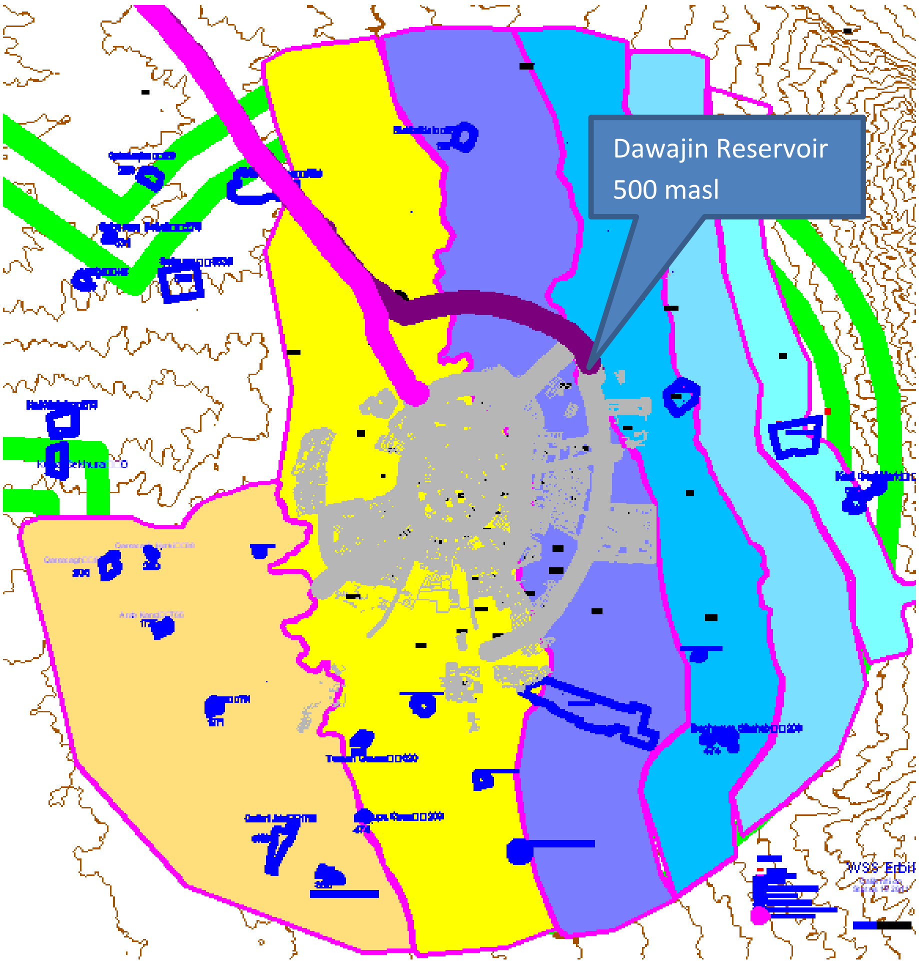


Figure 13-1: First allocation of the Network by pressure Zones

When developing the future design measure, the main aim was to establish also a distribution network to supply the individual customers at a minimised energy demand. Therefor the water for a supply zone should always be pumped only to the elevation where it is needed. In this way, energy is saved to a significant extent.

The best solution is the division of the town area along elevations contours in 50 meter steps to form the main supply areas.

For the Erbil city centre and its western parts a rehabilitation project was already completed. Generally, it is very difficult to construct new big main pipes in densely built up areas within the city. Therefore, it was necessary to identify possible new reservoir locations at the required elevations.

The following chapters summarize all measures needed for the hydraulically optimization of the whole supply area of Erbil for the design 2035 scenario.

13.2 Resources

The future daily demand for 1.9 million inhabitants will be about 720,000 m³/d. It is required to fully upgrade Ifraz III to 10,000 m³/h and the construction of the new ERBIL/Ifraz IV WTP with a capacity of 20,000 m³/h.

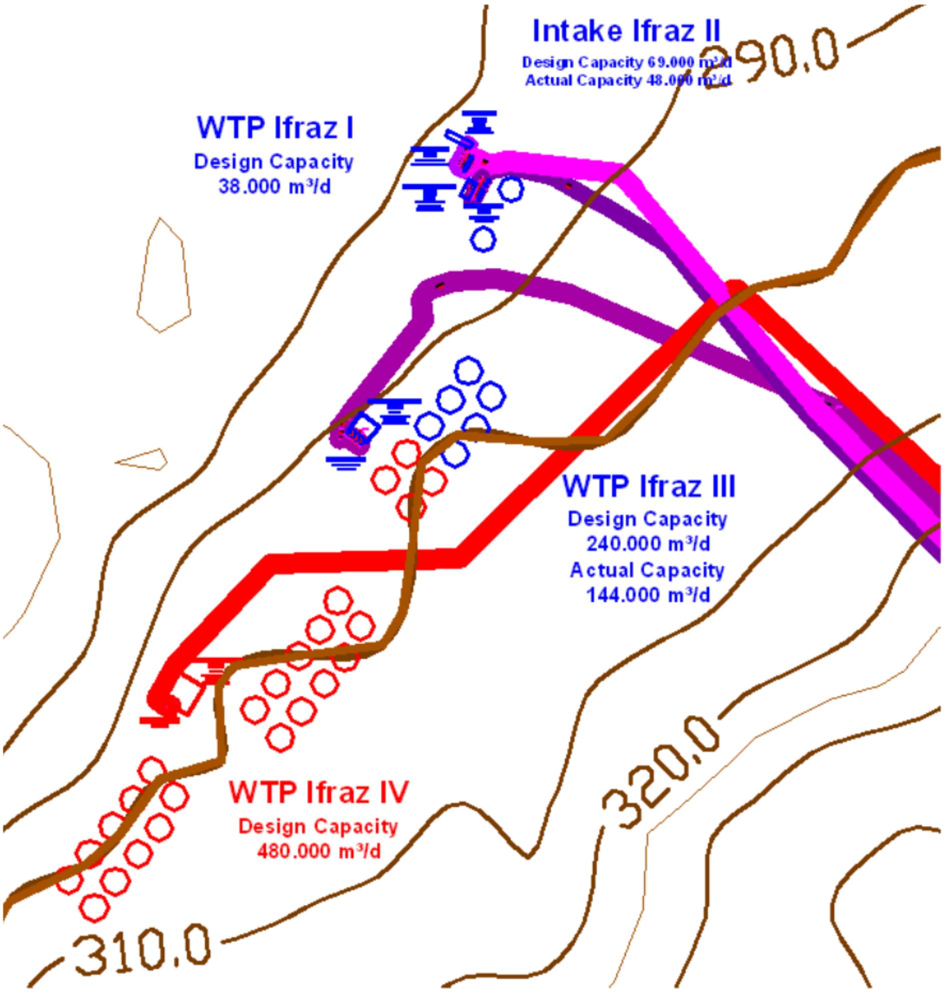


Figure 13-2: Water Treatment Plants

Theoretically the water production of Ifraz III and IV would be able to cover the whole future demand of Erbil.

If Ifraz I and II are kept in use, 806,000 m³/d can be supplied to Erbil from this source. This is a reserve of about 12 %.

Treatmentplant	Design Capacity	Actul Capacity	Future Capacity	Future Capacity	Future Capacity	Demand 2032
	[m³/d]	[m³/d]	[m³/d]	[m³/h]	[m³/d]	[m³/d]
Ifraz 1	38.000	38.000	38.000	1.583	-	
Ifraz 2	69.120	48.000	48.000	2.000	-	
Ifraz 3	240.000	144.000	240.000	10.000	240.000	
Ifraz 4	-		480.000	20.000	480.000	
Total	347.120	230.000	806.000		720.000	720.000
		Reserve %	11,9		-	

Table 13-1: Water Production and Demand 2035

The current supply is produced by Ifraz I, II and III with a daily delivery rate of 230,000 m³. Additionally about 800 wells registered by WD Erbil supply the area inside the Green Belt together with an unknown number of not official deep wells. The ground water level is therefore decreasing dramatically. In 2011 and the years before the ground water level decreased up to 4 m per year, especially in the east of Erbil city.

That is the reason why the deep wells were not included in the future resources for the supply. The deep well usage needs to be decreased to an arguable degree for preventing a further lowering of the ground water level and to let the groundwater volume recover. The remaining deep wells will be a reserve in case of emergencies.

13.3 Water Treatment Plants

13.3.1 WTP IFRAZ III

The WTP Ifraz III needs to be upgraded from the present capacity of 6,000 m³/h to 10,000 m³/h (original design capacity).

Option:

In April 2012, problems were reported from the DN 1,500 GRP having more frequently pipe bursts than expected. Therefore, the consultant wants to propose an alternative to be discussed:

- Do **not** to increase Ifraz III capacity to avoid maximum working stress for DN 1,500 GRP.
- Increase the IFRAZ IV project capacity to cover the additional capacity of 4,000 m³/h.

The increase (from 20.000 m3/h to 24.000m3/h) is 20% has to be compared to the rehabilitation/ extension (with possible further problems on the GRP main) of Ifraz III. Comparing of advantages and disadvantages and consideration of failure probability shall be part of a focused hydraulic / financial study to support decision-making.

13.3.2 WTP IFRAZ IV

A new WTP has to be constructed with a capacity of about 20,000 m³/h.

13.4 Reservoirs

The future total constructed storage capacity for Erbil shall be about 30% of the Average Daily Demand. This allows continuous supply during the daily fluctuation of demand, especially peak hour demand, and for fire fighting. This storage capacity volume of reservoirs shall be applied as a standard also for future extensions.

In order to maintain supply areas in the network, each area shall be supplied through an individual reservoir, and pressure reduced areas when required. DMAs shall be surrounded by circular pipes allowing pressure up to 12 bars. One single controlled inflow point to the pressure reduced area or to the proposed DMA shall be equipped with metering devices to allow state of the art NRW statistic and leakage control. For minor elevated sectors also booster pumps, which supply the corresponding network directly, shall be used.

Results for existing and proposed reservoirs are as follows:

Existing reservoirs:

- Dawajin old 24 000 m^3 existing
- Kasnazan Reservoir 5.000 m^3 existing

Proposed reservoirs:

- Berkot reservoir 70.000 m^3
- Dawajin new 50.000 m^3 (extension of existing one)
- Pirzeen 60.000 m^3
- Kasnazan 20.000 m^3

The available storage per supply area is given in the following table together with the corresponding percentage of the peak day demand.

Supply Area	Population	Peak Day Demand	Storage Capacity	
		m^3/d	m^3	%
SA Kasnasan Town	32,133	15,183	5,000	32.9
SA Kasnasan	154,509	62,993	20,000	31.7
SA Pirzeen+Bahrka	490,429	185,382	60,000	32.4
SA Dawajin	616,900	226,526	74,000	32.7
SA Berkot	627,272	230,165	70,000	30.4

Table 13-2: Storage capacity compared to Peak Day Demand for each SA

The location and elevations of the reservoir were determined using the following basic considerations. Initial point is the existing Dawajin reservoir at an elevation of 500 m. The elevation of the new reservoirs should be:

- about 450 masl for the city center and
- 550 masl, 600 masl and 650 masl for the higher areas in the north and the east respectively.

The search for suitable locations for the reservoir was complicated, since most locations at the right altitude were already in use and most free plots were already assigned. This required considerable additional time. The finally identified locations are a compromise between availability and pressure requirements. Pressures in the parts of the distribution mains are higher than normally recommended which requires additional pressure reducing valves.

In cooperation with the WD Erbil three locations, which are very important for the supply, were finally identified. These locations, each of an area of 2 hectares, were confirmed in their location using a GPS device. The WD Erbil is now trying to acquire these locations for construction. A corresponding official letter showing the reservoir positions was established and handed over to the GDWS Erbil for further processing and land acquisition. This is an urgent and important matter as the hydraulic model uses these locations for all its calculations and proposals.

The proposed new reservoirs are listed in the following sections with a short description including of coordinates.

13.4.1 Berkot Terminal Reservoir

A new reservoir for the SA Berkot is needed. The volume of the reservoir is calculated to have 70,000 m³ with a maximum water level of 448.0 masl. Location: North of Erbil center at Kurdistan university compound. Coordinates of the plot are:

a) X = 411,642 Y = 4,011,422

b) X = 411,638 Y = 4,011,322

c) X = 411,838 Y = 4,011,315

d) X = 411,842 Y = 4,011,414

The location is shown in the following figure.

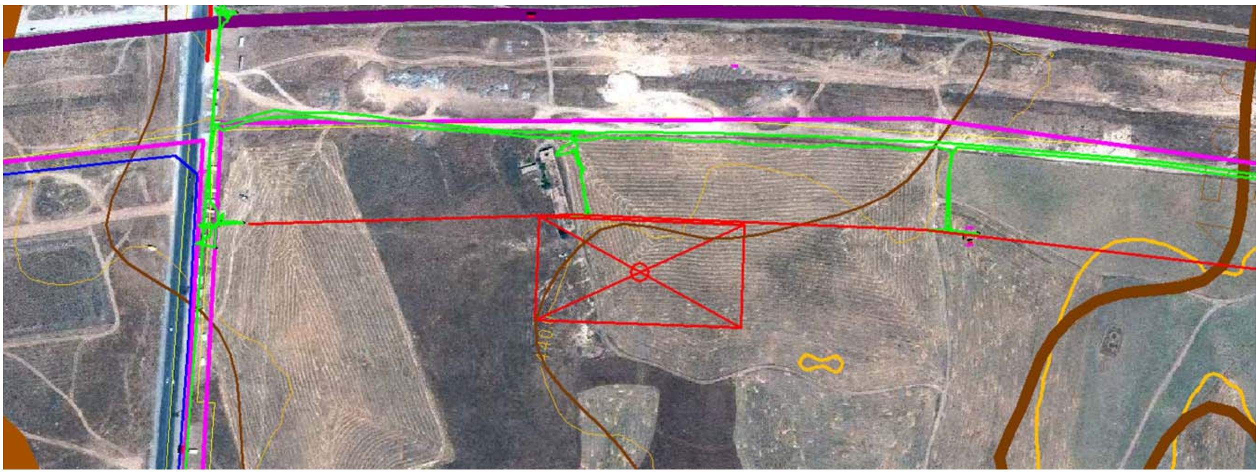


Figure 13-3: Area of Berkot Reservoir

13.4.1 DAWAJIN RESERVOIR

The Dawajin reservoir needs to be extended by additional 50,000 m³. The elevation has to be the same as the existing reservoir (bottom 489.5 masl, max. water level 495.5 m). Location: East of Erbil center beside Salahadin Street next to the old Dawajin reservoir.

13.4.2 Pirzeen Reservoir

A reservoir with 60,000 m³ capacity is needed for the SA Pirzeen. The bottom level is 570.0 masl and a max. water level is 578.5 masl. Location: After checkpoint junction to the old Salahadin Main Street. The plot's coordinates are as follows:

a) X = 419773 Y = 4015297

b) X = 419726 Y = 4015385

c) X = 419550 Y = 4015290

d) X = 419597 Y = 4015202

The location is shown on the following figure.

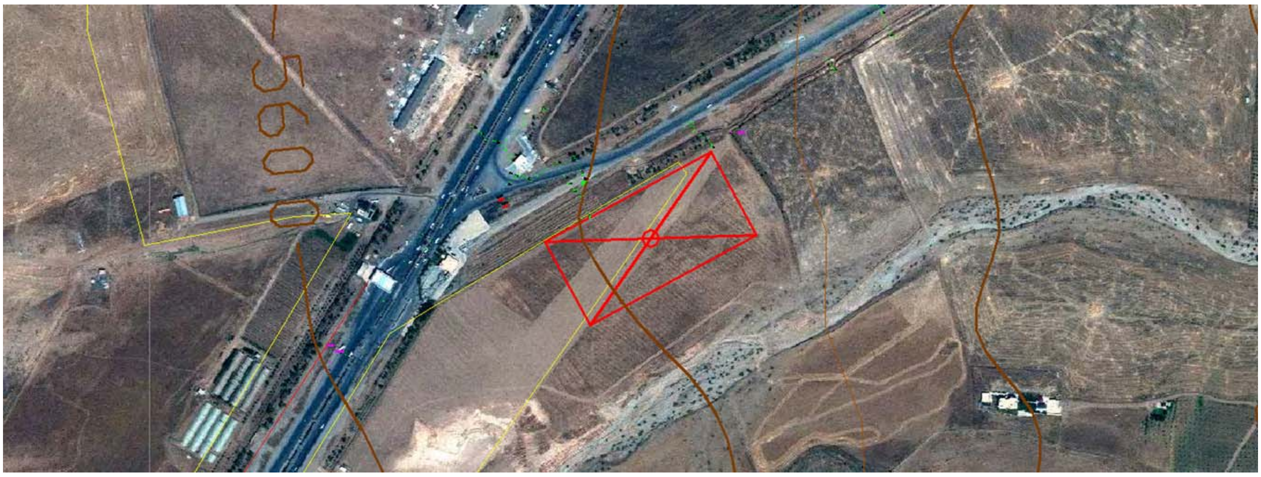


Figure 13-4: Area of Pirzeen Reservoir

13.4.3 Kasnazan Reservoir

The new reservoir for the SA Kasnazan is calculated to have 20,000 m² capacity, a bottom level of 635.0 masl and a max. water level of 641.0 masl. Location: Beside Main Street and to the east of existing Kasnazan playground. The plot's coordinates are as follows:

a) X = 423587 Y = 4007704

b) X = 423681 Y = 4007739

c) X = 423613 Y = 4007927

d) X = 423519 Y = 4007892

The following figure shows the location of the reservoir.

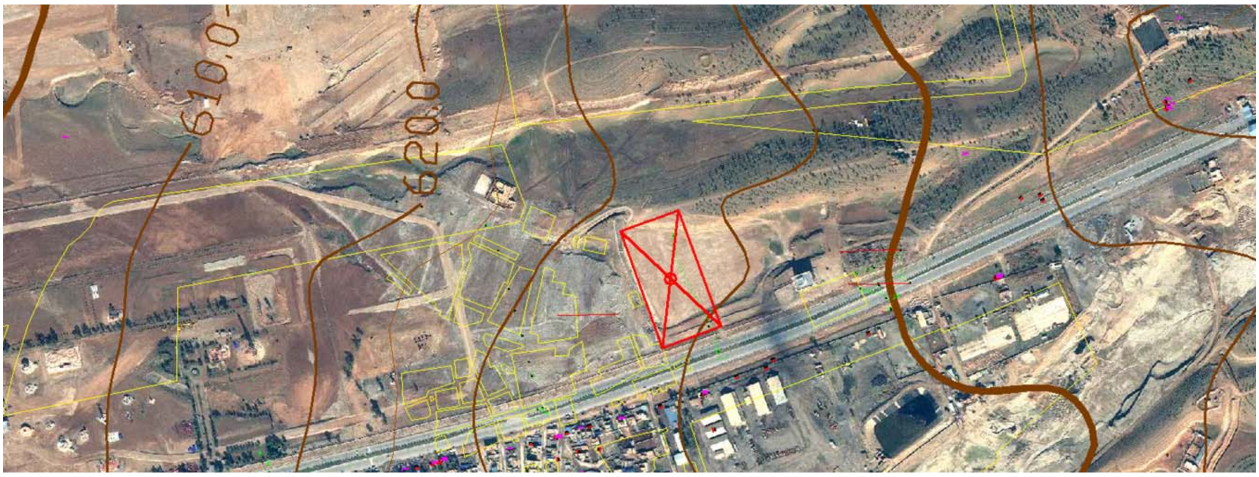


Figure 13-5: Area of Kasnazan Reservoir

13.5 New Booster Stations

13.5.1 HIGH LIFT PUMPS WTP IFRAZ IV

The High Lift Pumps in the new Ifraz IV WTP are calculated to have an overall capacity of 20,000 m^3/h, which result in an input power of 16,000 kW.

13.5.2 BS BERKOT - DAWAJIN

The pumps from BS Berkot are calculated to have an overall capacity of 14,000 m^3/h, which result in an input power of 3,200 kW.

13.5.3 BS DAWAJIN - PIRZEEN

The pumps of the BS Dawajin - Pirzeen are calculated to have an overall capacity of 9,000 m^3/h, which result in an input power of 3,700 kW.

13.5.4 BS DAWAJIN - KASNAZAN

The pumps of the BS Dawajin - Kasnazan are calculated to have an overall capacity of 3,500 m^3/h, which result in an input power of 2,500 kW.

13.5.5 BS KASNAZAN

The pumps of the BS Kasnazan – Kasnazan Town are calculated to have an overall capacity of 650 m^3/h, which result in an input power of 100 kW.

13.6 Transmission Mains

The layout of the proposed zoning with their reservoirs and the backbone of transmissions are shown in detail in the maps in Appendix 1.

For every supply area, a sketch is provided in A4/A3 format to show key assets and new pipes according hydraulic modelling.

The design principals applied for transmission mains, and suggested to be used also in future, is as follows:

- Backbone transmission mains feed reservoirs, these feed their dedicated supply areas divided into DMAs,
- The supply areas are fed by one dedicated supply connection, either the outflow of a reservoir or from a pump station,
- A system of ring mains surrounding each DMA providing water using one dedicated inflow connection.

The advantage of these principals is that control of pressure and consumption can be easily handled at the single inflow point. Even the practice of any water rationing is easier to handle.

The design of the detailed distribution pipes inside DMAs is subject to further detailed designs. For the overall considerations under this hydraulic investigations the consulted estimates a need of pipes with smaller diameter DN 80/100 in the range between 500 km up to 1.000 km until 2035. This figure is not included in the summary Table 13-12: Estimated pipe quantities.

13.6.1 SA DAWAJIN

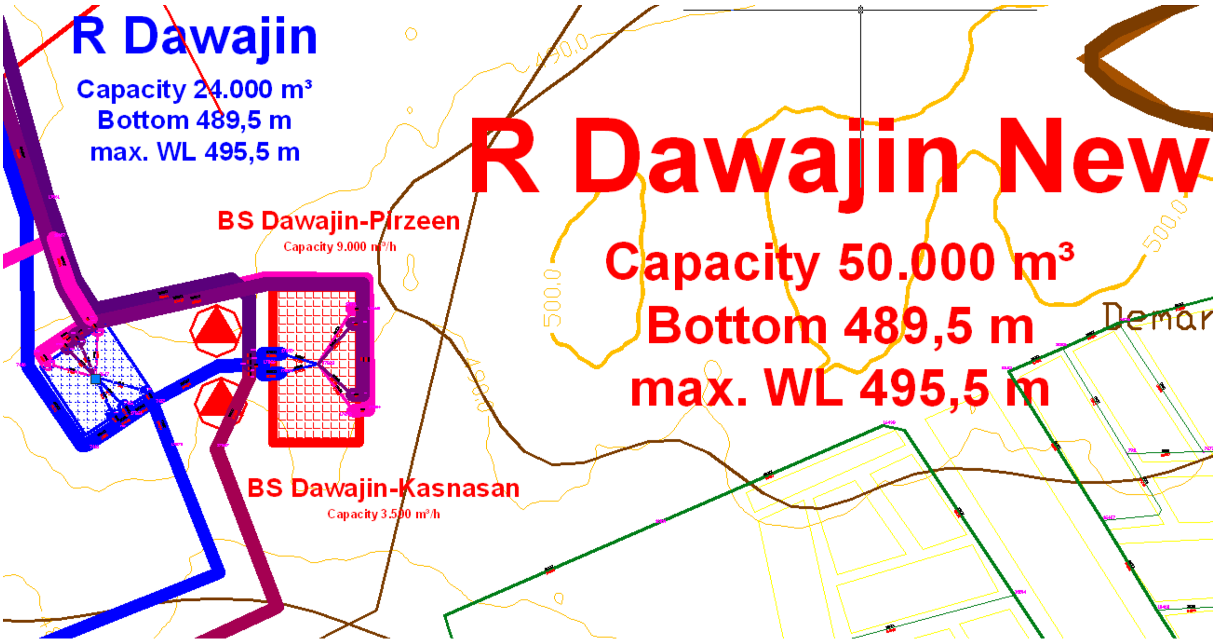


Figure 13-6: Existing and New Dawajin Reservoir

From the Dawajin reservoirs a transmission main is leading to the north through Pirmam Road to the 60th Meter Road (DN 1200 and DN 800 DI). The whole area inside 60th Meter Road will be supplied through a pressure reducing valve from the Dawajin reservoirs. The control value of the pressure reducing valve is 3.2 bars.

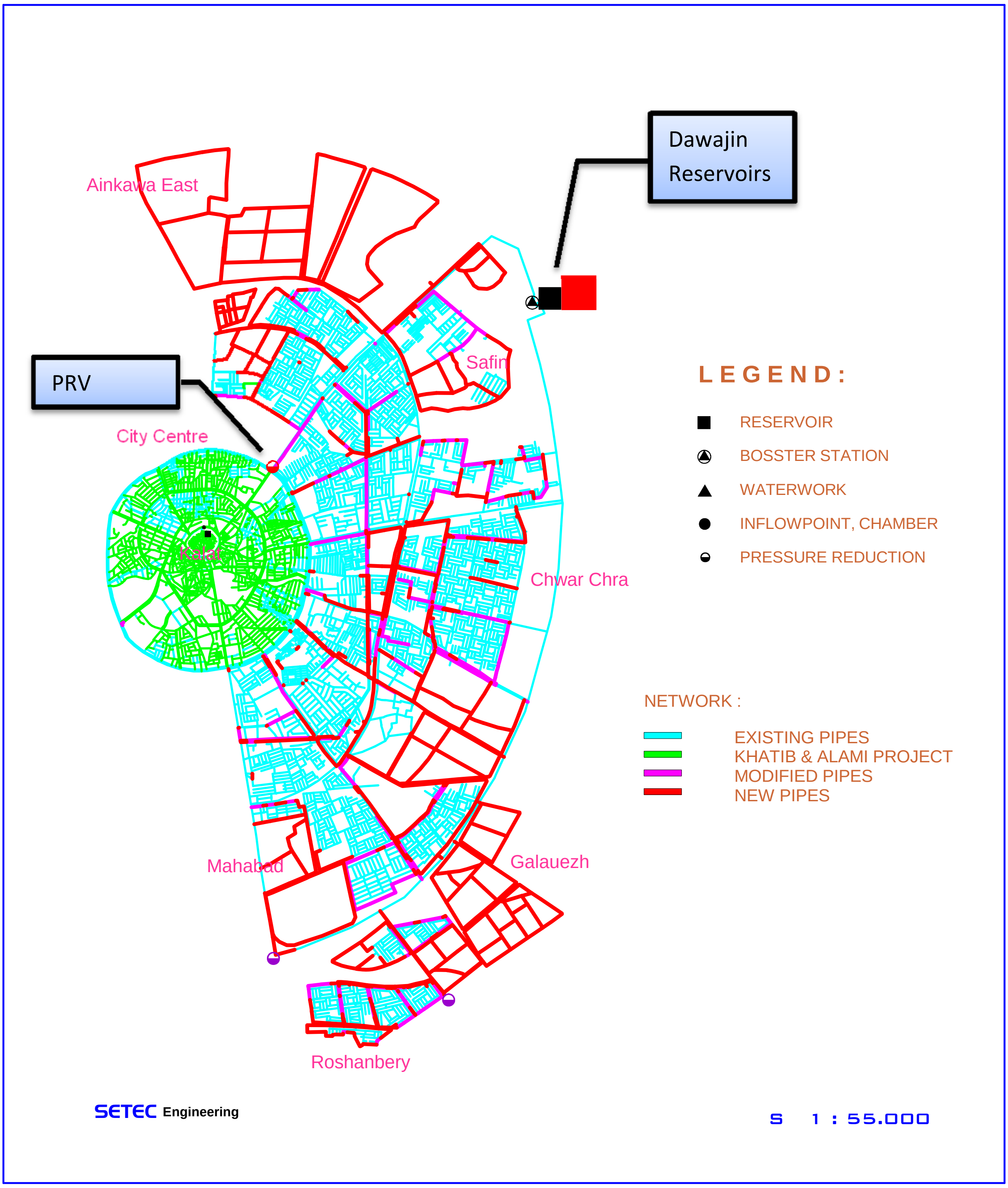


Figure 13-7: Design Measures SA Dawajin

Starting at Pirmam Road a DN 800 DI is leading to the Gulan Road to the north as well as to the Jamal Haydary Road to the south and is reduced to DN 500 in the Kirkuk Road.

The second main pipe leaving Dawajin is a DN 700 leading along the 5th Ring Road to the south until Kirkuk Road.

The existing main pipes were integrated as much as possible into the design of the borders for new supply areas.

The boarders of the supply area are as follows:

- In the north the 5th ring. Along this ring it is not possible to construct a new pipe to the north, since in the north of the ring the existing TM Ifraz III and in the south the proposed TM Berkot-Dawajin is situated.
- The western border is formed by the Quarters Ainkawa East, Kuestan and Kani, the 60th Meter Road and further in the south the Kirkuk Road.
- The 5th ring in the east
- In the south east Roshanbery and parts of Galauezh can be still supplied.

In this way the existing main pipes can be fully used.

The following table shows all measures needed for the extension and reinforcement of the supply area.

Supply Area	Material	Diameter	Length
SA Dawajin	YY	200	30,684
SA Dawajin	YY	250	2,461
SA Dawajin	YY	300	563
SA Dawajin	YY	400	388
SA Dawajin	YY	500	36
SA Dawajin	ZZ	100	17,123
SA Dawajin	ZZ	125	15
SA Dawajin	ZZ	150	20,031
SA Dawajin	ZZ	200	87,670
SA Dawajin	ZZ	250	9,826
SA Dawajin	ZZ	300	4,189
SA Dawajin	ZZ	350	637
SA Dawajin	ZZ	400	2,231
SA Dawajin	ZZ	500	1,552
SA Dawajin	ZZ	700	288
SA Dawajin	ZZ	1200	22
SA Dawajin	ZZ	1500	129
SA Dawajin	ZZ	2000	11
	Total		177,856

Table 13-3: Design Measures SA Dawajin

In Appendix 1, the results of the hydraulic calculations are shown in graphic presentation. In LC 1 (Minimum Hourly Demand) the system pressure accounts up to 7.5 bars (Appendix 1, Page 52). The area inside 60th meter Road requires a reduced pressure and the control value for the PRV is 3.2 bars.

The pressure loss during Peak Hourly Demand is about 2.5 bars. (Appendix 1, Page 53). In Roshanbery a new connection to the SA Pirzeen should be established for internal emergency distribution. The water can be supplied through a pressure reducing valve. Apart from that, peak demands can also be covered with this connection.

A new connection at the end of the DN 700 in the 5th ring to the SA Berkot has also to be established with a pressure reducing valve. This connection can be used for supplying the southern parts of SA Berkot and can also be used for internal emergency distribution.

13.6.2 SA BERKOT

This supply area covers the water distribution to the western and southern parts of Erbil. It will be supplied by the Berkot reservoir.

Starting at the reservoir the new feeding pipe of the SA follows the 5th ring way down until Kirkuk Road. The diameter reduces from DN 1800 to DN 700. All parts of the water network until 60th Meter Road shall be integrated in this SA.

In locations of low elevation outside the 5th ring way the system pressure is reduced by a PRV on the main pipe DN 600 in the Nawroz Road.

Inside Kirkuk Road there are two connections to other supply areas. One is to SA Dawajin and the other one to SA Pirzeen, both through a PRV. During construction phase of the new system parts, subareas of the SA Berkot can be supplied from the other SAs through these PRVs. After the Design 2035 is reached, the connections can be used for peak demand coverage as well as for internal emergency distribution.

The high system pressure will be reduced by PRVs on main pipes. The important valves are shown in the Hydraulic Calculation Maps as well as in the graphic presentation in the Annex 3.

Pressure and flow conditions are shown for both, LC 1 and LC 2, in Appendix 1, Pages 56 and 57.

In LC 1 system pressures account up to 7.5 bars. The system pressure in the main pipes accounts to 9.5 bars, the pressure loss due to Peak Hourly Demand is about 2.5 bars.

Demand peaks can be covered by a connection to the SA Pirzeen. The additional supply capacity can account up to 1,000 m³/h and is delivered through PRVs from SA Pirzeen. (Appendix 1, Page 57)

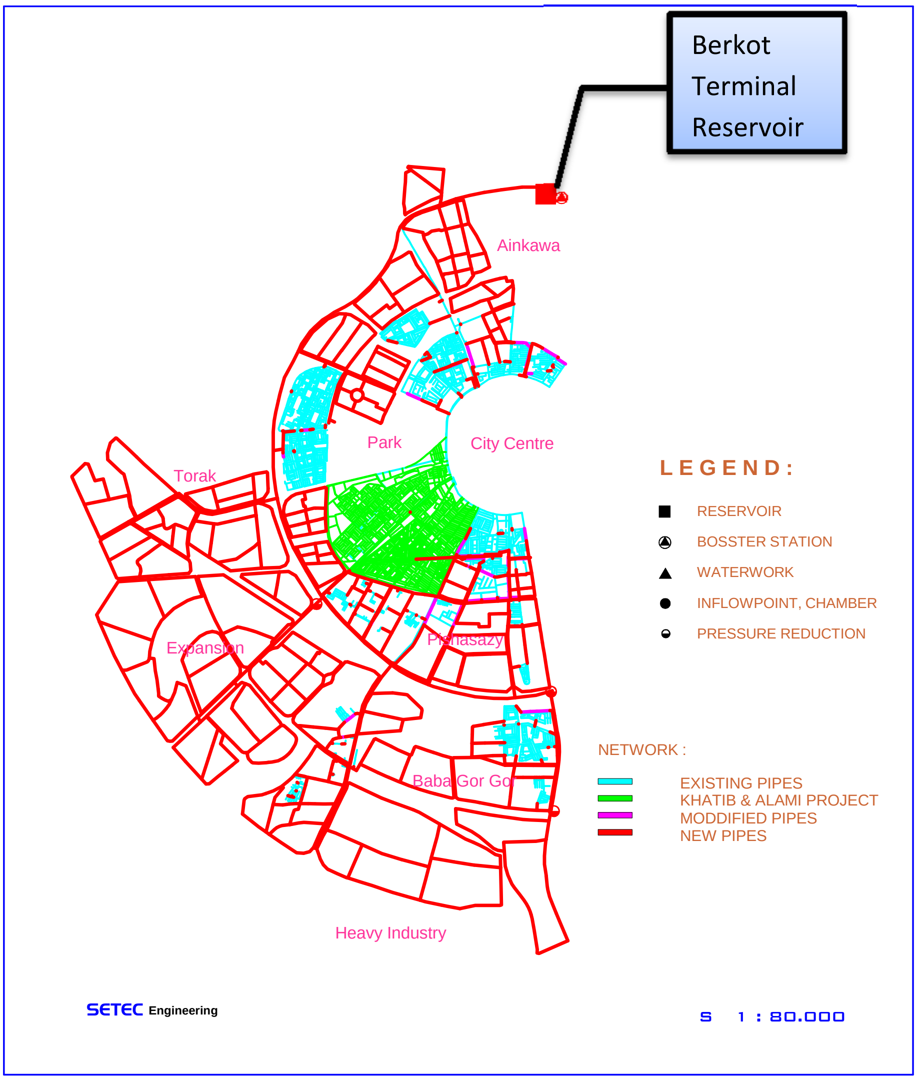


Figure 13-8: Design Measures SA Berkot

The following table shows all measures needed for the extension and reinforcement of the supply area Berkot.

Supply Area	Material	Diameter	Length
SA Berkot	YY	100	154
SA Berkot	YY	150	1.485
SA Berkot	YY	200	6.050
SA Berkot	YY	250	3.213
SA Berkot	YY	300	15
SA Berkot	ZZ	100	10.747
SA Berkot	ZZ	125	325
SA Berkot	ZZ	150	104.534
SA Berkot	ZZ	200	170.087
SA Berkot	ZZ	250	20.702
SA Berkot	ZZ	300	9.525
SA Berkot	ZZ	350	3.680
SA Berkot	ZZ	400	3.338
SA Berkot	ZZ	500	9.709
SA Berkot	ZZ	600	4.296
SA Berkot	ZZ	700	3.959
SA Berkot	ZZ	800	3
SA Berkot	ZZ	900	2.277
SA Berkot	ZZ	1000	946
SA Berkot	ZZ	1200	2.540
SA Berkot	ZZ	1500	7.539
SA Berkot	ZZ	1800	3.517
	Total		368.638

Table 13-4: Design Measures SA Berkot

For hydraulic optimization and extension of the SA altogether 370 km of new main pipes and reinforced pipes respectively in the range of DN 100 to DN 1,800 are required.

13.6.3 SA PIRZEEN

SA Pirzeen is proposed to cover the north and east of Erbil. The storage is provided by the Pirzeen reservoir.

The new main pipe DN 1200, starting at the reservoir, is proposed to follow the Birmam Road and the Ring way 6 until the Kirkuk Road (DN 1200 – DN 600). At the Kirkuk Road there is a connection needed to SA Berkot using a pressure reducing valve. This connection is used to supply SA Berkot during peak demands and can also be used for internal emergency distribution.

In the north of the town Daratu a connection in DN 500 should be constructed to connect Roshanbery.

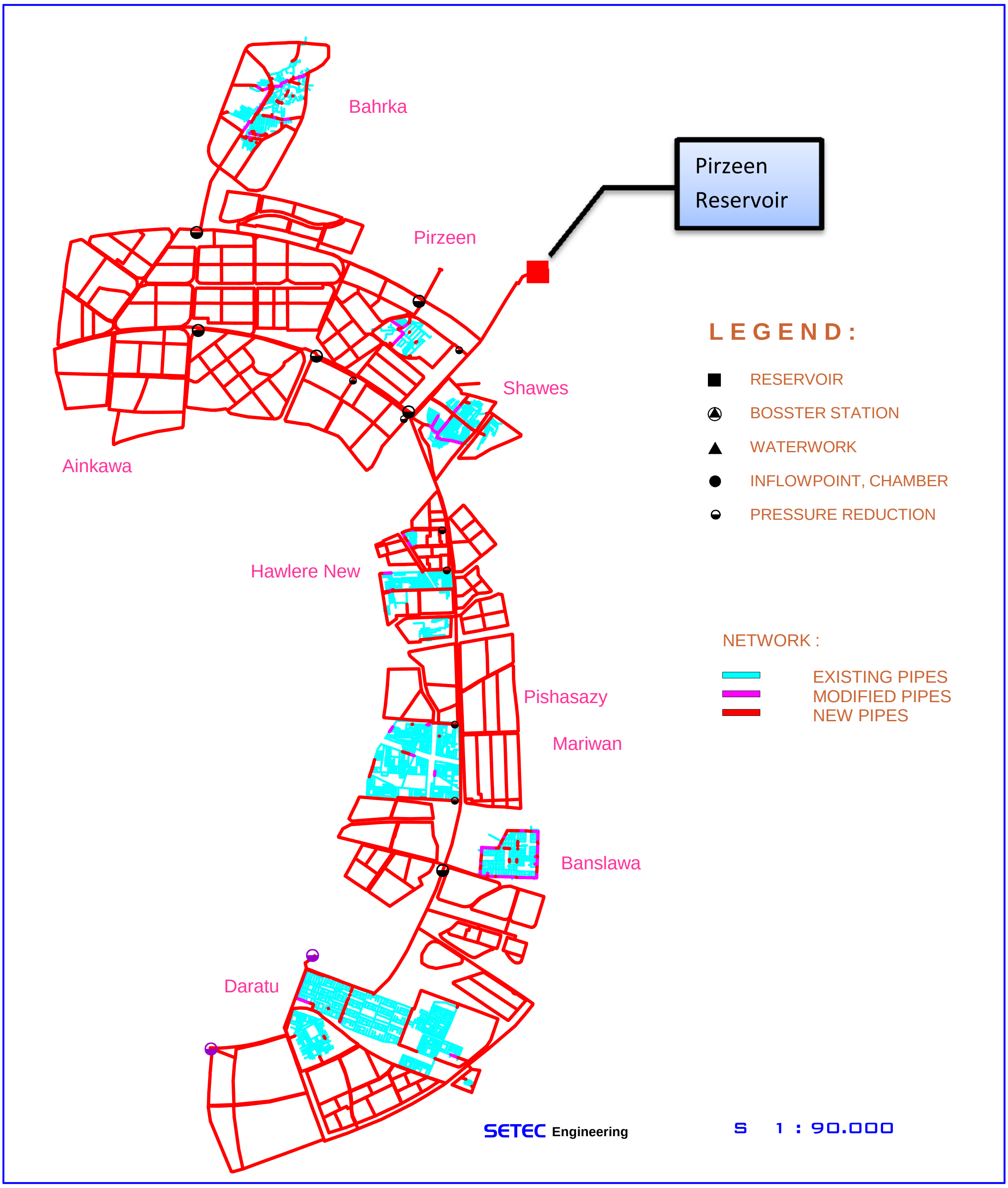


Figure 13-9: Design Measures SA Pirzeen

The main pipes for the supply of the northern parts of the SA will be laid at the 6th and 7th ring way. Through the 7th ring way Baharka town is also connected to the Erbil system.

The relatively high system pressure is reduced by pressure reducing valves at the main pipes.

Pressure and flow conditions are shown in Appendix 1 Pages 63 and 64 for both, LC 1 and LC 2.

For covering the Peak Hourly Demand of the SA Berkot about 1,000 m³/h will be delivered through the control valve in the Kirkuk Road. The control valve is designed as a pressure reducing valve with the control value of 2.6 bars.

The following table shows all measures needed for the extension and reinforcement of the supply area Pirzeen.

Supply Area	Material	Diameter	Length
SA Pirzeen	YY	100	604
SA Pirzeen	YY	125	152
SA Pirzeen	YY	150	5.540
SA Pirzeen	YY	200	6.451
SA Pirzeen	YY	250	727
SA Pirzeen	YY	300	608
SA Pirzeen	YY	350	345
SA Pirzeen	ZZ	100	57.625
SA Pirzeen	ZZ	125	172
SA Pirzeen	ZZ	150	61.290
SA Pirzeen	ZZ	200	254.323
SA Pirzeen	ZZ	250	12.683
SA Pirzeen	ZZ	300	22.740
SA Pirzeen	ZZ	350	3.688
SA Pirzeen	ZZ	400	4.815
SA Pirzeen	ZZ	500	8.137
SA Pirzeen	ZZ	600	9.079
SA Pirzeen	ZZ	700	6.943
SA Pirzeen	ZZ	800	2.168
SA Pirzeen	ZZ	900	2.743
SA Pirzeen	ZZ	1000	6.562
SA Pirzeen	ZZ	1200	5.365
SA Pirzeen	ZZ	1400	2.085
	Total		474.846

Table 13-5: Design Measures SA Pirzeen

For hydraulically optimization and extension of the SA altogether about 475 km of pipes are required to be constructed or reinforced. The diameter range of these pipes is DN 100 to DN 1,000.

13.6.4 SA KASNAZAN

This SA shall deliver water to the higher elevated areas in the east of Erbil. The proposed Kasnazan reservoir will supply the area.

Starting at the reservoir the feeding pipe DN 800 to the SA is leading to the 7th ring way and is split there to a DN 500 and a DN 600. The DN 500 follows the 7th ring way to the north and the DN 600 follows the 7th ring way to the south. Parts of Kasnazan town, existing distribution networks and Banslawa town will be integrated in the SA and divided to proposed DMAs.

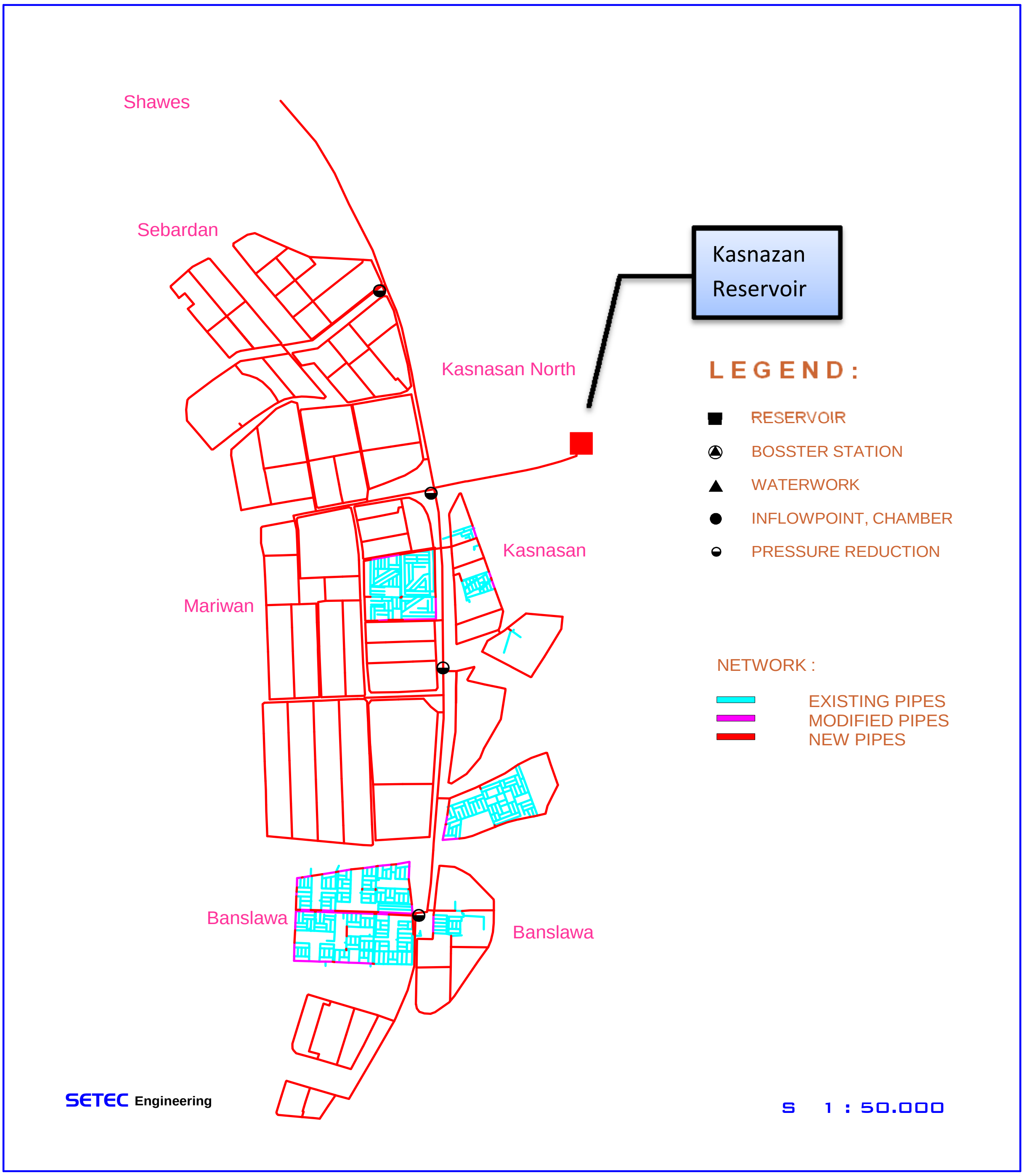


Figure 13-10: Design Measures SA Kasnazan

The high system pressure in some areas will be reduced by PRVs on main pipes. The important valves are shown in the Hydraulic Calculation Maps as well as in the graphic presentation in the Annex 1.

Pressure and flow conditions are shown for both, LC 1 and LC 2, in Appendix 1, Pages 67 and 68.

In LC 1 system pressures accounts up to 7.5 bars. The system pressure in the primary main pipes accounts to 9.5 bars, the pressure loss due to Peak Hourly Demand is about 2.5 bars.

The following table shows all measures needed for the extension and reinforcement of the supply area.

Supply Area	Material	Diameter	Length
SA Kasnazan	YY	200	7.566
SA Kasnazan	ZZ	100	34.251
SA Kasnazan	ZZ	150	2.243
SA Kasnazan	ZZ	200	95.601
SA Kasnazan	ZZ	250	2.746
SA Kasnazan	ZZ	300	4.528
SA Kasnazan	ZZ	400	2.914
SA Kasnazan	ZZ	500	7.888
SA Kasnazan	ZZ	600	821
SA Kasnazan	ZZ	800	1.993
	Total		160.551

Table 13-6: Design Measures SA Kasnazan

About 160 km of main pipes are designed and required to be constructed or reinforced for hydraulically optimization and extension of the SA. The Diameter range of these pipes is DN 150 to DN 800.

13.6.5 SA KASNAZAN TOWN

SA Kasnazan town shall be supplied by the existing Kasnazan reservoir to be fed by Kasnazan booster station. The reservoir supplies the majority area of Kasnazan and the new provision of services along the 8th ring way to the north.

The inflow pipe to the network has to be reinforced up to DN 500 until the 8th ring way. Inside the ring way a DN 400 needs to be laid to the north. The existing network of Kasnazan needs to be strengthened in some parts.

Pressure and flow conditions are shown in Appendix 1, Pages 70 and 71 for both, LC 1 and LC 2.

In LC 1 system pressures account up to 9.5 bars. The pressure loss due to Peak Hourly Demand is about 1.5 bars.

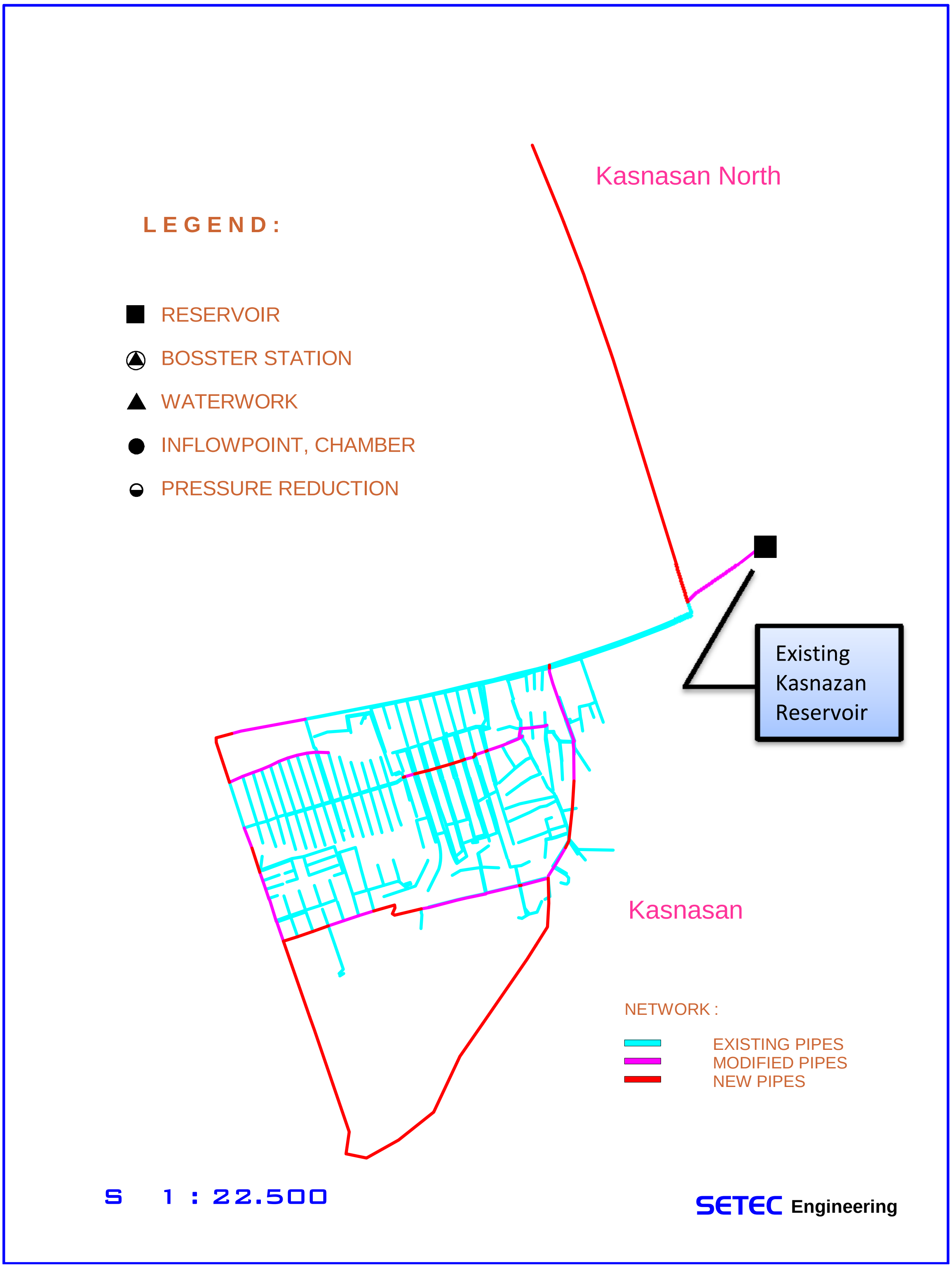


Figure 13-11: Design Measures SA Kasnazan Town

The following table shows all measures needed for the extension and reinforcement of the supply area.

Supply Area	Material	Diameter	Length
SA Kasnazan Town	YY	150	1.672
SA Kasnazan Town	YY	200	1.382
SA Kasnazan Town	YY	500	371
SA Kasnazan Town	ZZ	100	5
SA Kasnazan Town	ZZ	150	718
SA Kasnazan Town	ZZ	200	3.229
SA Kasnazan Town	ZZ	400	2.072
	Total		9.449

Table 13-7: Design Measures SA Kasnazan Town

For hydraulically optimization and extension of the SA altogether about 10 km of main pipes need to be constructed or reinforced. The Diameter range of these pipes is DN 100 to DN 500.

13.6.6 TM IFRAZ IV

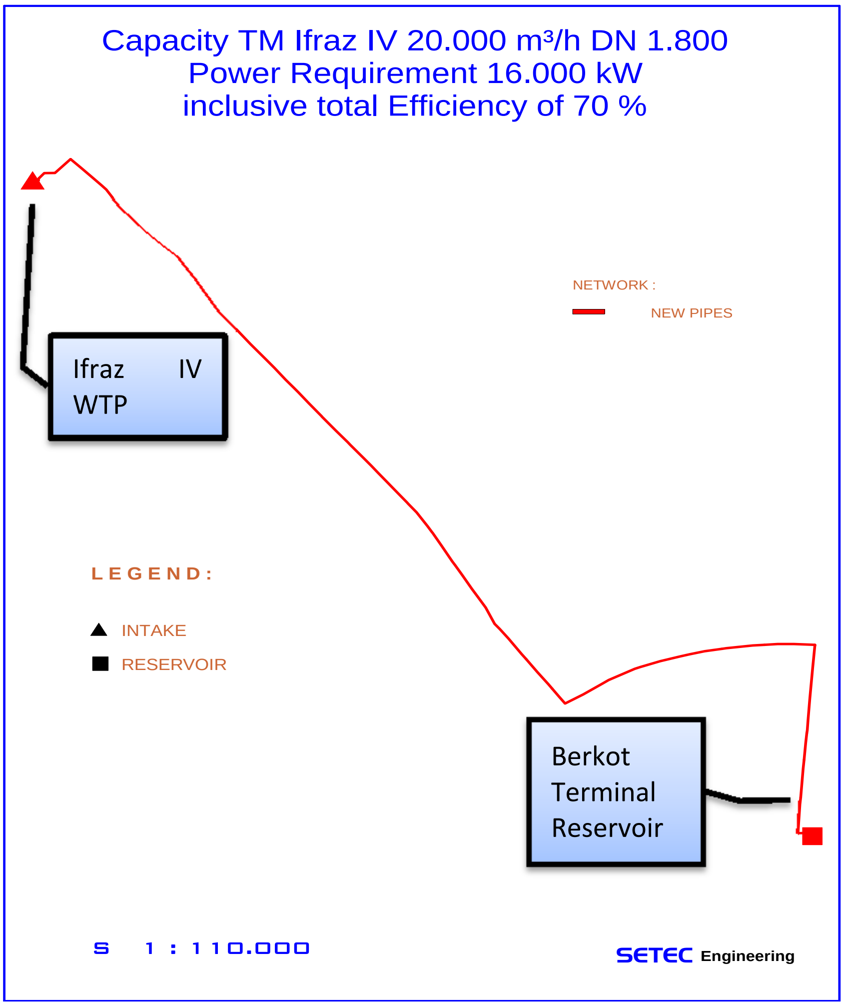


Figure 13-12: Design Measures TM Ifraz IV

The TM from Ifraz IV intake/WTP to the Berkot terminal reservoir needs to be a DN 1,800. The transmission pipe routing is more or less in parallel to the existing TM Ifraz I to III, until reaching the 7th ring way. From there it follows the 7th ring way and the main street to Baharka leading to the 5th ring way and ending at the Berkot reservoir at Kurdistan University estate.

The design capacity of the pumps needs to be 20,000 m³/h. The required delivery rate of electricity is about 16,000 kW, including a total efficiency of 70 %.

See also option suggested in section 13.3.1

The static system pressure of the pipe close to the high lift pump station at Ifraz accounts to 15.3 bars. When the design capacity of 20.000 m³/h is pumped the pressure raises to 20.1 bars. (Appendix 1, Pages 73 and 74)

Supply Area	Material	Diameter	Length
TM Ifraz IV	ZZ	1800	31.527

Table 13-8: Design Measures TM Ifraz IV

The whole TM has a length of 31.5 km.

13.6.7 TM BERKOT – DAWAJIN

The Dawajin reservoir is supplied by the booster station located at the Berkot terminal reservoir. The TM follows the 5th ring way in the south of the street.

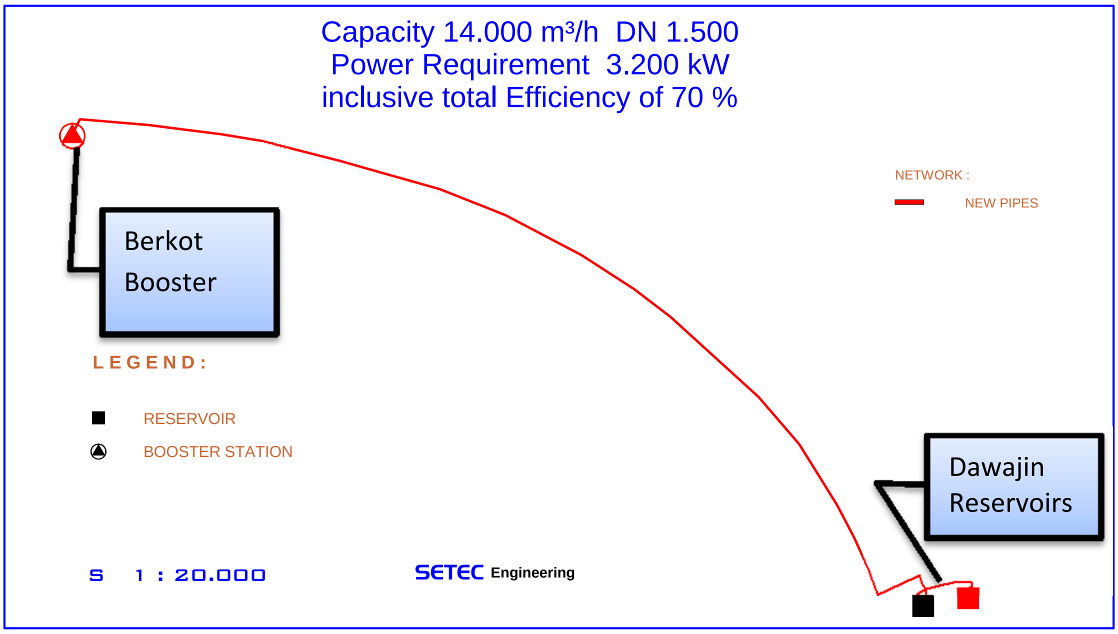


Figure 13-13: Design Measures TM Berkot – Dawajin

The design capacity of the pumps required is 14,000 m³/h. The corresponding electricity delivery rate accounts up to 3,200 kW, including a total efficiency of 70 %. In this way the whole water demand usually covered by the Dawajin reservoir can be boosted from Berkot terminal reservoir to Dawajin reservoirs in case of a blackout of the Ifraz III TM. Thus this system design proposed can be used as internal supply security in case of emergency.

The static pressure right after the pumps at Berkot reservoir accounts to 5.4 bars. When full capacity is reached, the system pressure raises to 6.3 bars. (Appendix 1, Pages 76 and 77)

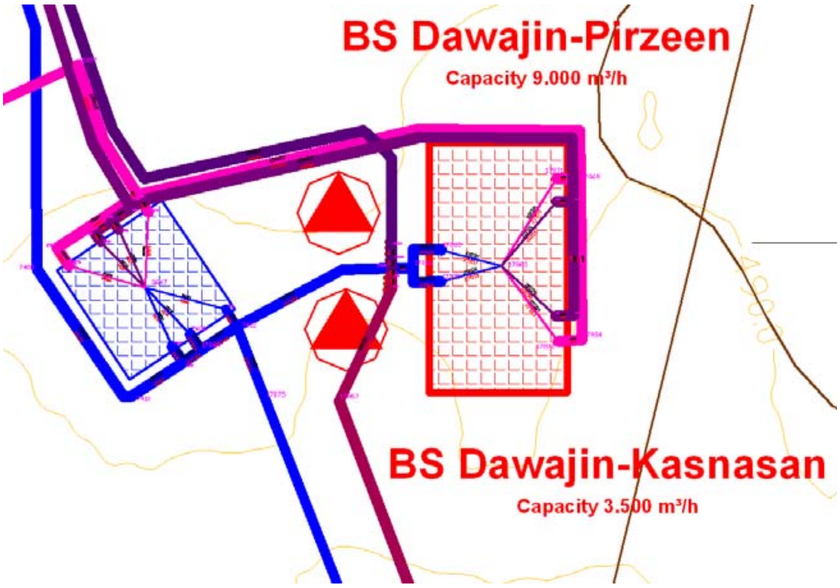
See also option suggested in section 13.3.1

Supply Area	Material	Diameter	Lenght
TM Berkot-Dawajin	ZZ	1500	5.508

Table 13-9: Design Measures TM Berkoz – Dawajin

The transport main's overall length accounts to 5.5 km of DN 1,500.

13.6.8 TM DAWAJIN – PIRZEEN AND TM DAWAJIN – KASNAZAN



Both booster stations should be supplied by the new DN 2,000 which will connect the old and the new Dawajin reservoir strictly on the same level. This configuration will bring the best supply security.

Figure 13-14: Booster Station Dawajin – Pirzeen and Dawajin – Kasnazan

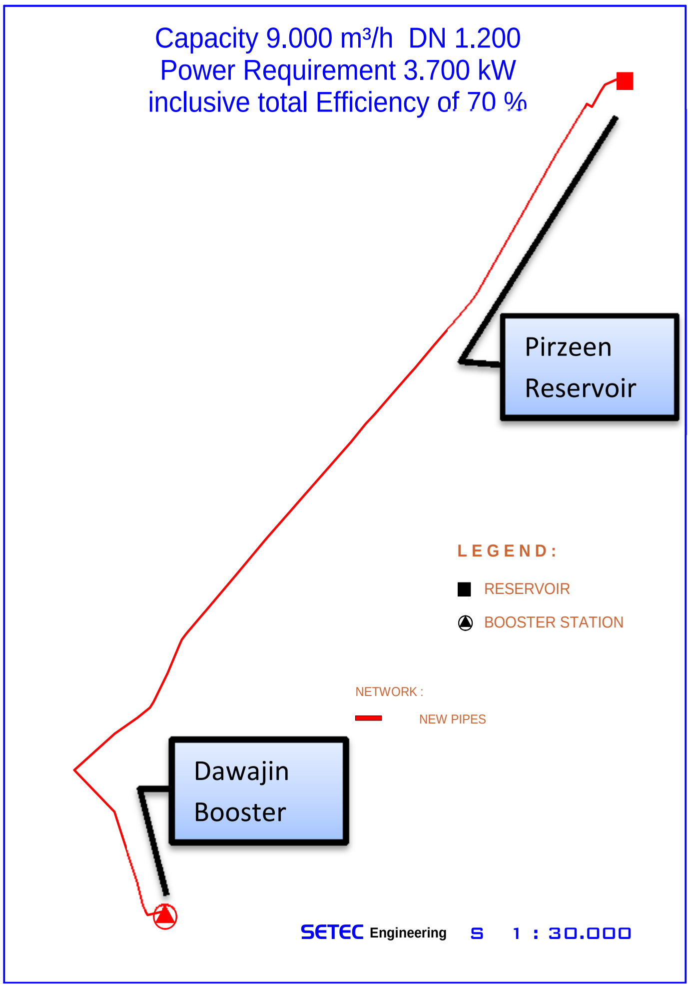


Figure 13-15: Design Measures TM Dawajin - Pirzeen

The TM Dawajin – Pirzeen DN 1,200 is first following the 5th ring way and then following the Pirman Road to the Pirzeen reservoir in the far north of Erbil.

The design capacity of the booster station is 9,000 m³/h. The required delivery rate of electricity is about 3,700 kW, including a total efficiency of 70 %. With this capacity the Peak Day Demand of the SA Pirzeen and the additional 1,000 m³/h for peak demands of the SA Berkot can be covered.

The static pressure right after the pumps at Dawajin reservoir accounts to 8.4 bars. When full capacity is reached, the system pressure raises to 10.5 bars. (Appendix 1, Pages 79 and 80)

Starting from the Dawajin reservoir the transport main DN 800 Dawajin – Kasnazan is first following the 5th ring way to the south until the Koya Street and then following the Koya Street until the Kasnazan reservoir.

The required design capacity of the TM Dawajin – Kasnazan shall reach 3,500 m³/h. The corresponding required delivery rate of electricity is about 2,500 kW, including a total efficiency of 70 %. With this capacity the Peak Day Demand of the SA Kasnazan and SA Kasnazan town will be covered.

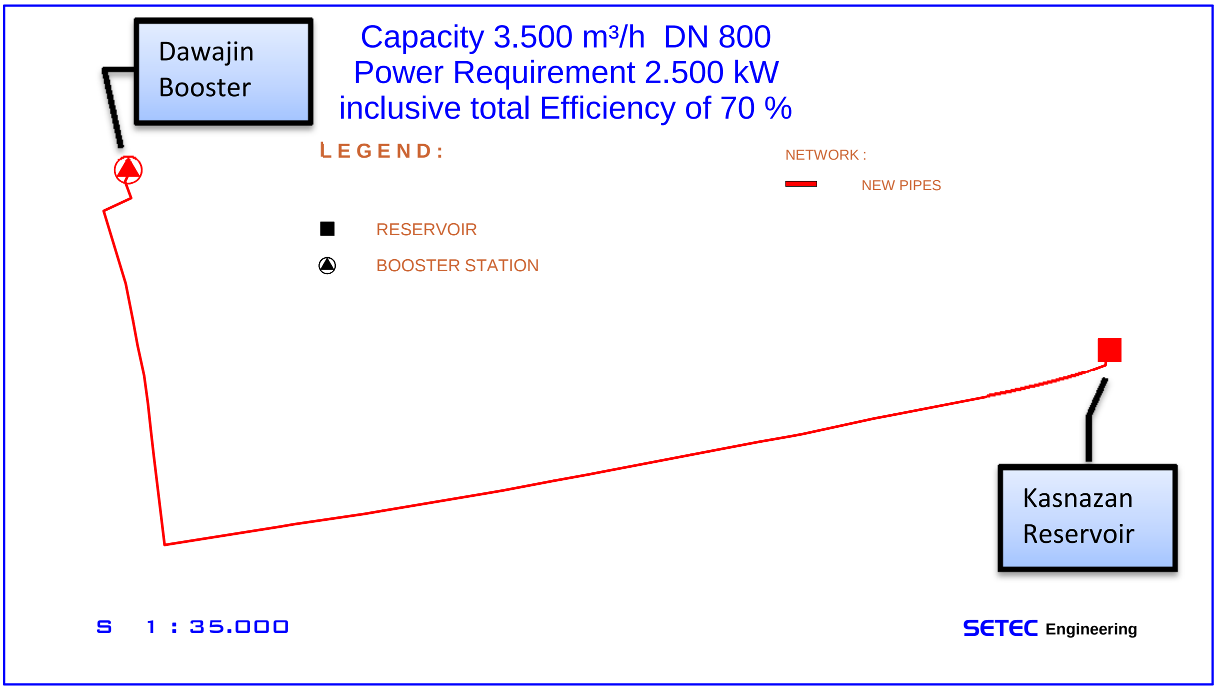


Figure 13-16: Design Measures TM Dawajin – Kasnazan

The static pressure right after the pumps at Dawajin reservoir booster accounts to 14.6 bars. When full capacity is reached, the system pressure raises to 17.9 bars. (Appendix 1, Pages 82 and 83)

Supply Area	Material	Diameter	Lenght
TM Dawajin-Pirzeen	ZZ	1200	8.322
TM Dawajin-Kasnazan	ZZ	800	10.554

Table 13-10: Design Measures TM Dawajin – Pirzeen and TM Dawajin – Kasnazan

The whole TM Dawajin – Pirzeen has a length of 8.3 km in DN 1,200.

The TM Dawajin – Kasnazan has a length of 10.5 km in DN 800

13.6.9 TM KASNAZAN – KASNAZAN TOWN

The booster station at Kasnazan reservoir is calculated to supply the existing Kasnazan Town reservoir through the corresponding TM. The pipe follows the Koya street from Kasnazan to Kasnazan Town reservoir.

The design capacity of the pumps required is 650 m³/h. The corresponding electricity delivery rate accounts up to 100 kW, including a total efficiency of 70 %. In this way the Peak Day Demand of the Kasnazan Town supply area will be covered.

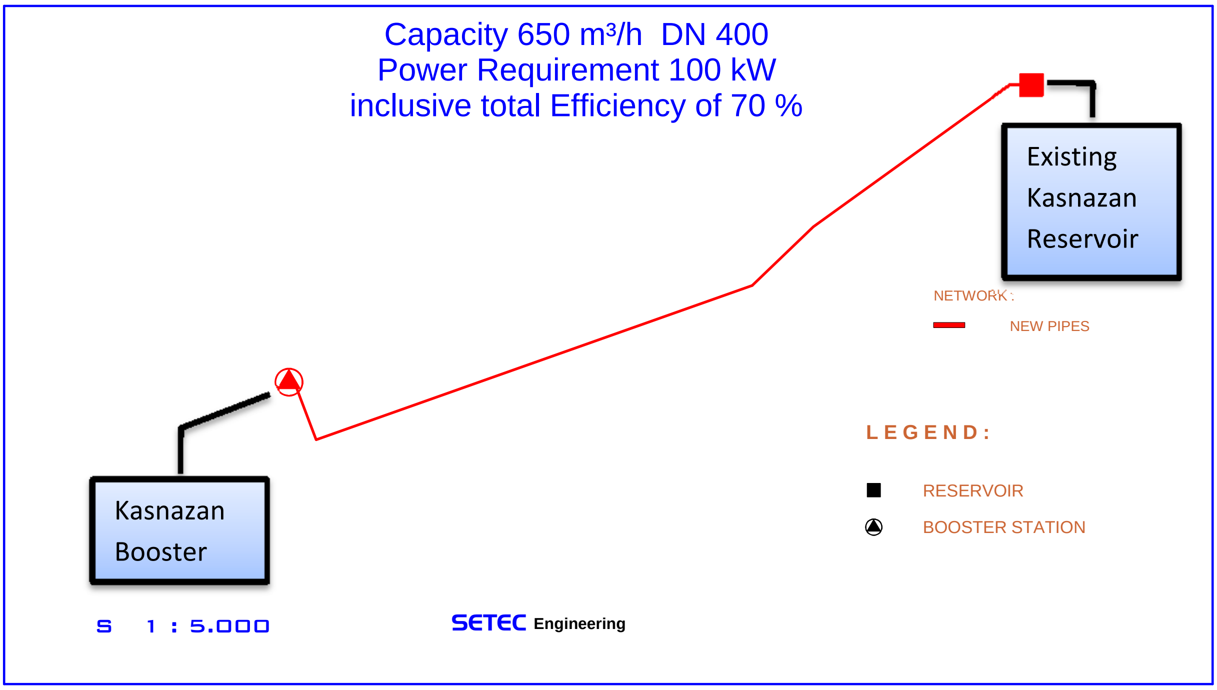


Figure 13-17: Design Measures TM Kasnazan – Kasnazan

The static pressure right after the pumps at Kasnazan reservoir accounts to 3.5 bars. When full capacity is reached, the system pressure raises to 3.9 bars. (Appendix 1, Pages 85 and 86)

Supply Area	Material	Diameter	Length
TM Kasnazan	ZZ	400	956

Table 13-11: Design Measures TM Kasnazan – Kasnazan

The transport main's overall length accounts to 1.0 km of DN 400.

13.6.10 TM IFRAZ III

According to WD Erbil the upgrade of Ifraz III is already envisaged. The results of the hydraulic calculations are based on raising the capacity of Ifraz III TM to full design capacity from current 6.000 m^3/h up to 10,200 m^3/h.

Therefor the 4 High Lift Pumps at Ifraz and the 4 pumps at Maroda Intermediate Pump Station needs to be extended to the planned 7 pumps.

The static system pressure of the pipe close to the pump station in Ifraz accounts to 9.2 bars. (Appendix 1 Page 87) When design capacity of 10,200 m^3/h is boosted by 6 pumps the pressure raises to 12.5 bars. (Appendix 1, Page 88) The required delivery rate of electricity is about 4.850 kW, including a motor efficiency of 95 %.

The static system pressure accounts to 9.2 bars right after the pumps in Maroda Intermediate Pump Station. (Appendix 1 Page 89) When design capacity of 10,500 m^3/h is boosted by 6 pumps the pressure raises to 12.0 bars. (Appendix 1, Page 90) The required delivery rate of electricity is about 4.400 kW, including a motor efficiency of 95 %.

13.6.11 TM IFRAZ I AND IFRAS II BS AINKAWA

The supply area of the western part of Erbil will be supplied by the proposed Berkot reservoir. The existing Ifraz I as well as the existing Ifraz II booster station in Ainkawa shall therefore support the supply demand of the SA Berkot network directly, using the Berkot reservoir as a floating reservoir.

The static system pressure accounts to 15.6 bars right after the pumps at Ifraz I intake/WTP pump station. (Appendix 1 Page 91) When the full capacity of 1,583 m³/h is boosted by 4 pumps the pressure raises to 19.9 bars. (Appendix 1, Page 92) The required delivery rate of electricity is about 1.400 kW, including a motor efficiency of 95 %.

The existing Ifraz II WTP/booster station at Ainkawa consists of two pump assemblies. The pumps No. 1, 2 and 3 featuring a different pump head (35 m) than Pumps No. 4, 5 and 6 (30 m). With the first set is possible to booster about 2,000 m³/h to the Erbil distribution network. (Appendix 1, Page 58) Pumps No. 4, 5 and 6 are only capable of delivering about 1,750 m³/h directly to the Erbil distribution network. (Appendix 1, Page 59).

13.6.12 SUMMARY OF PIPE QUANTITIES

The following table gives a summary of the pipe quantities required for the proposed measures.

Dimension	Material	Length		Dimension	Material	Length
200	DI K+A	41144		100	DN New	119751
250	DI K+A	964		125	DN New	512
300	DI K+A	763		150	DN New	188817
400	DI K+A	4383		200	DN New	610910
500	DI K+A	5241		250	DN New	45956
700	DI K+A	243		300	DN New	40982
800	DI K+A	1101		350	DN New	8005
1000	DI K+A	35		400	DN New	16327
90	PE K+A	95		500	DN New	27286
110	PE K+A	258588		600	DN New	14195
160	PE K+A	42888		700	DN New	11189
100	DN Rehab	758		800	DN New	14718
125	DN Rehab	152		900	DN New	5021
150	DN Rehab	17547		1000	DN New	7508
200	DN Rehab	52134		1200	DN New	16249
250	DN Rehab	6400		1400	DN New	2085
300	DN Rehab	1186		1500	DN New	13518
350	DN Rehab	345		1800	DN New	35043
400	DN Rehab	388		2000	DN New	11
500	DN Rehab	407		**Total**		**1,612,844**

Table 13-12: Estimated pipe quantities

13.7 Supply Areas

Starting from the existing Dawajin reservoir and the new locations of Berkot, Pirzeen and Kasnazan reservoirs the water network is divided into different supply areas.

For saving of pump energy costs, considering existing main pipes and further usage of existing reservoirs, each reservoir was allocated at a certain elevation. Especially the existing and the proposed Dawajin reservoir were taken into account as given elevation-points.

The following figures shows the reservoir and their corresponding supply areas.

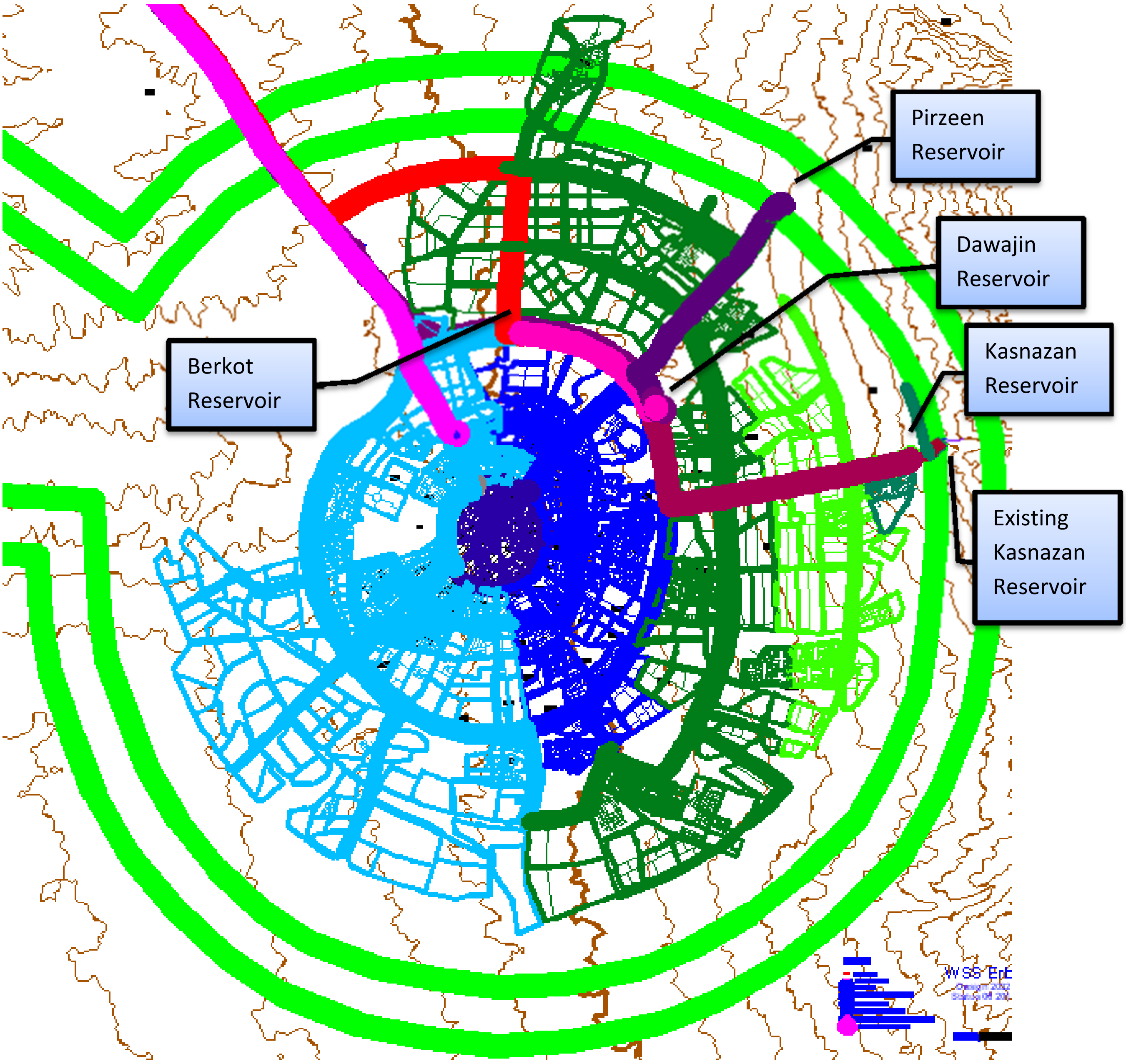


Figure 13-18: Supply Areas Erbil

The area inside the Green Belt (marked by the two green circles) is now under the administrative responsibility of WD Erbil. The supply areas are named by the corresponding reservoirs. In Figure 13-18 the supply areas are shown in different colors. SA Berkot is light blue, the SA Dawajin blue, the pressure reduced area inside 60th meter Road of SA Dawajin dark blue, the SA Pirzeen dark green, the SA Kasnazan light green and the SA Kasnazan Town is olive green.

The transport mains supplying the reservoirs are colored in red and different shades of purple respectively.

13.8 Pressure Reduction at Transmission Mains

Pressure reducing devices are required at the transmission pipes as follows:

SA Dawajin 2 Chamber

SA Berkot 1 Chamber

SA Pirzeen 8 Chamber

SA Kasnazan 4 Chamber

13.9 SCADA System

The current SCADA-system needs to be improved and extended. All existing and new devices should be connected to the central SCADA-system. This includes all new and old booster stations, reservoirs and chambers of the DMAs inflows.

At the central SCADA-system all relevant information (flow rate, pressure etc.) should be collected and visualized. With the help of this, all control operations should be easy to handle and the water consumption of each DMA could be controlled daily. Increase in water losses can be recognized early.

13.10 DMA's

The supply areas on their part were divided into further small zones, the so-called District Metering Areas (DMAs). Where appropriate the designed DMAs zones are surrounded by a strong circular ring main to allow also higher pressure. The inflow point to the DMA is designed but detailed distribution pipe design inside DMA is not part of this study.

Size and shape of the DMAs are designed to fit according to the elevation contour lines. The water consumption of these DMAs will be monitored by flow measurements, the measuring results can also be used to estimate the leakage and NRW rate in the monitored DMA. In connection with a pressure reducing valve or optional an active pressure control plunger valve the system pressure can be adjusted for the optimal pressure.

The rehabilitation project for the city centre (JICA/ K&A) divides the SA into 38 different DMAs. Similarly it is proposed to divide the overall area of supply inside the green belt into about 248 different DMAs.

If a location of a proposed new reservoir position must be changed because of failed land acquisition, only the primary main pipe routing system would have to be adjusted accordingly and the hydraulic model needs to be recalculated. For the DMAs no change of concept should be required.

The inflow to each DMA is marked by an inflow point in the Network Calculation Map (red filled circle) in Annex3.

The developed calculation model includes about 1,450 km of current pipes of Erbil City. The future overall supply areas requires an additional 1,250 km of pipelines of larger diameter.

The elaborated hydraulic model database includes all existing and proposed transmissions, primary mains and distribution mains, 300 km of existing pipes of the surrounding towns inside green belt and important pipes for the future DMAs (a total of about 3,000 km) used for modelling the design horizon of 2035. The data are visualised in the hydraulic map attached

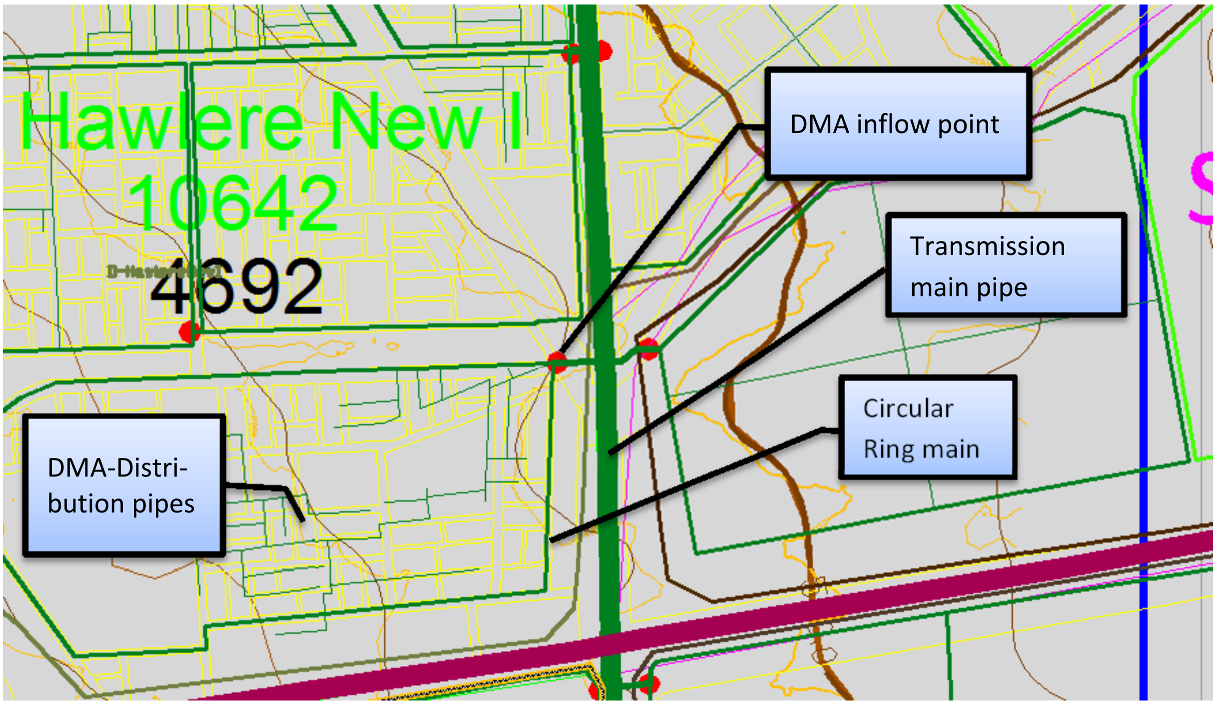


Figure 13-19: Example DMA

13.11 Time Step Simulation (24 h) for the entire Supply Area of Erbil

The time dependent dynamic loads of the entire supply area can be represented using hydraulic time step simulation. This is done by a follow-up of steady state calculation with different load cases. The result of the first calculated load case is used as basic condition for the following second load case, followed by the third and again and again to cover 24 hours of supply simulation. The time step simulation for the supply area consists of 96 individual calculations, thus the time steps are 15 minutes.

The conditions and parameters have to be defined precisely for the calculation of reservoirs (volume and water level), pumps (pump characteristics), and control valves (pressure reducing valves etc.) as well as closed valves (dividing supply areas) and trigger values for devices.

In the same way all operating sequences for all control valves and pumps (e.g. start of pump operation depended on water level of the corresponding reservoir) need to be defined representing the load case to be calculated.

The results of the calculation are graphically presented in form of demand patterns:

- Total network balance in the whole supply area
- Reservoir's water levels
- Reservoir's volume load
- filling degree of reservoirs in %
- filling rates of reservoirs, describing the flow rates to and from the reservoir
- the cumulated input flow for each reservoir, pump station and water work
- the absolute system pressure as well as the relative system pressure of each knot and the flow rate, pressure loss and flow velocity of each pipe section can be shown can be shown
- furthermore the input power and energy demand of each pump can be illustrated

In Appendix 1 all graphics of the time step simulation are attached. The most important frame conditions are summarized on page 93.

The calculation is depended on standardized demand patterns (Demand in % of the daily demand).

The demand patterns used are depended on the demand figures of the respective supply areas and therefore the maximum and minimum flow rates are different.

Smaller supply areas have a bigger Minimum Hourly Demand and a bigger Peak Hourly Demand compared to bigger supply areas. The greater the supply area is, so smaller is the difference between Minimum Hourly Demand and Peak Hourly Demand.

The following figures show the used demand patterns.

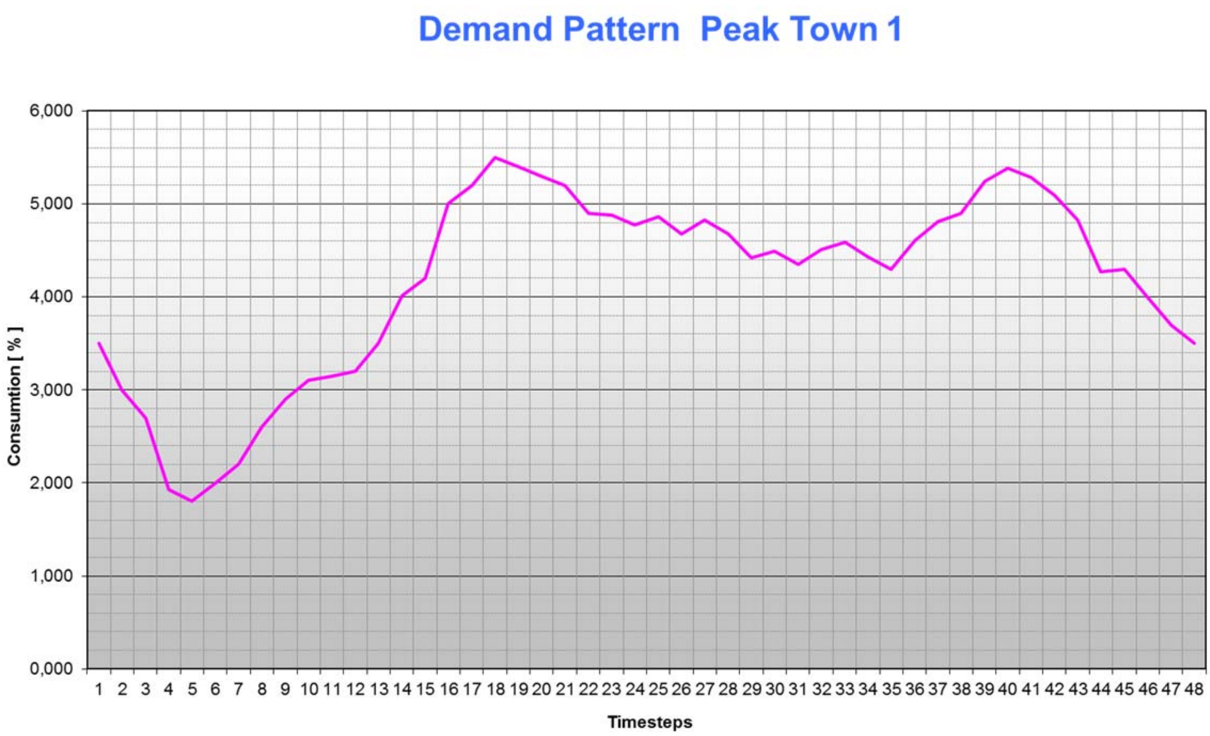


Figure 13-20: Demand Pattern Peak Town 1

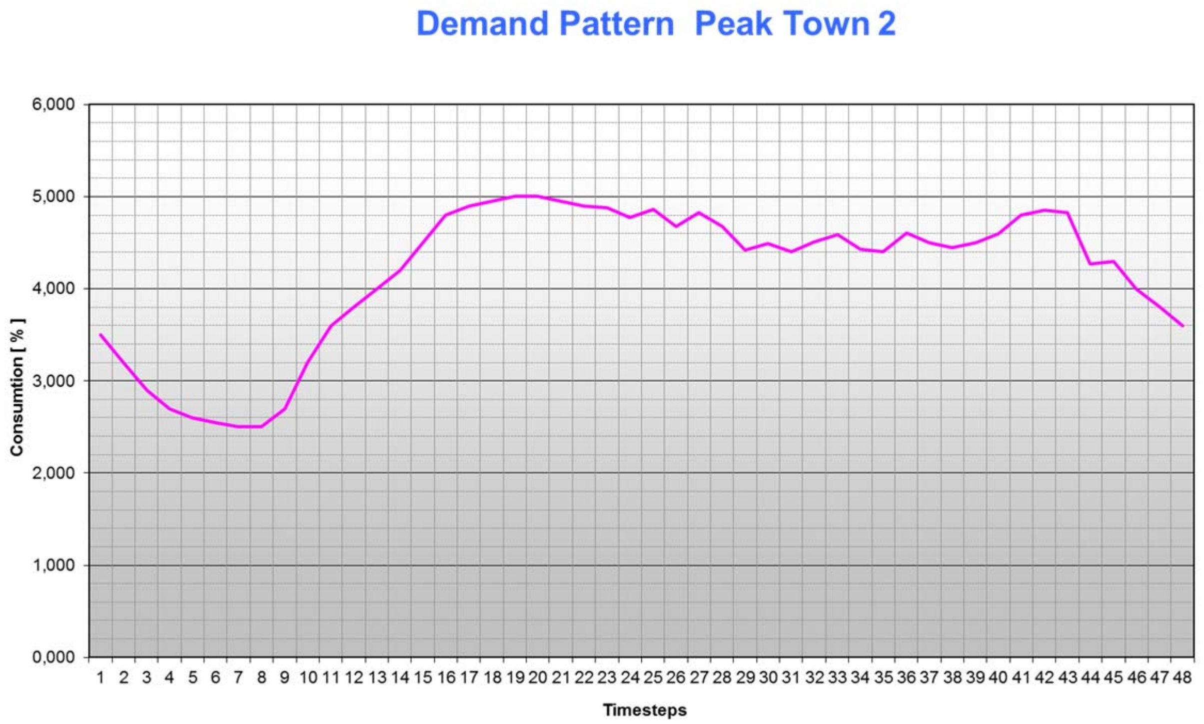


Figure 13-21: Demand Pattern Peak Town 2

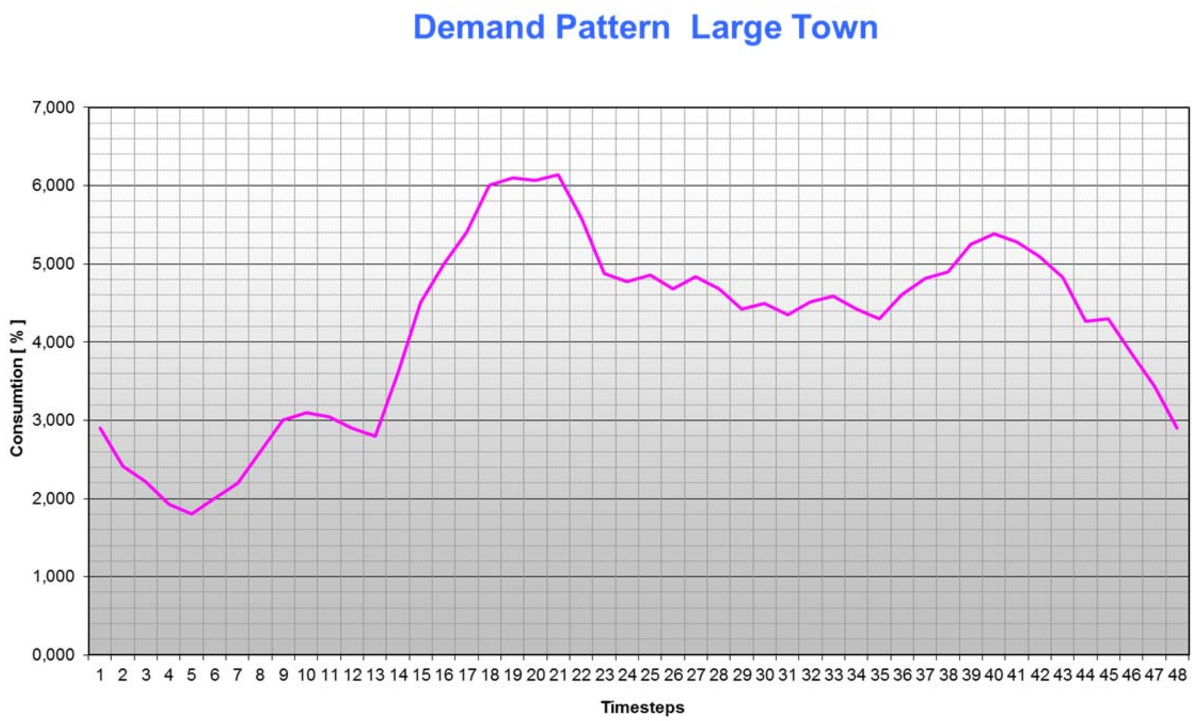


Figure 13-22: Demand Pattern Large Town

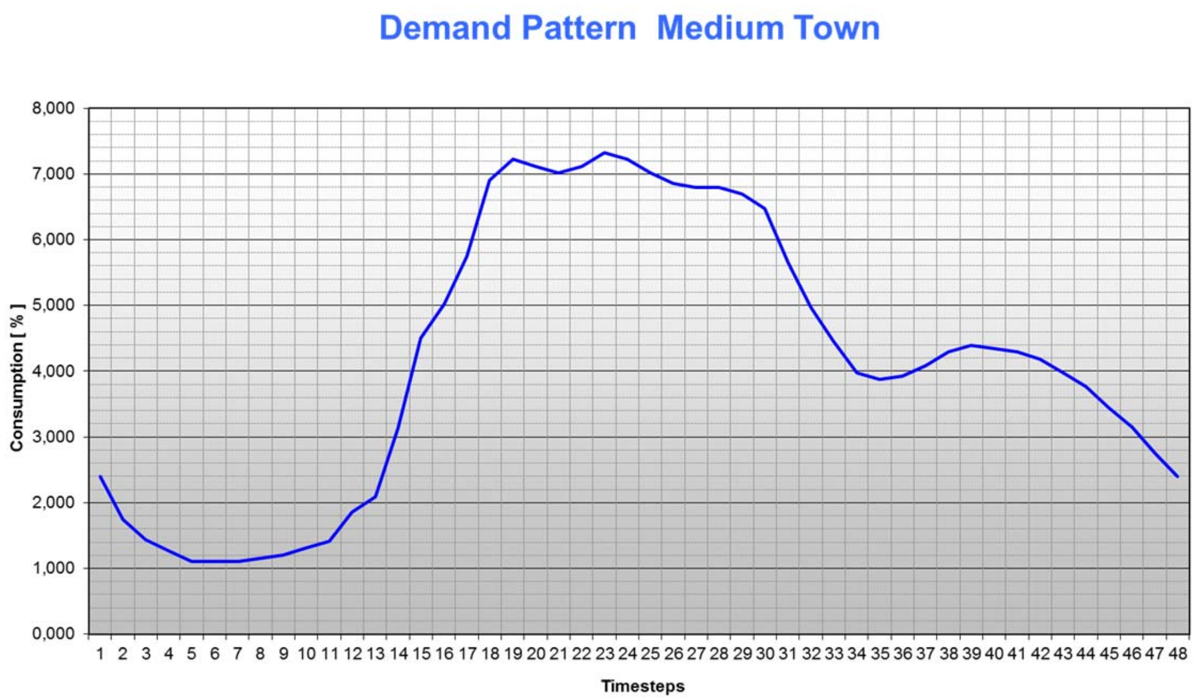


Figure 13-23: Demand Pattern Medium Town

The calculation uses the following assumptions: the WTPs of Ifraz I, II and III are covering the base load and WTP Ifraz IV covering the remaining demand. It is also assumed WTP Ifraz III is extended to 10,000 m³/h.

The required high lift pumps (20.000m³/h) at the proposed new Ifraz IV WTP were calculated with two different pump assemblies. One pump assembly was controlled by the water level of the Dawajin reservoir, the other one was controlled by the water level of the Berkot reservoir. Each pump was assumed to pump 2,000 m³/h.

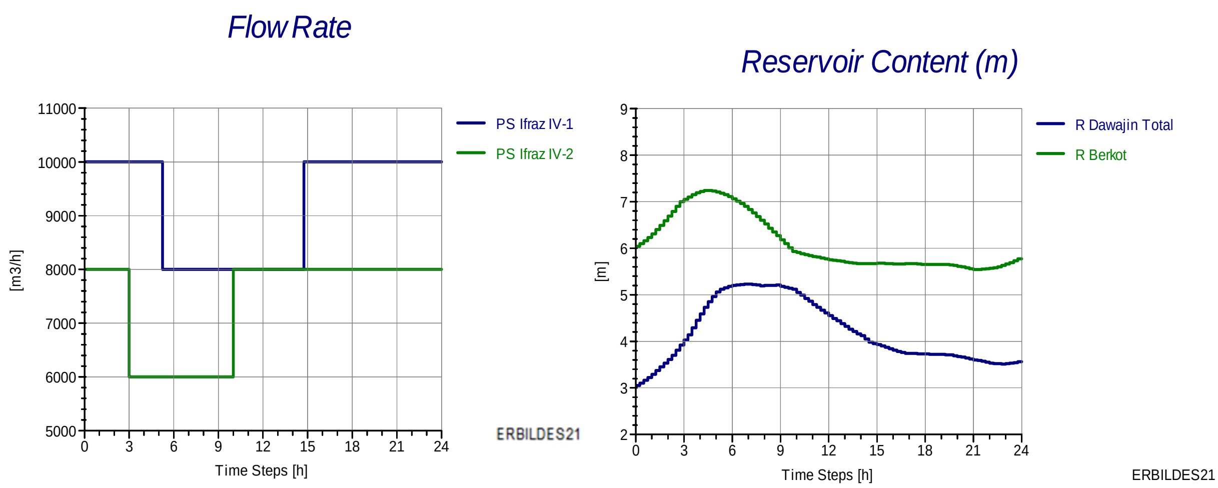


Figure 13-24: Flow Rate PS Ifraz IV Part1 / Part2 and corresponding Water Levels Dawajin and Berkot Reservoir

For the automatic control of the pumps so called trigger values were defined. For each pump an upper and a lower trigger value was defined.

When the upper trigger value is reached (water level of 5.0 m for Dawajin reservoir, 7.0 m for Berkot reservoir), one pump assembly is stopped. When reaching the lower trigger value (4.0 m for Dawajin and 6.0 m for Berkot reservoir), the corresponding pump assembly starts to operate again. Assuming an up-to-date SCADA-system is installed, the control of the pumps should be easily handled.

All pump assemblies for Erbil were defined with trigger values depended on the water level of the corresponding reservoir. The pumps for new components were calculated approximately as “generic pumps”. Thus there is no efficiency included in the calculated input power and energy use.

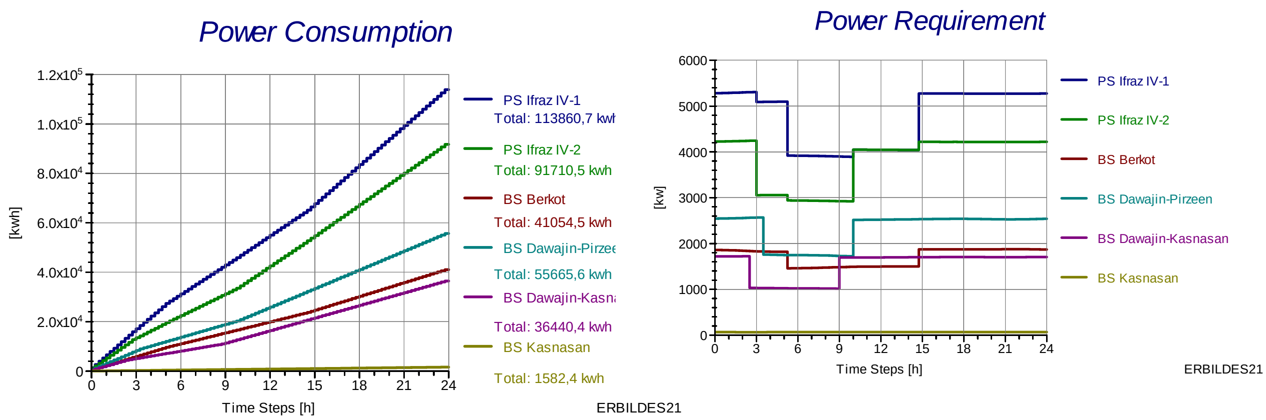


Figure 13-25: Power Consumption and Power Requirement new Plants

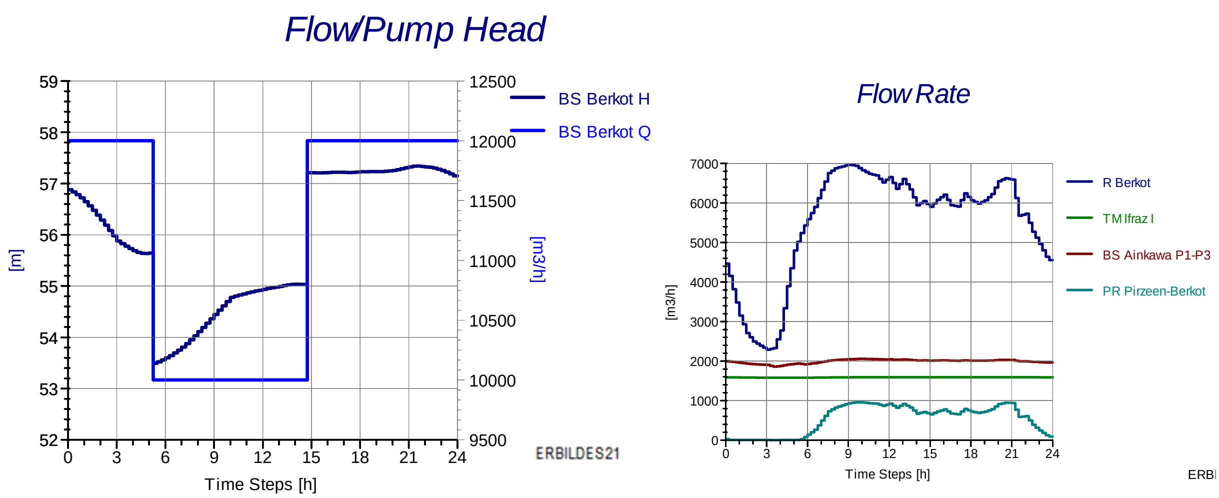


Figure 13-26: Flow- and Pressure Conditions BS Berkot

The generic pumps calculations results also in the correlation between pump head and flow rate. With this knowledge the pumps can easily be chosen by the corresponding pump characteristic.

Peak demands in the SA Berkot are covered by the SA Pirzeen through the PRV. For calculations, the control value of the PRV was set to 2.6 bars. The Figure 13-26 shows the covering of the SA Berkot’s demand by the different sources.

The high lift pumps from Ifraz I operate continuously and deliver about 1,600 m³/h directly to the SA Berkot network. The capacity of the BS Ainkawa is depended of the water level of the Berkot reservoir. When the Berkot reservoir is almost full the capacity of the BS Ainkawa decreases from about 2,000 to 1,850 m³/h.

An increasing demand leads to higher pressure losses and therefore at about 5:30h A.M the SA Pirzeen starts supplying the SA Berkot through the PRV. During Peak demand the capacity supplied from SA Pirzeen raises up to 1,000 m³/h.

The time-step simulation results can be used for an overall optimization of the proposed system design. Additionally, it can prove the general hydraulic concept. The estimated trigger values for pumps can be implemented by the SCADA-system. The simulation also offers the chance for analyzing possible emergency distribution scenarios. E.g. the impact can be analyzed hydraulically for unscheduled pump stoppages. A systematical control of the pumps can avoid or at least delay the falling dry of reservoirs.

14 ASSESSMENT OF COST

14.1 Base of Assessment

The cost estimate elaborated for the proposed measures under the design scenario 2035 can serve as a first magnitude of investment required for the implementation of the envisaged IFRAZ IV project and other urgent water projects needed in Erbil North and East. The estimate is based on rates for similar projects carried out in the Erbil region recently. The client has also supplied rates and prices especially for pipelines of larger diameters.

However, more accurate costing is required based on detail designs of the individual set of measures to be implemented at a time.

14.2 List of Measures

The proposed main measures (detailed in section 13) are listed below with a short description.

- IFRAZ IV WTP and Transmission DN 1.800 to the related proposed Berkot reservoir of 70,000 m³, operating like a terminal.
- Pump station at Ifraz, no intermediate booster station is required to reach the proposed reservoir at Berkot.
- The Berkot reservoir supplies the city center zone and south - west zone of the City by gravity
- A booster transfers water from Berkot reservoir to a proposed reservoir at Dawajin 50.000 m³.
- A booster transfers water from Dawaijin reservoir to a proposed reservoir at Pirzeen 60.000 m³.
- A booster transfers water from Dawaijin reservoir to a proposed reservoir at Kasnazan 20.000 m³.
- A booster transfers water from new Kasnazan reservoir to a the existing reservoir at Pirzeen 5.000 m³.
- The treated water from the extended Ifraz 3 WTP will be pumped through the existing DN 1500 system to the existing Dawajin 20,000 m³ and the additional planned new Dawajin reservoir 50,000 m³.
- The existing Ifraz 3 DN 1500 transmission and envisaged upgrade to 10.000 m³/h will be integrated into the new system.

14.3 Cost Assessment of Main Components

14.3.1 PRODUCTION

The required production for Erbil has to rely on surface water abstraction from the Great Zab river at Ifraz. Project title is IFRAZ IV.

The various measures and their cost are given in the following table.

Production Site	Production Q/h	Total amount (U$D)	required
Ifraz III WTP rehabilitated	Upgrade to 10.000 m^3/h	4,000,000	2018
New IFRAZ IV WTP and TM	20,000 m^3/h	20,000,000	2016
Deep well cancellation	0 m^3/d		2018
Ifraz I support of SA Berkot	1,500 m^3/h		
Ifraz II support of SA Berkot	1,900 m^3/h		
Total Production	30,000 m^3/h (+ 3,400 m^3/h) 720,000 m^3/day (+ 81,600 m^3/day) => 360 Liter / capita / day	**24,000,000**	2032

Table 14-1: Cost of securing water production

14.3.2 RESERVOIR STORAGE CAPACITY

New ground level concrete reservoirs have to be constructed and the securement and purchase of the required land in adequate location is an urgent task to be done by GDWS as a priority measure. The proposed reservoirs are:

Pos.	Location	Storage capacity	Action	Unit	Unit rate	Total amount
		[m³]			[U$]	[U$]]
1	New Dawajin, 490 m	1 x 50,000	new	m³	500	25,000,000
2	New Berkot, 440 m	1 x 70,000	new	m³	500	35,000,000
3	New Pirzeen, 570 m	1 x 60,000	new	m³	500	30,000,000
4	New Kasnasan, 635 m	1 x 20,000	new	m³	500	10,000,000
5	Rehabilitation Dawajin	1 x 20.000	rehab	LS		1.000.000
Total		**220,000**				**101,000,000**

Table 14-2: Estimated Costs for Reservoirs

14.3.3 PUMPING STATIONS

The High Lift Pumps in the new Ifraz IV WTP should have an overall capacity of 20,000 m^3/h, which result in an input power of 16,000 kW.

The pumps from BS Berkot - Dawajin should have an overall capacity of 14,000 m^3/h, which result in an input power of 3,200 kW.

The pumps of the BS Dawajin - Pirzeen should have an overall capacity of 9,000 m³/h, which result in an input power of 3,700 kW.

The pumps of the BS Dawajin - Kasnazan should have an overall capacity of 3,500 m³/h, which result in an input power of 2,500 kW.

The cost for the proposed pumping station is estimated as follows:

Pos.	**From**	**To**	**Action**	**Height [m]**	**Quantity [m³/h]**	**No. of Pumps**	**Unit**	**Total amount [€]**
							Works & Pumps	
1	IFRAZ IV WTP High Lift Pumping Station	Berkot Res. 448 m	new	160	20,000	12	200,000	2,400,000
2	Berkot Res. BS Berkot – Pirzeen Res.	Pirzeen Res. 578 m	new	130	9,000	6	100,000	600,000
3	Berkot Res. BS Berkot – Dawajin Res	New Dawajin Res. 496 m	new	50	14,000	6	150,000	900,000
4	New Dawajin Res. BS Dawajin - Kasnasan	New Kasnasan Res. 641 m	new	145	3,500	6	100,000	500,000
5	New Kasnasan Res. BS Kasnasan - existing Kasnasan Res.	existing Kasnasan Res.	new	39	650	3	50,000	150,000
Total								**4,550,000**

Table 14-3: Cost Estimates for New Pumping Stations

14.3.4 TRANSMISSION MAINS

The cost estimate includes supply and installation of main pipes and fittings as well as civil works required according the hydraulic model study.

Pos.	Action	DN	Material	Length [m]	Unit	Unit rate [U$]	Total amount Supply and installation [U$]
					Mat. & Works		
1	new	2,000	ST	11		3000	33,000
2	new	1,800	ST	35,043	m	2,500	62,500,000
3	new	1,500	ST	13,518	m	1,600	11,456,000
4	new	1,400	ST	2,085	m	1,500	10,815,000
5	new	1,200	ST	16,249	m	1,300	9,861,800
6	new	1,000	ST	7,508	m	1,100	7,053,200
7	new	900	ST	5,201	m	960	6,004,800
8	new	800	ST	14,718	m	900	4,015,800
9	new	700	ST	11,189	m	484	5,415,476
10	new	600	ST	14,195	m	378	5,365,710
11	new	500	ST	27,286	m	301	8,213,086
12	Rehab	500	ST Rehab	407	m	301	122,507
Total				147,410			**130,856,379**

Table 14-4: : Estimated Cost for Transmission and mains 2032, Welded steel 12 mm, supply and installation

14.3.5 PRIMARY/DISTRIBUTION SYSTEM

Existing Distribution mains of DN 500 to DN 200 made of Steel, PE or DI must be replaced to avoid losses and to deliver this saved amount of water to required locations and to guarantee sufficient supply of the entire city.

Following Table shows estimated length of pipes and cost for the distribution rehabilitation and extension to be incorporated in the new design of the water distribution system of Erbil. The cost estimate assumes replacement of the existing distribution system including customer connections.

Pos.	Action	DN	Material	Length [m]	Unit	Unit rate [U$]	Total amount Supply and installation [U$]
					Mat. & Works		
1	new	100	ST	119,751		31	3712281
2	new	125	ST	512	m	35	62,500,000
3	new	150	ST	188,817	m	52	11,456,000
4	new	200	ST	610,910	m	80	10,815,000
5	new	250	ST	45,956	m	95	9,861,800
6	new	300	ST	40,982	m	142	7,053,200
7	new	350	ST	8,005	m	228	6,004,800
8	new	400	ST	16,327	m	375	4,015,800
9	Rehab	100	ST	758	m	31	23,498
10	Rehab	125	ST	152	m	35	5,320
11	Rehab	150	ST	17,547	m	52	912,444
12	Rehab	200	ST	52,134	m	80	4,170,720
13	Rehab	250	ST	6,400	m	95	608,000
14	Rehab	300	ST	1,186	m	142	168,412
Estimated Total Cost Distribution Main Extension and Replacement				1.109,4	km		**121,307,275**

Table 14-5: Cost Estimates for Distribution Mains and Installation

14.3.6 BULK METERS

Meters are proposed to measure flow at the outlet of the reservoirs, main transmission pipes and at inflow points to supply sectors like DMAs to monitor and control the entirely water flow in the system. In water-monitoring systems, meters may initiate certain action, such as starting the leak detection cycle in the system after identification of noticeable problems.

Pos.	Bulk meter	Diameter	Nos	Action	Lump sum Price per	Chamber	Total Price
	type	[DN]	[p.c.]		unit [U$]	Constr.	[U$]
1	Ultra sonic flow meter, supply, installation, power supply and PLC	100-800	248	new	10,000		2,000,000
Total			248				**2,000,000**

Table 14-6: Cost estimate bulk meters

14.3.7 PRESSURE CONTROL

State of the art pressure reducer or controlled plunger valve systems shall be installed at inflow points to Supply sectors / DMAs are to allow controlled modulation of flow if the downstream pressure is less than a certain value or when the set pressure is reached. A pressure control plunger valve ensures that the downstream pressure does not become too high. It shall be used at inflow points from the ring main pipe system into the controlled supply sectors / DMAs and in other situations that require reductions from higher pressure planes to lower-pressure planes. During night-time without significant water demand the programed plunger valve operates like a nearly closed to avoid high consumption from leaks. Modulation starts time and demand depended and from a pressure monitoring point inside the zone. To supply peak hours the valve is fully open. Inflow control by plunger valves allow storage of data, local pressure with time modulation, pressure at critical point, modulation of flow and modulation of critical point.

Pos.	Pressure Control plunger valves	Diameter [DN]	Number [p.c.]	Action	Price per unit [U$]	Chamber Constr.	Total Price [U$]
1	hydraulic	400	20	new	51,600	3,000	1,092,000
2	hydraulic	300	30	new	40,000	3,000	1,290,000
3	hydraulic	250	50	new	34,300	3,000	1,865,000
4	hydraulic	200	50	new	31,200	3,000	1,710,000
5	hydraulic	150	50	new	27,500	3,000	1,525,000
Total			200				**7,482,000**

Table 14-7: Cost estimate plunger PRV

14.3.8 RUNNING ENERGY COST PER YEAR

Pumping cost for the Scenario were calculated on the basis of opportunity cost of 60 IQD/ 5 US Cent/kWh and under the assumption that by pumping direct into the distribution reservoirs with controlled pumps 24h/7d, the average energy consumption will be about as follows.

The WD thought to pump all water produced from IFRAZ IV (290 masl) to the highest point beside KRG monument in the eastern Kasnazan hills of Erbil with an elevation of about 700 masl, elevation. The elevation difference is 410 meter. The consultant recommends a more economical solution by organising distribution reservoirs according to proper pressure zoning. This solution avoids significant unnecessary energy costs caused by lifting water to higher elevations than actually needed.

14.3.9 ENERGY COST FOR SCENARIO 2032 DISTRIBUTION RESERVOIRS

The consultant has made a cost comparison between the two scenarios:

i.) Lift all water to the highest point and distribute

ii.) Lift only the required volumes of water to each supply area.

The rough calculation made results in an annual saving of about 1,000, 000 U$D. These funds could be much better used for basic and advanced design engineering and support in decision-making.

This energy cost scenario calculation supports the conclusion to design multi-level distribution reservoirs having supply areas in the same pressure level. The design of distribution reservoirs on different levels according hydraulic model is the best technical practice and most sustainable economic solution.

14.3.10 SUMMARY OF PIPELINES AND RESERVOIRS

The following table summarises pipelines and reservoirs.

							Capacity		Reservoir			Start point	End Point
No.	Location	FromReservoir	To Reservoir	Type	Pump Quantity	Pump Head	Pump	Total	Capacity	DN	Length	masl	masl
1	TM	WTP ERBIL IV	Terminal	Pump	12	160	1800	20000		1800	25.000	290	450
2	TM	Terminal	New Dawajin	Pump	6	50		5000		1800	10.000	440	500
3	TM	Terminal	North East	Pump	6	120		5000			10.000	440	570
4	TM	New Dawajin	East	Pump	6	150		5000			10.000	490	540
5	TM	East	Kasnazan	Pump	3	60		5000			10.000	640	700
8	TM	Terminal	West Zone, South	Gravity	-			5000		1800	10.000	440	
9	TM	New Dawajin	Center Zone	Gravity				5000			10.000	490	
10	TM	North East	North East Zone	Gravity				5000			10.000	520	
11	TM	East	East Zone, South	Gravity				5000			10.000	640	
12	TM	Kasnazan	Kasnazan Zone	Gravity				3000			10.000	700	
												BWL	MWL
15	Reservoir	Terminal							50000			440	448
16	Reservoir	Dawajin renewal							20000			490	498
17	Reservoir	Dawajin							50000			490	498
18	Reservoir	East							30000			640	648
19	Reservoir	North East							30000			570	578
21		Distribution								1500	999	PN 16	
22		Distribution								1400	999	PN 16	
23		Distribution								1200	999	PN 16	
24		Distribution								1000	999	PN 16	
25		Distribution								800	999	PN 16	
26		Distribution								600	999	PN 16	
27		Distribution								500	999	PN 16	
28		Distribution								400	999	PN 16	
29		Distribution								300	999	PN 16	
30		Distribution								200	999	PN 16	

Table 14-8: Summary of pipelines and reservoirs

14.3.11 SUMMARY OF COST

The following table gives an overview of all cost.

Summary		Unit		Cost	Total amount
	[]	[m]	[]	[U$/d]	[U$/year]
Table 14-1: Cost of securing water production / WTP		LS	1		24,000,000
Table 14-9: Estimated Costs for Reservoirs			4		101,000,000
Table 14-10: Cost Estimates for New Pumping Stations		PCS	4		4,550,000
Table 14-11: Estimated Cost for Transmission and mains		km	147,4		130,856,379
Table 14-5: Cost Estimates for Distribution mains and Rehabilitation		km	1.109,4		121,307,275
Table 14-12: Cost estimate bulk meters		pcs	248		2,000,000
Table 14-7: Cost estimate plunger PRV		pcs	200		7,482,000
House connections estimate		pcs	300,000	200	60,000,000
TOTAL					**446,650,204**

Table 14-13: Cost summary

The estimated cost of about 446 million USD should be increased by a contingency factor of about 20% reaching an overall total of

535 million USD

In addition, one has to consider further costs for designs and construction supervision.

15 MAPS PRODUCED

15.1 Hydraulic Model Map

The mapping representing the hydraulic models for the calibration state of 2011 and for the design scenario of 2032 are attached in APPENDIX 3 and as soft copy in the data collection submitted with this report.

15.2 Calibration Measurement Map

The measurement map is the base for the calibration measurements which are necessary for the computer model. It contains measurement points for pressure and flow measuring instrument with their individual numbers. A separate measurement map was not provided. The positions of the numbered measurement points are included in the hydraulic model map “Calibration Status 10 2011”.

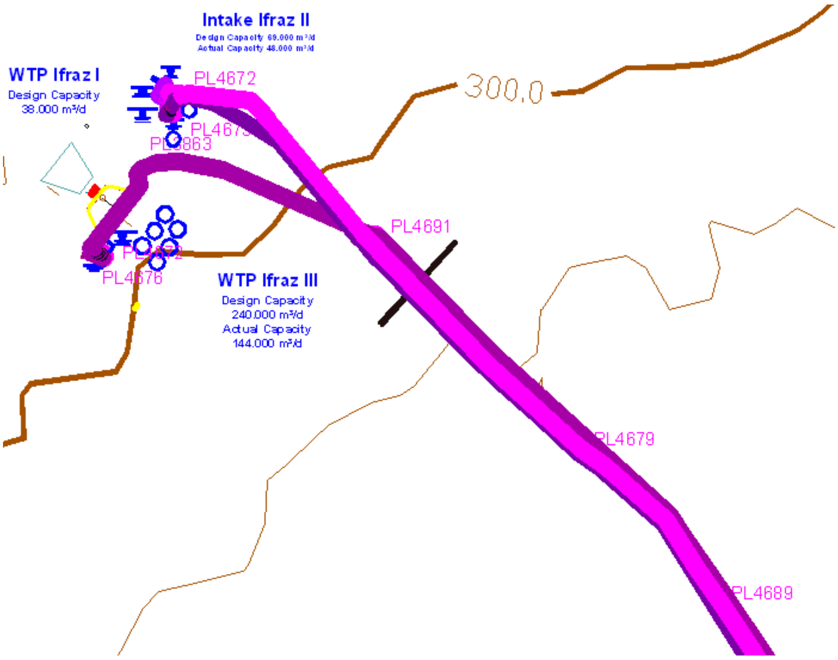


Figure 15-1 : Measurement map

The calibration measurement map is attached in APPENDIX 3 and included in the soft copy of project data

15.3 Hydraulic Result map

Hydraulic maps are simplified network maps for a clear graphic presentation visualizing the result of network calculations. The maps for the load case calculations or scenarios are prepared on a suitable scale to cover the area of the supply zone under processing or the entire system. These maps show the absolute pressure head (hydraulic grade), the flow velocity and the calculated pressure head at the measurement points.

The relative pressure (head or pressure head) are displayed combined with the flow conditions for every future load case. The pressure heads are visible as contour lines. The flow velocity and the calculated pressure head are shown at points of interest.

The various hydraulic maps are attached in APPENDIX 1 and included in the soft copy of project data.

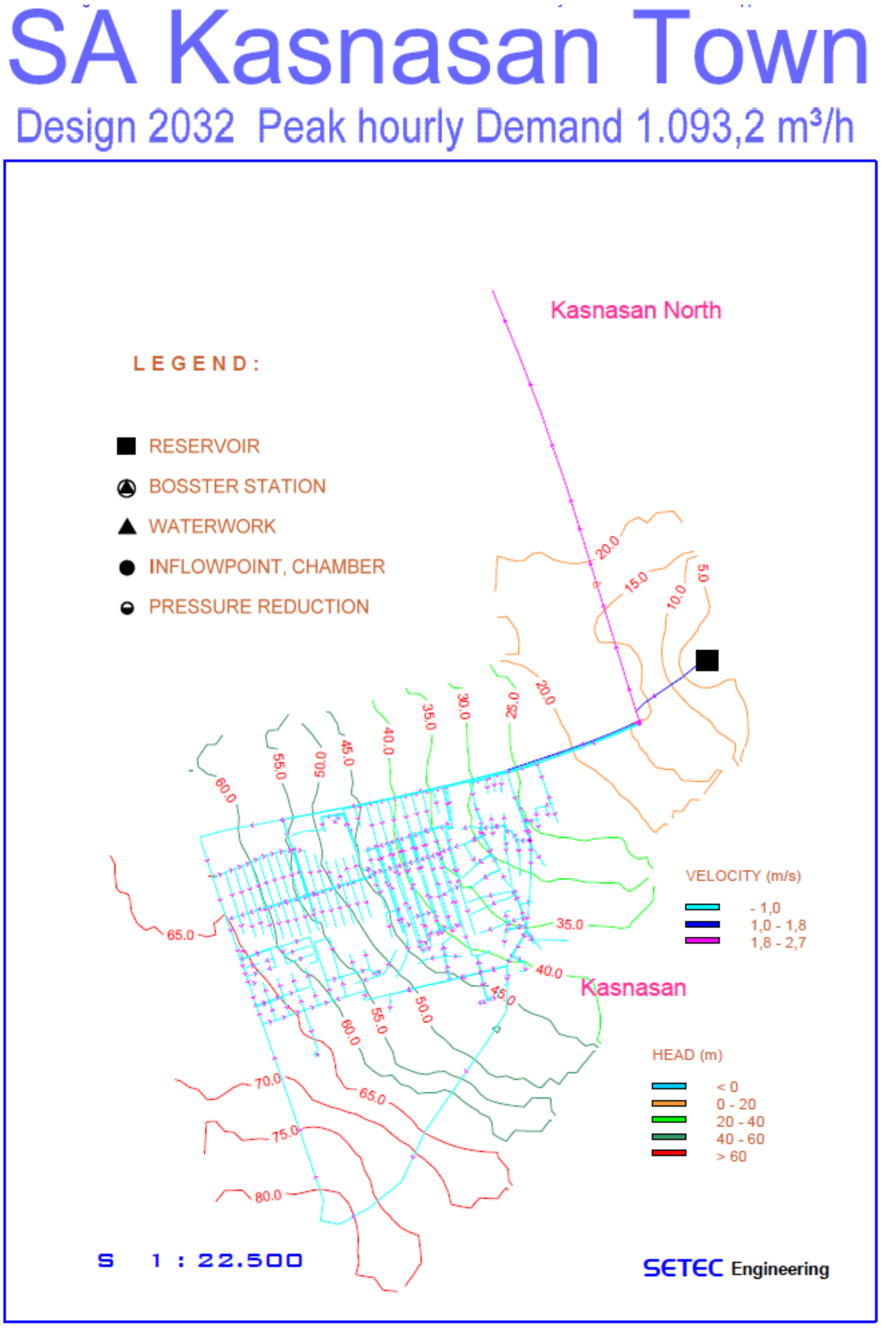


Figure 15-2: Example result map of pressure zoning

APPENDIXES

APPENDIX 1

Graphic Presentation

KURDISTAN REGIONAL GOVERNMENT - IRAQ

MINISTRY OF MUNICIPALITIES AND TOURISM

Kurdistan Region Infrastructure

Water Sector Master Plan

HYDRAULIC CALCULATION

ERBIL

APPENDIX 1

GRAPHIC PRESENTATION

JUNE 2012

SETEC Engineering

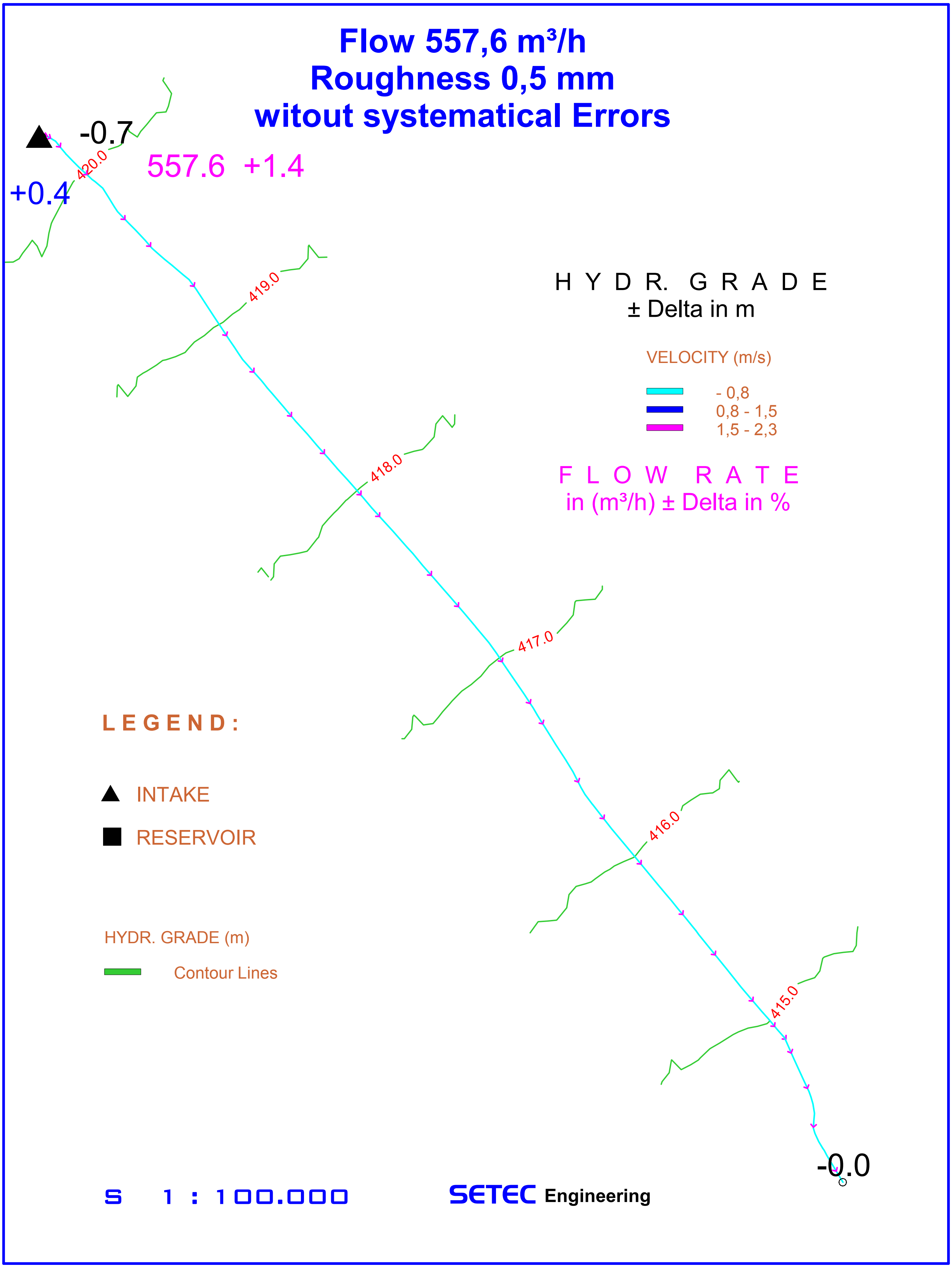
Graphic Presentation

Calibration

Load Cases

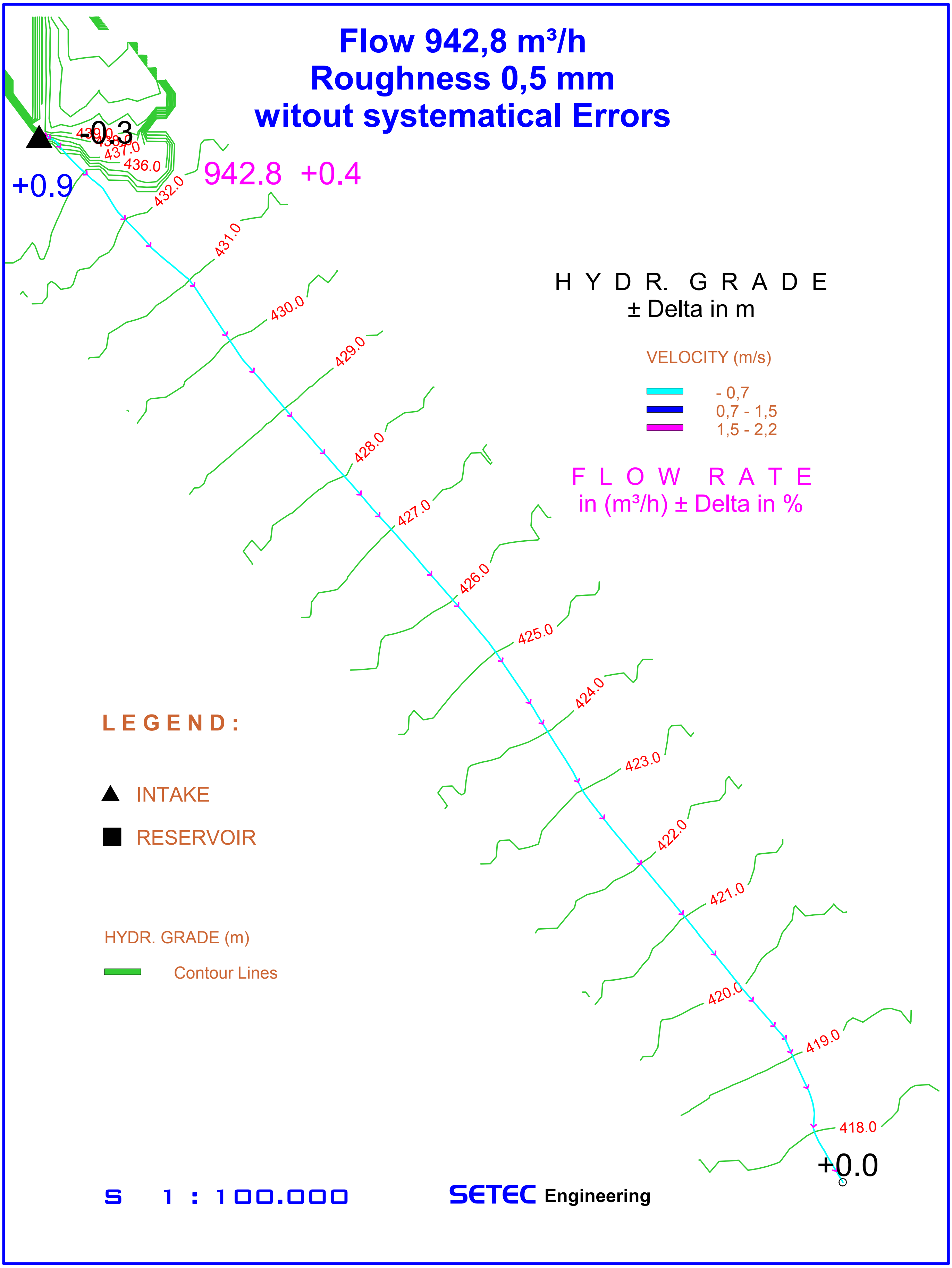
TM Ifraz I

Calibration Load Case 2.11



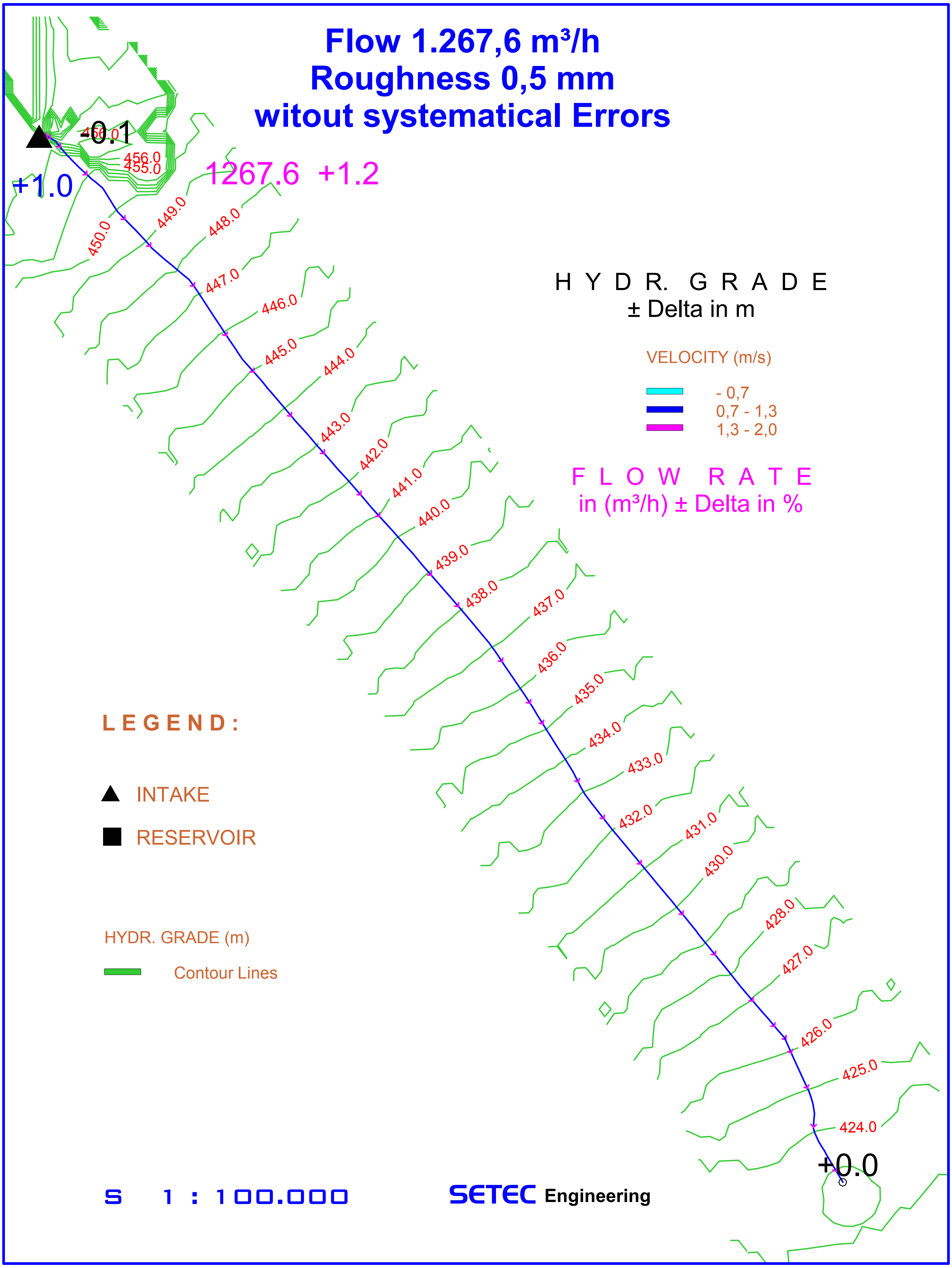
TM Ifraz I

Calibration Load Case 2.21



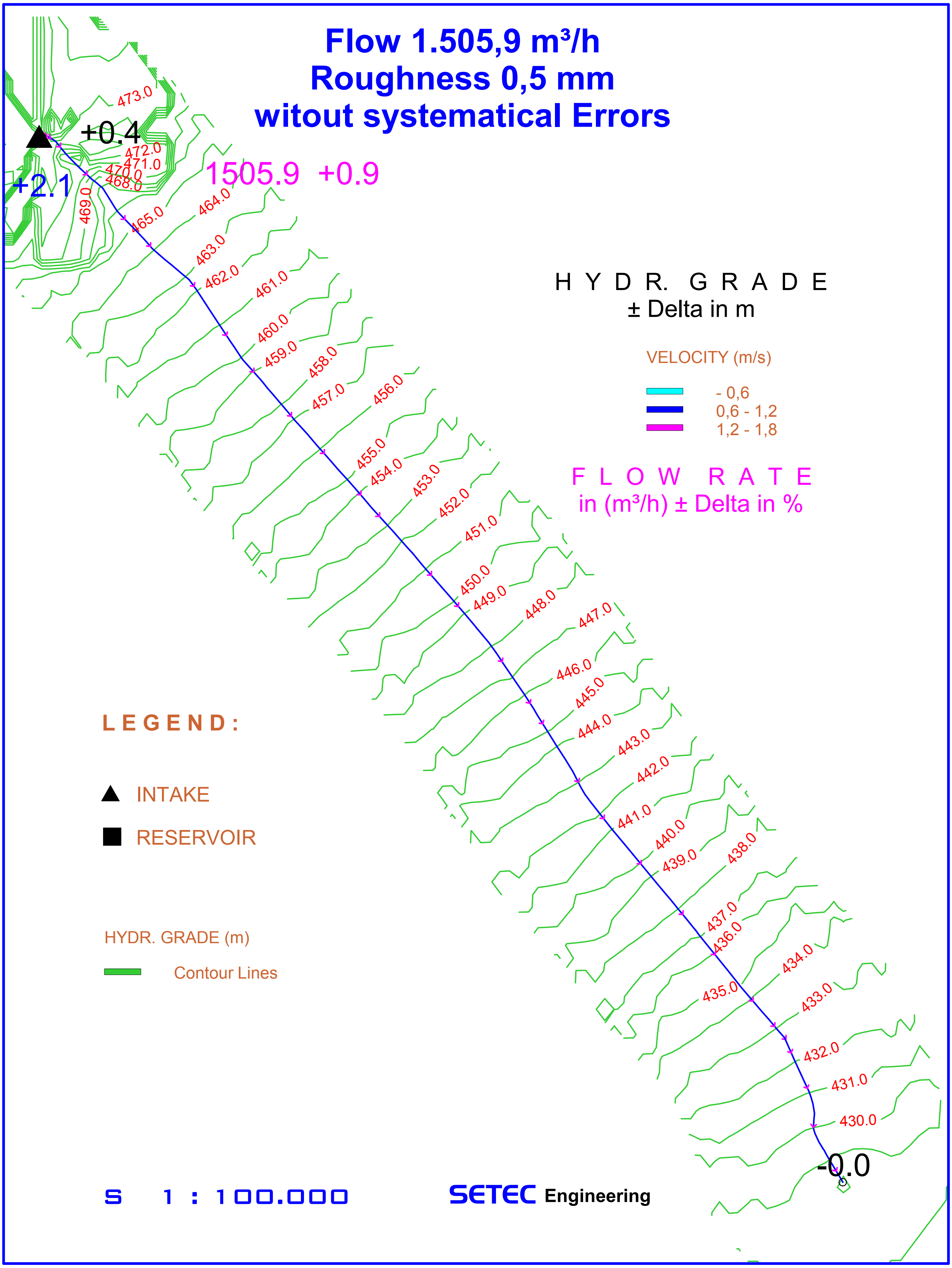
TM Ifraz I

Calibration Load Case 2.31



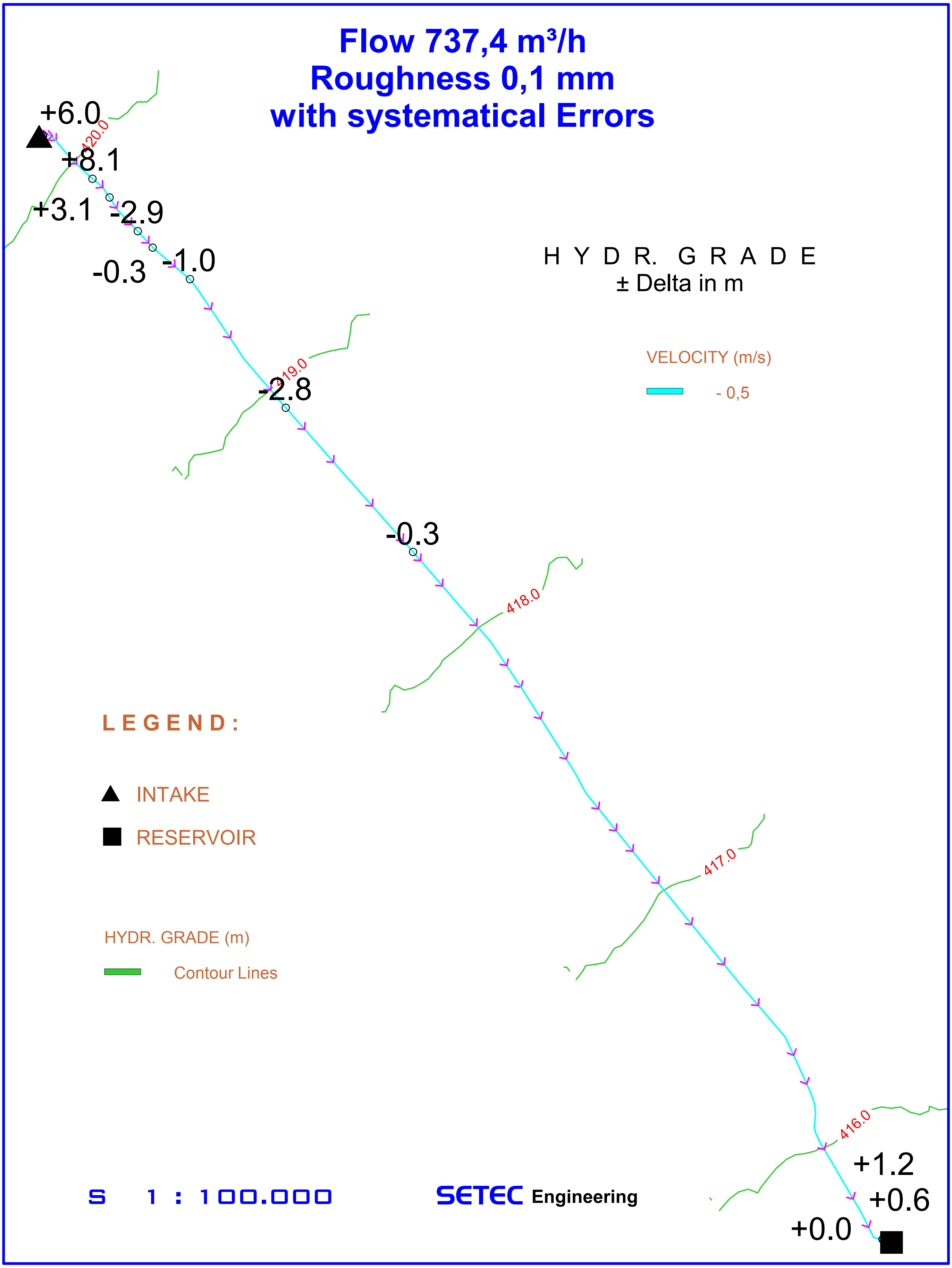
TM Ifraz I

Calibration Load Case 2.41



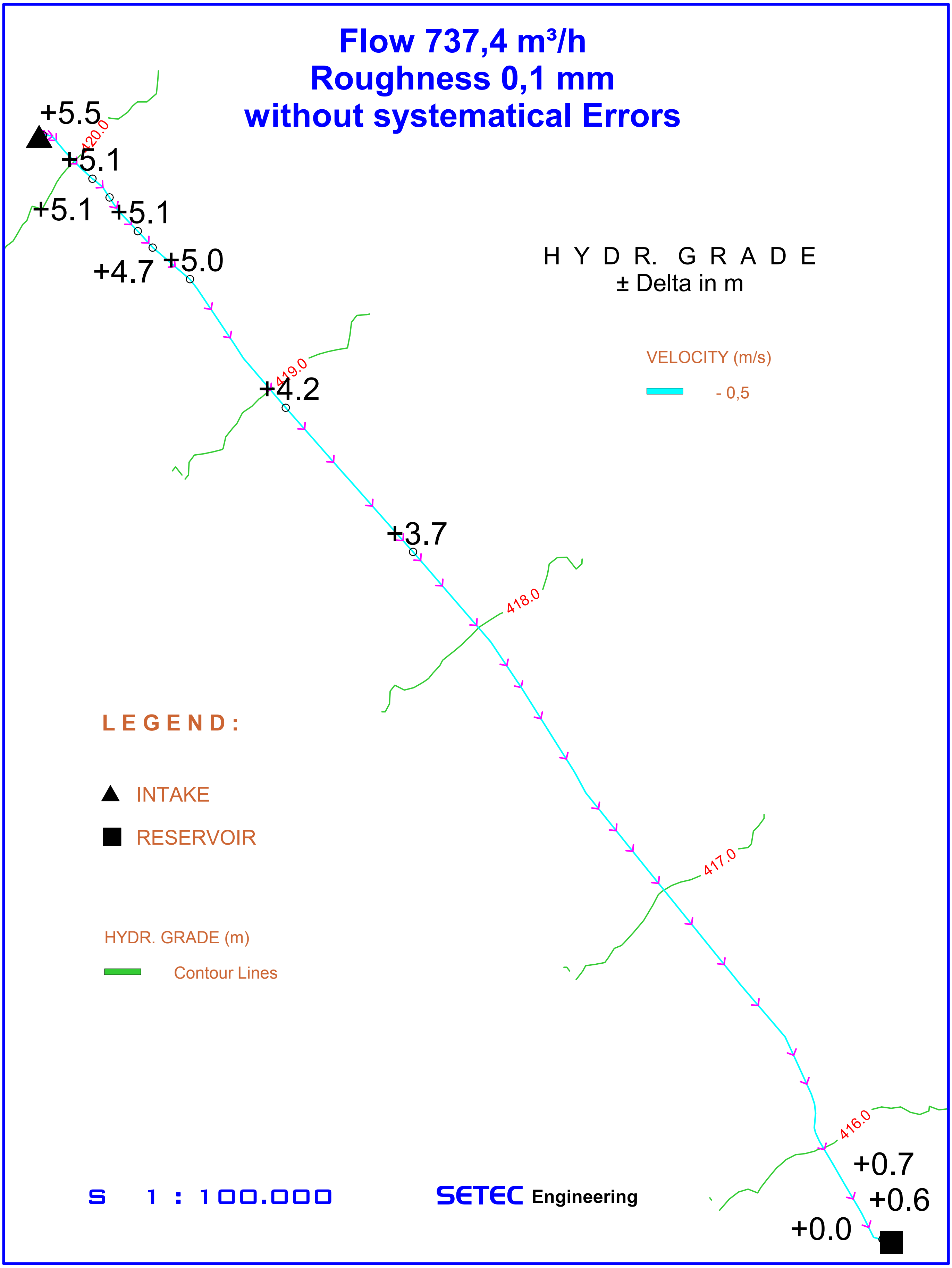
TM Ifraz II

Calibration Load Case 1.0



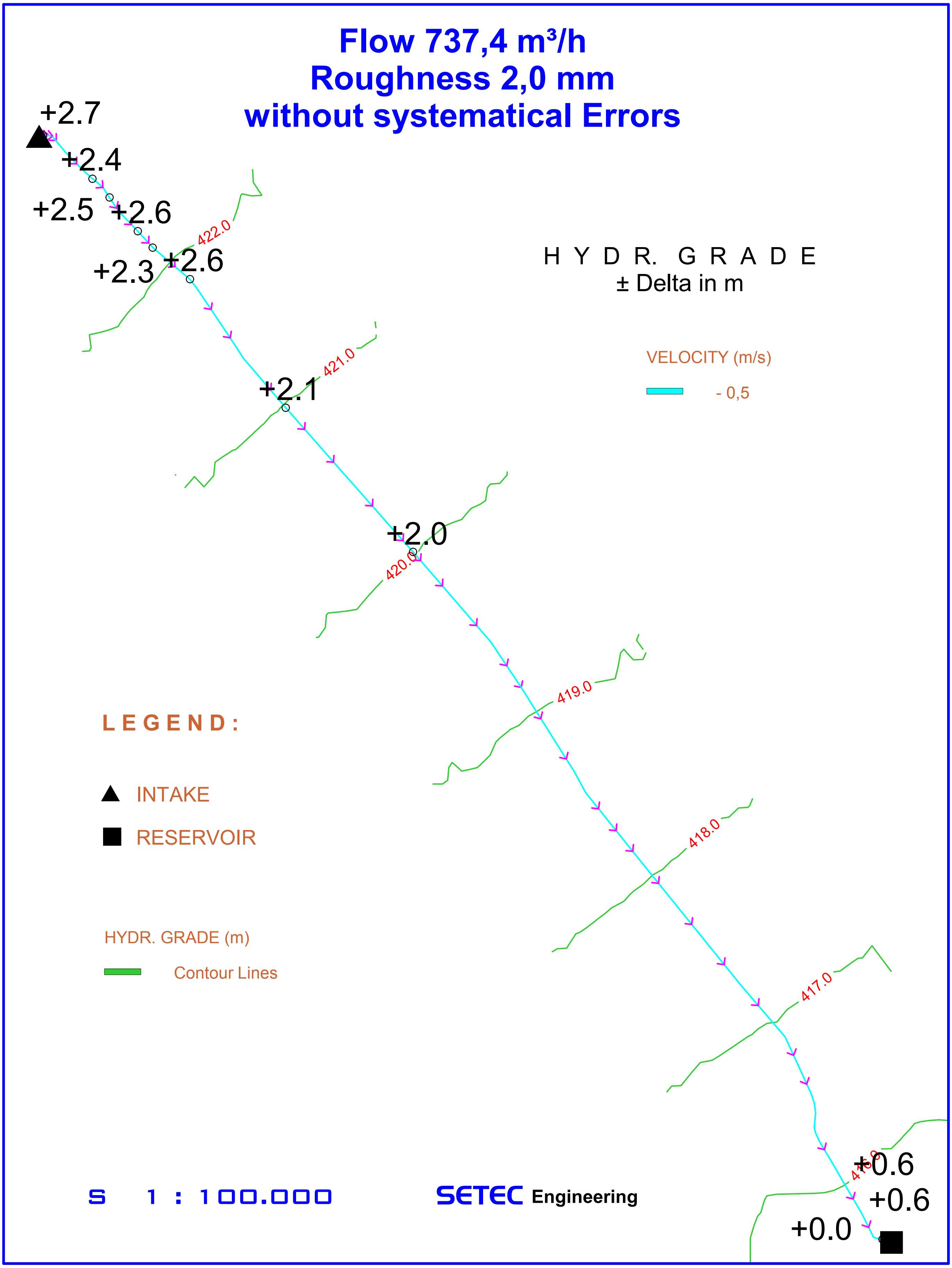
TM Ifraz II

Calibration Load Case 1.1



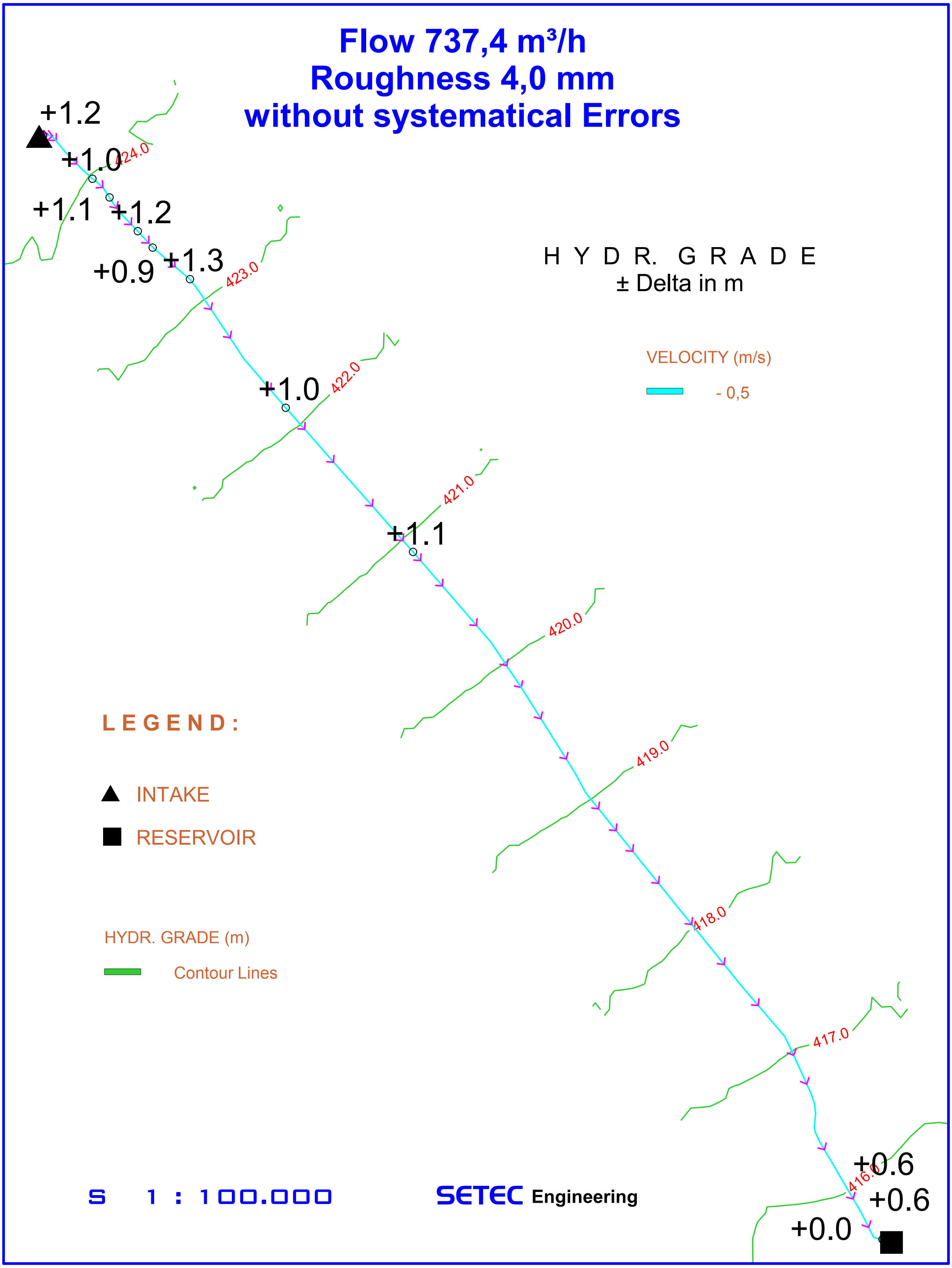
TM Ifraz II

Calibration Load Case 1.2



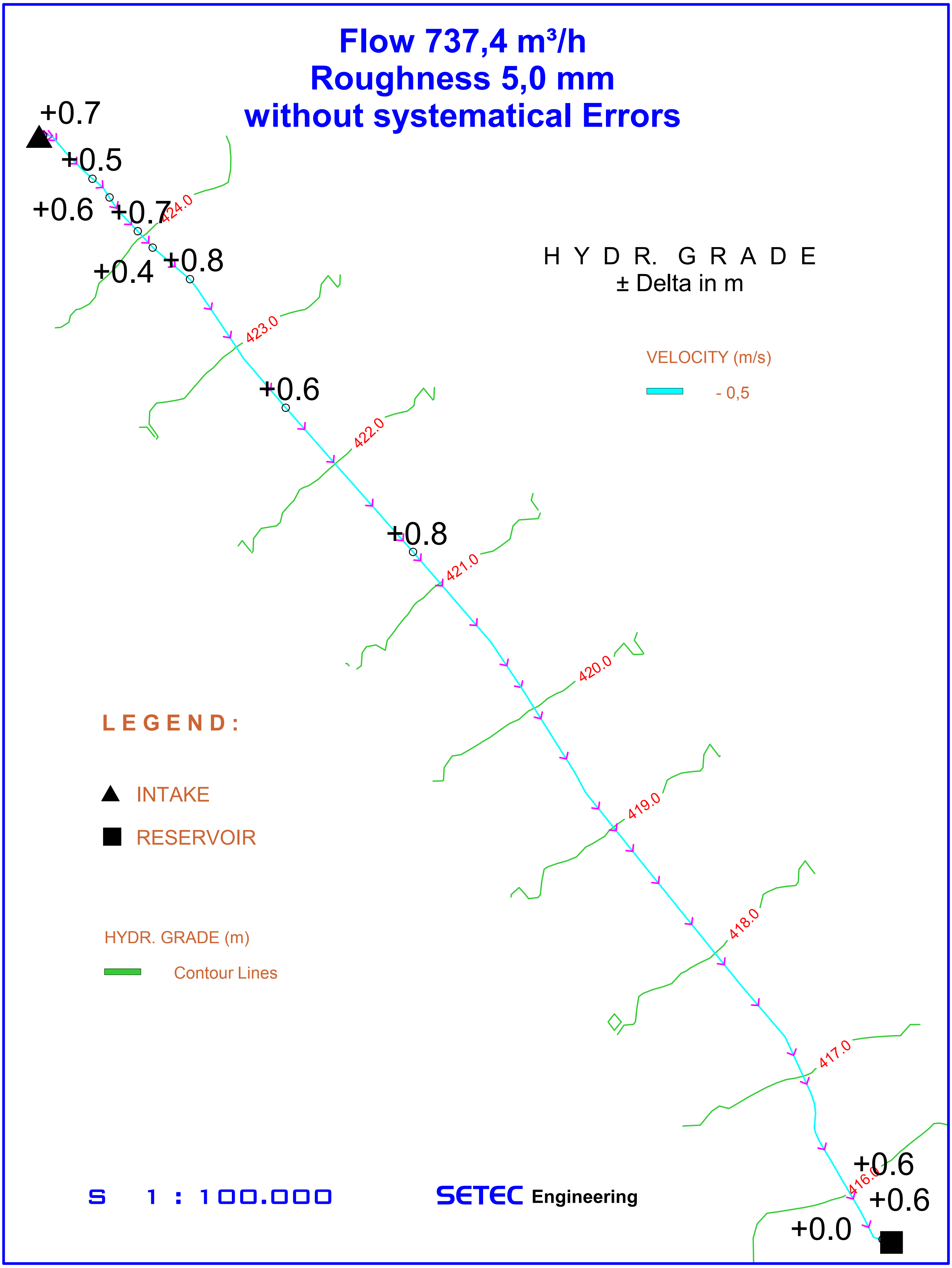
TM Ifraz II

Calibration Load Case 1.4



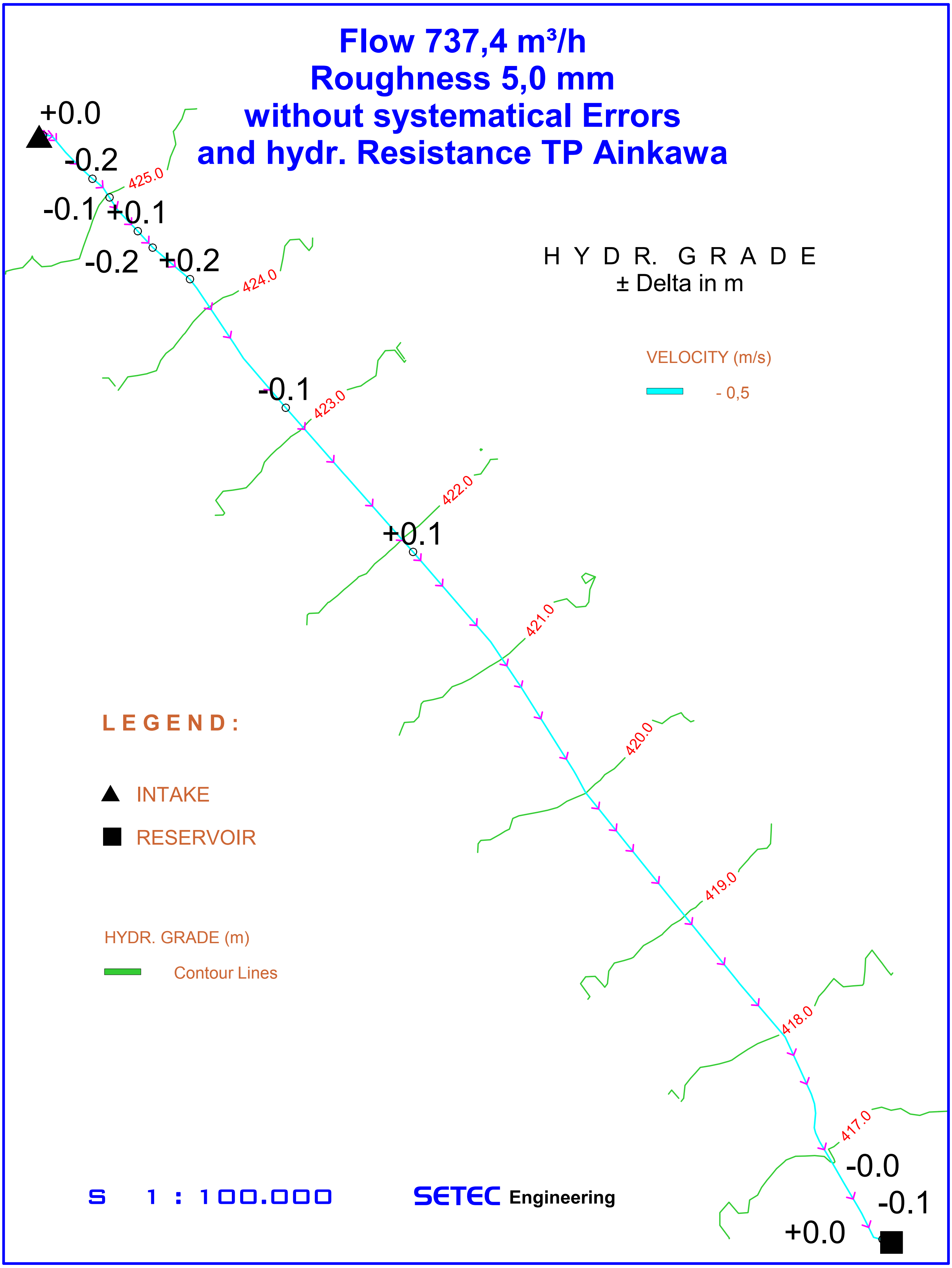
TM Ifraz II

Calibration Load Case 1.5



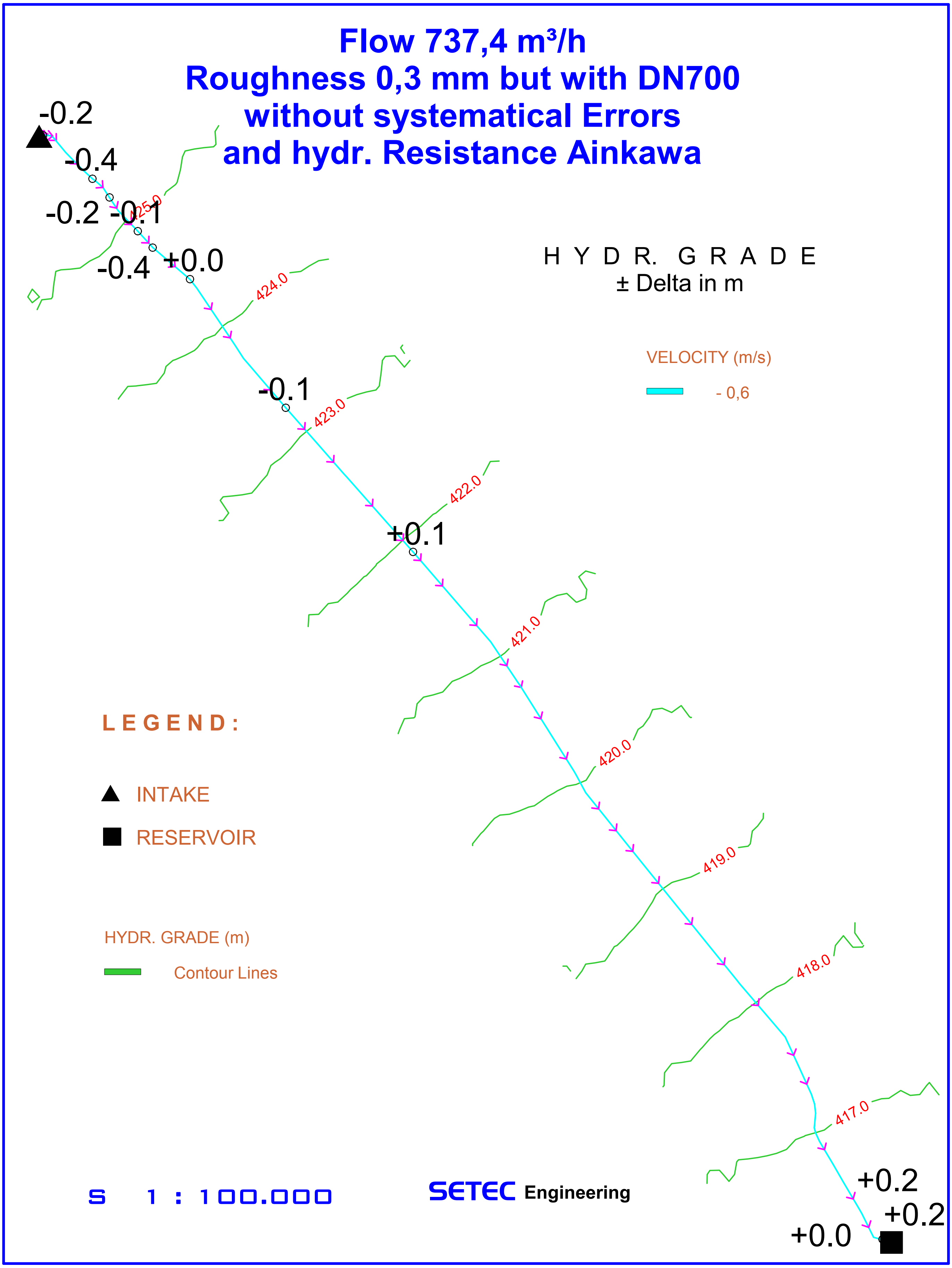
TM Ifraz II

Calibration Load Case 1.5a



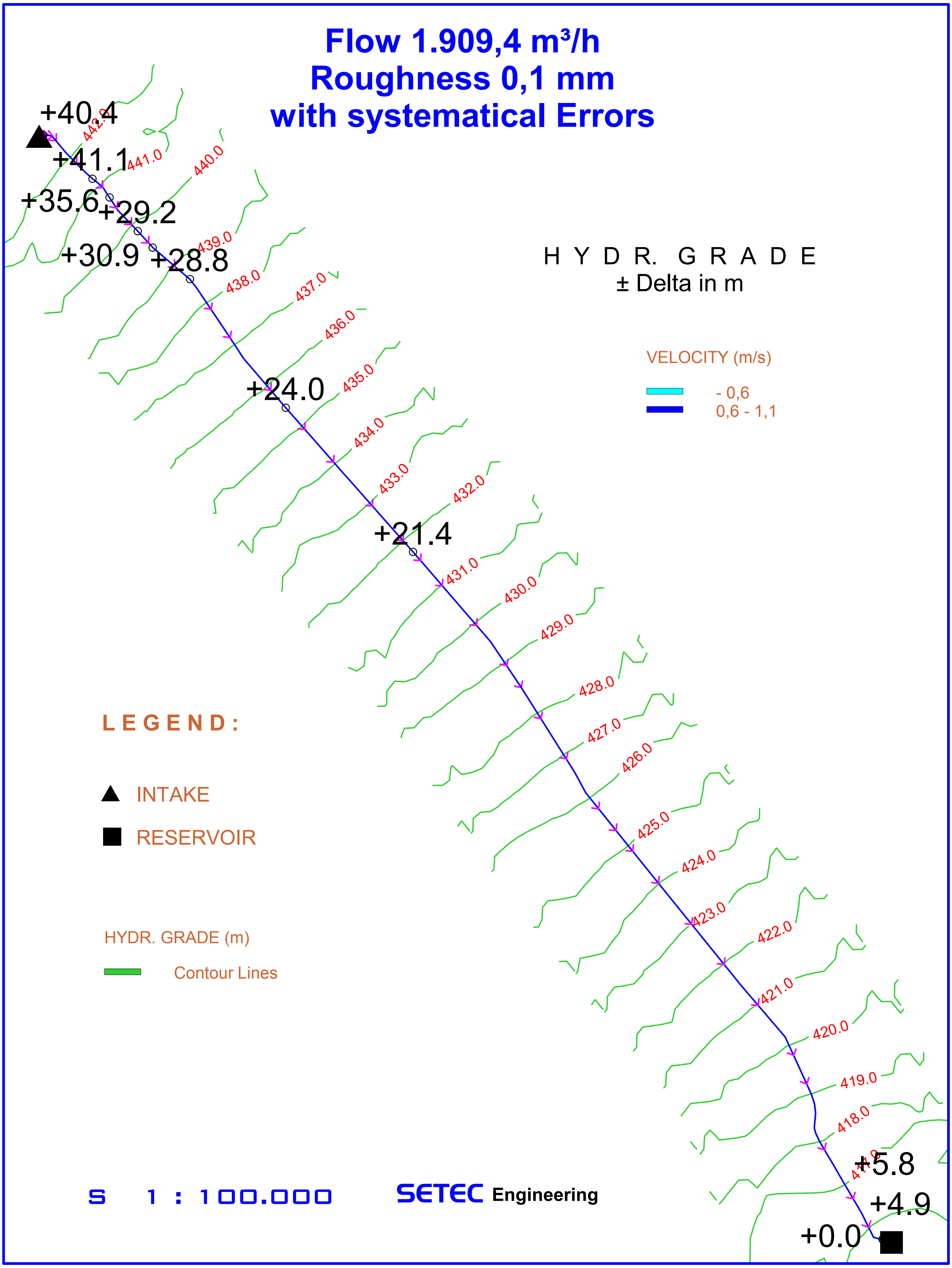
TM Ifraz II

Calibration Load Case 1.5b



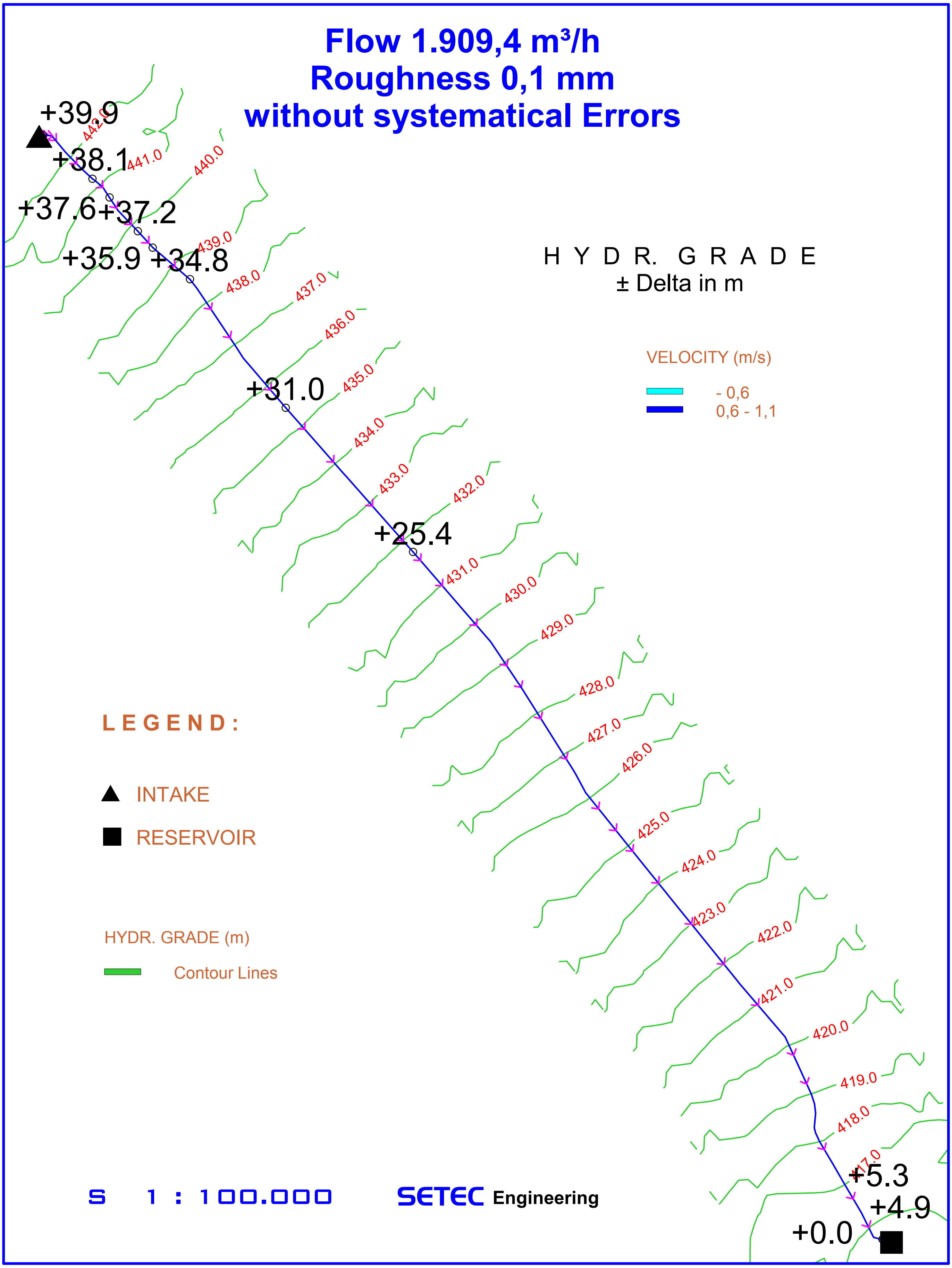
TM Ifraz II

Calibration Load Case 2.0



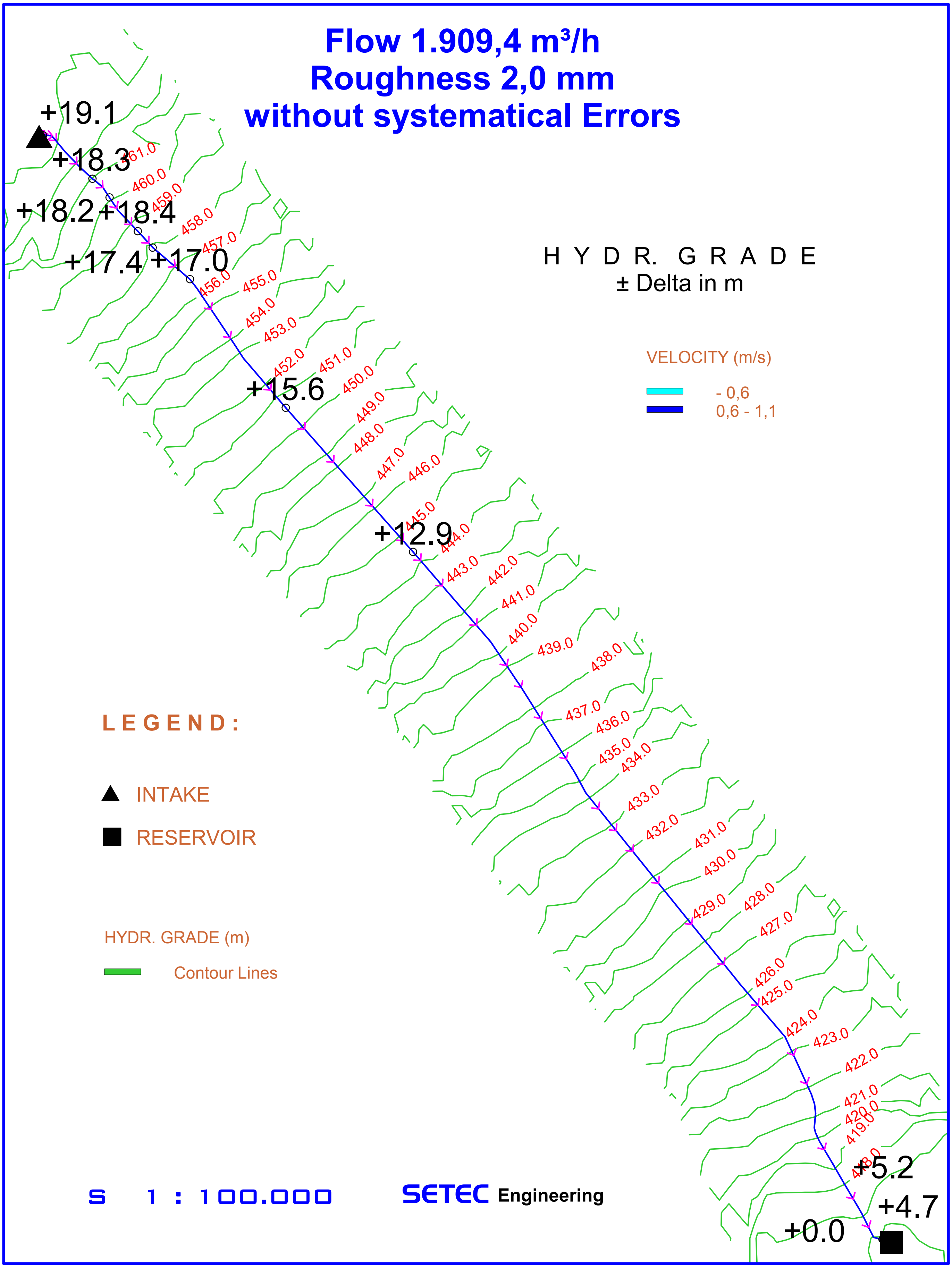
TM Ifraz II

Calibration Load Case 2.1



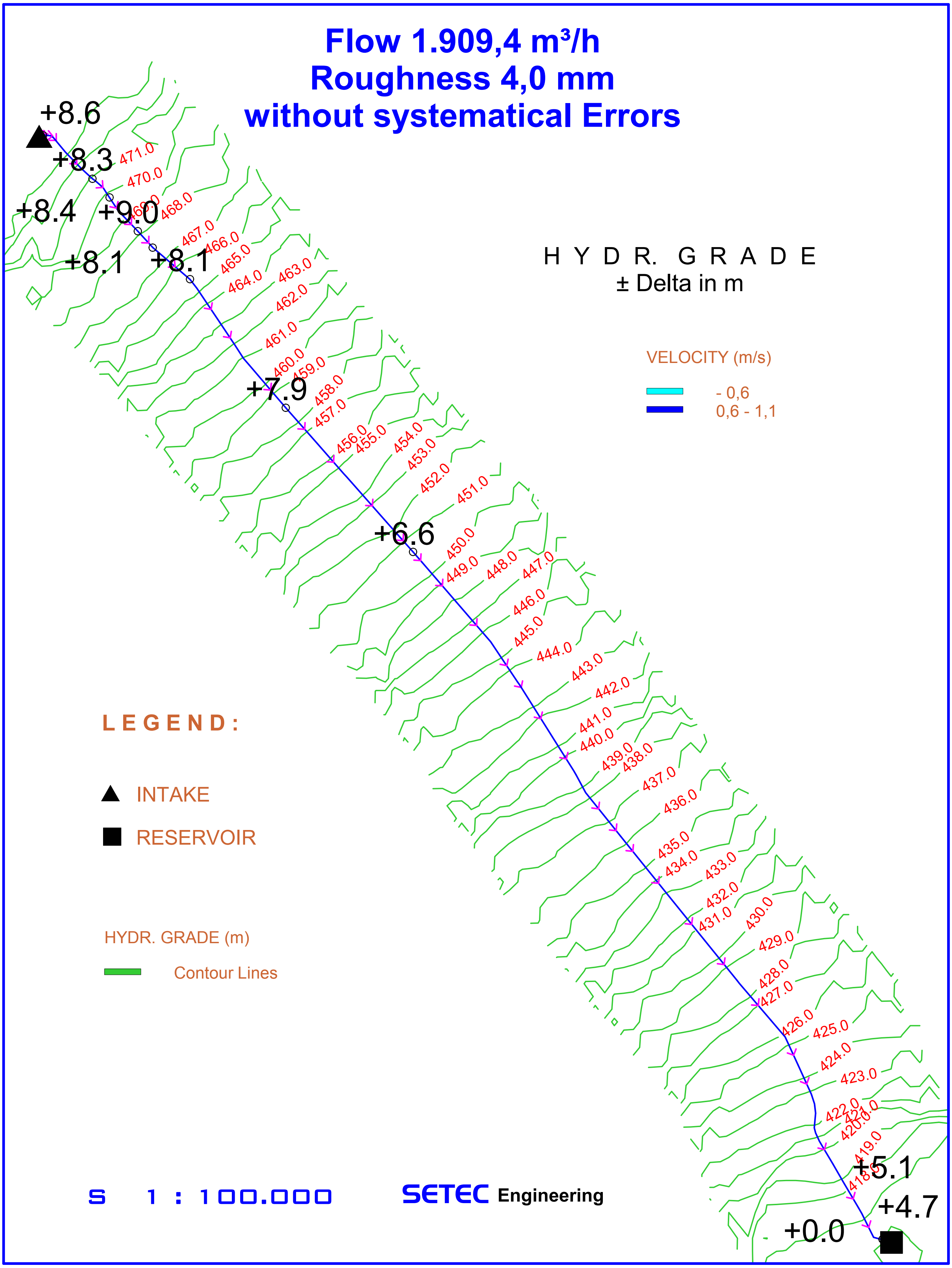
TM Ifraz II

Calibration Load Case 2.2



TM Ifraz II

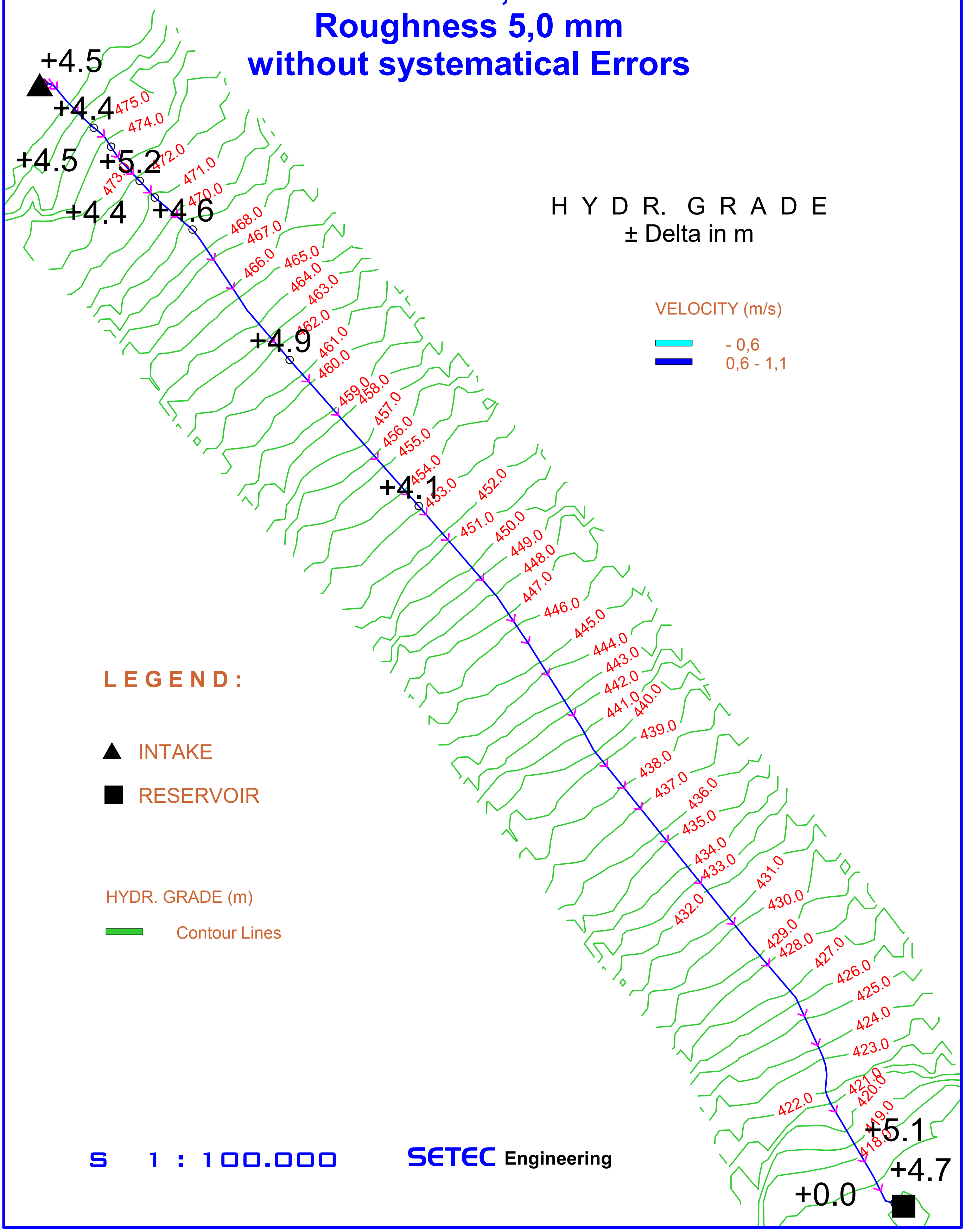
Calibration Load Case 2.4



TM Ifraz II

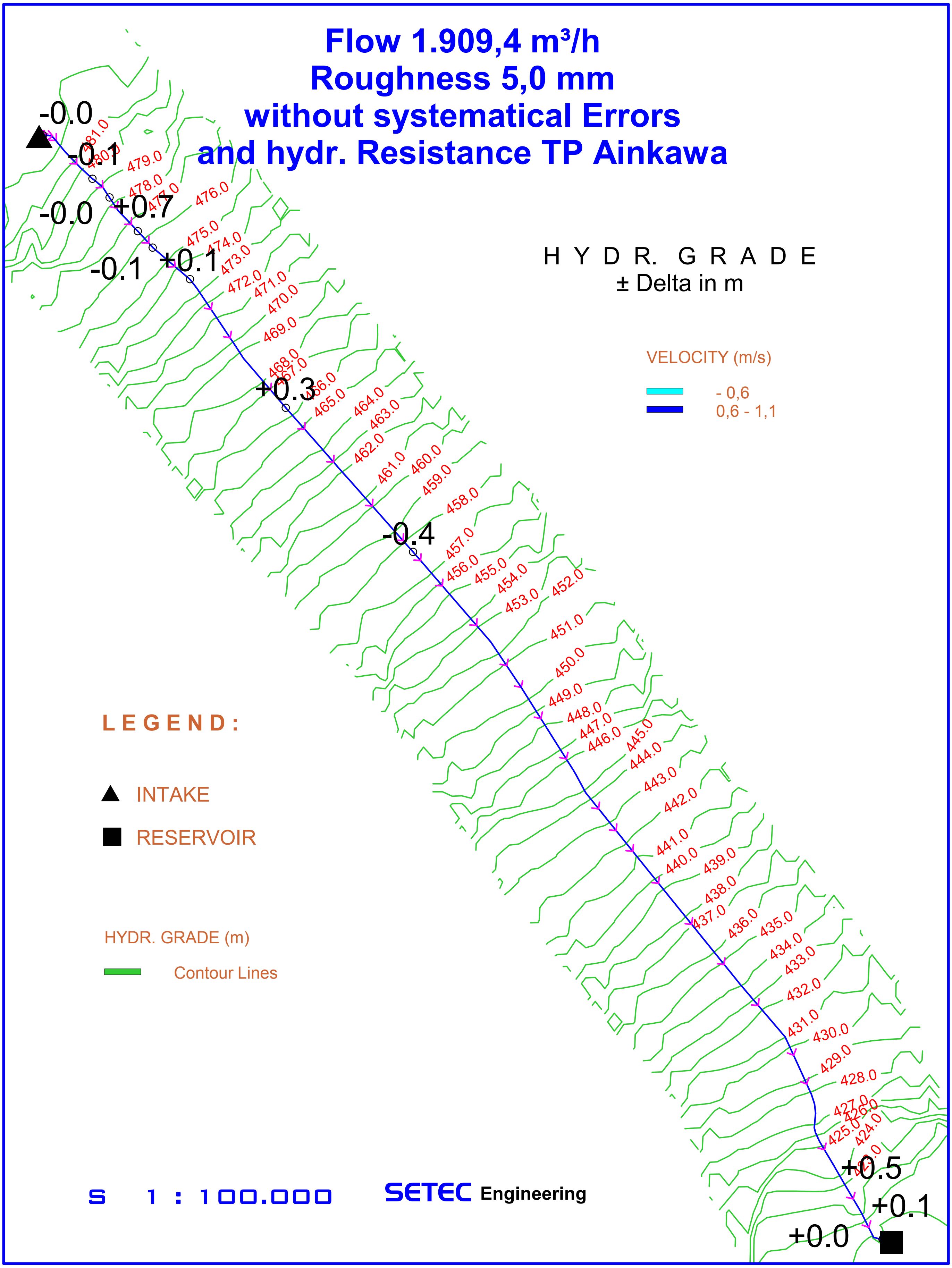
Calibration Load Case 2.5

Flow 1.909,4 m³/h
Roughness 5,0 mm
without systematical Errors



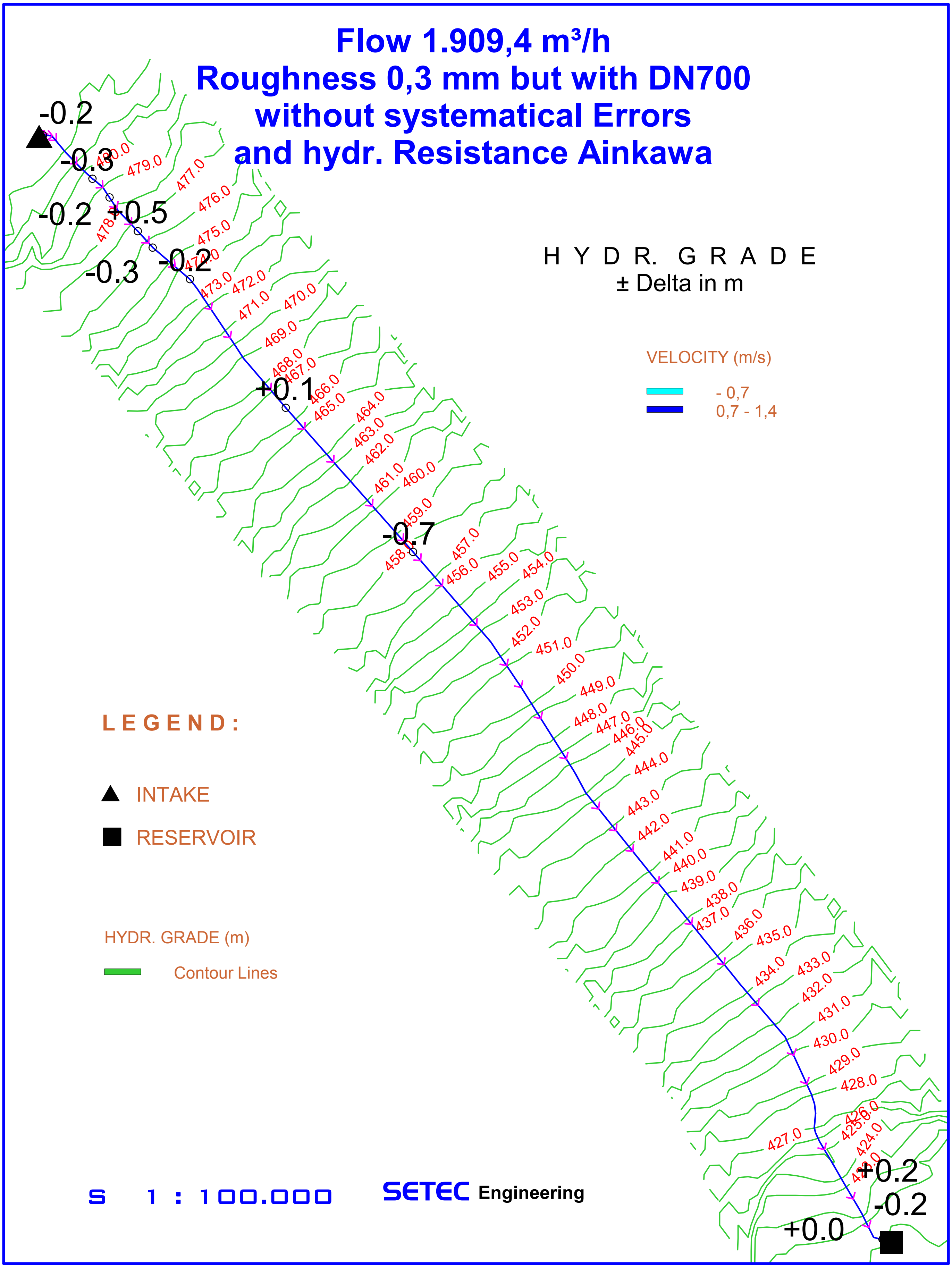
TM Ifraz II

Calibration Load Case 2.5a



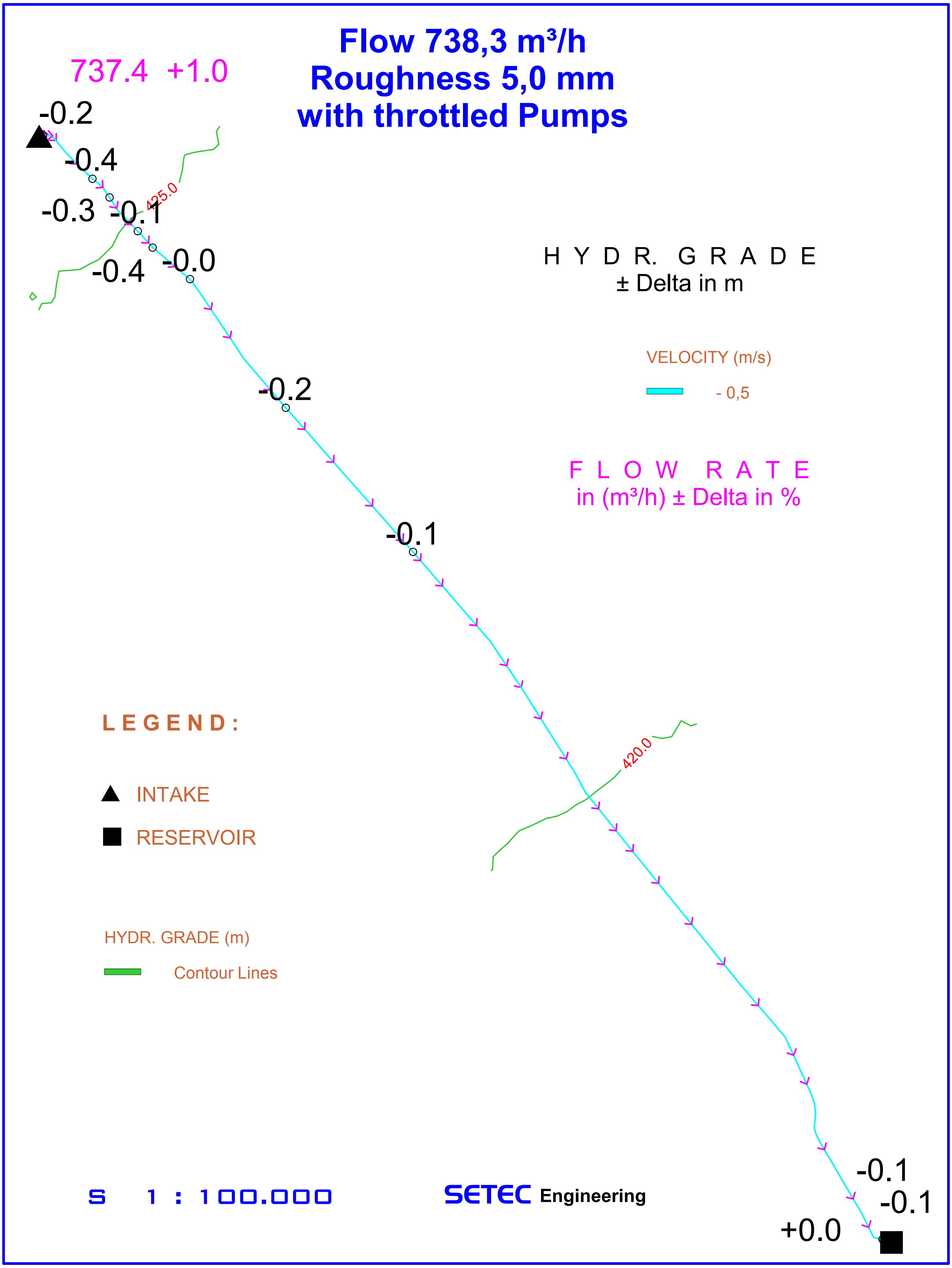
TM Ifraz II

Calibration Load Case 2.5b



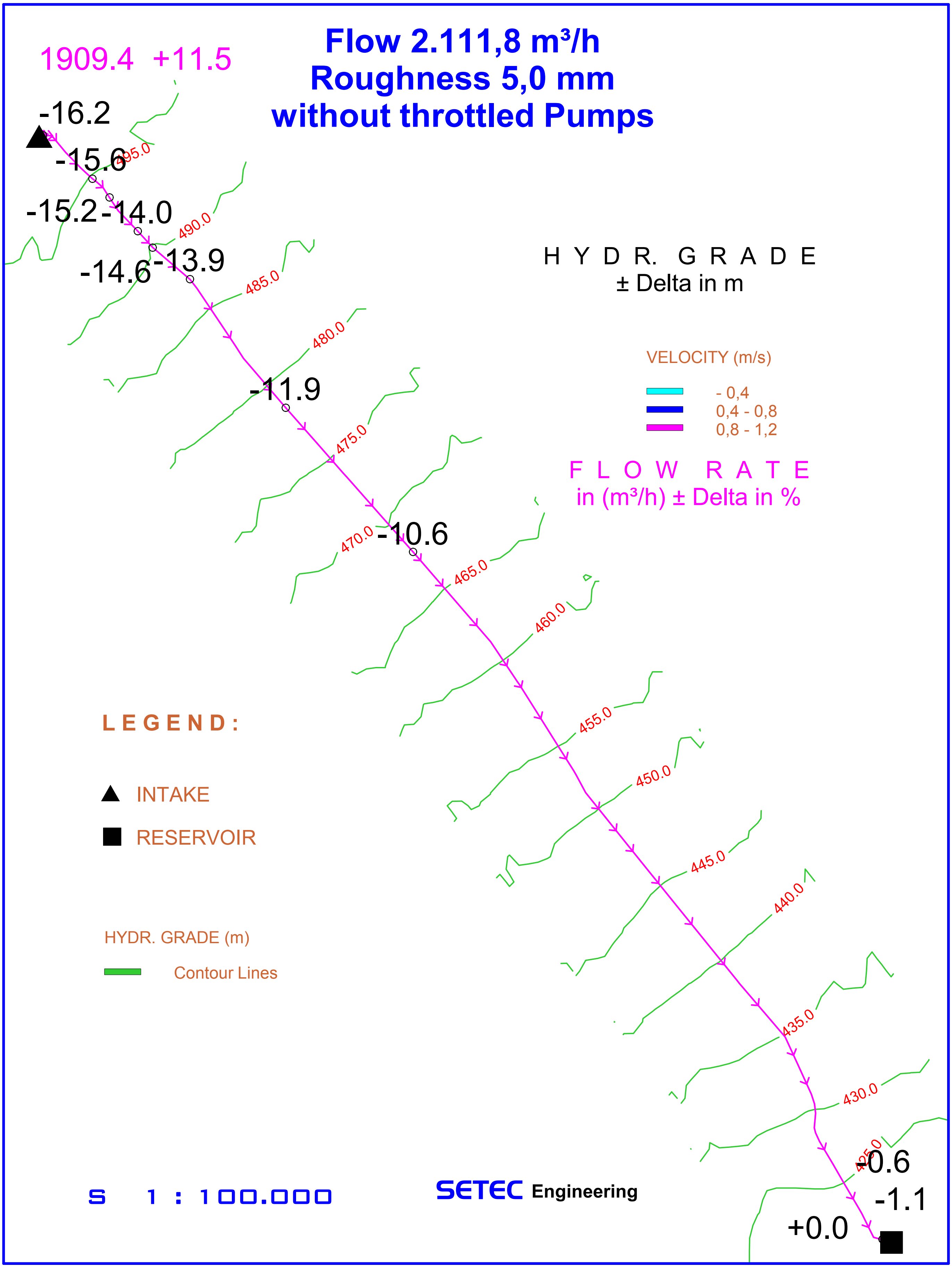
TM Ifraz II

Calibration Flow 737,4 m³/h



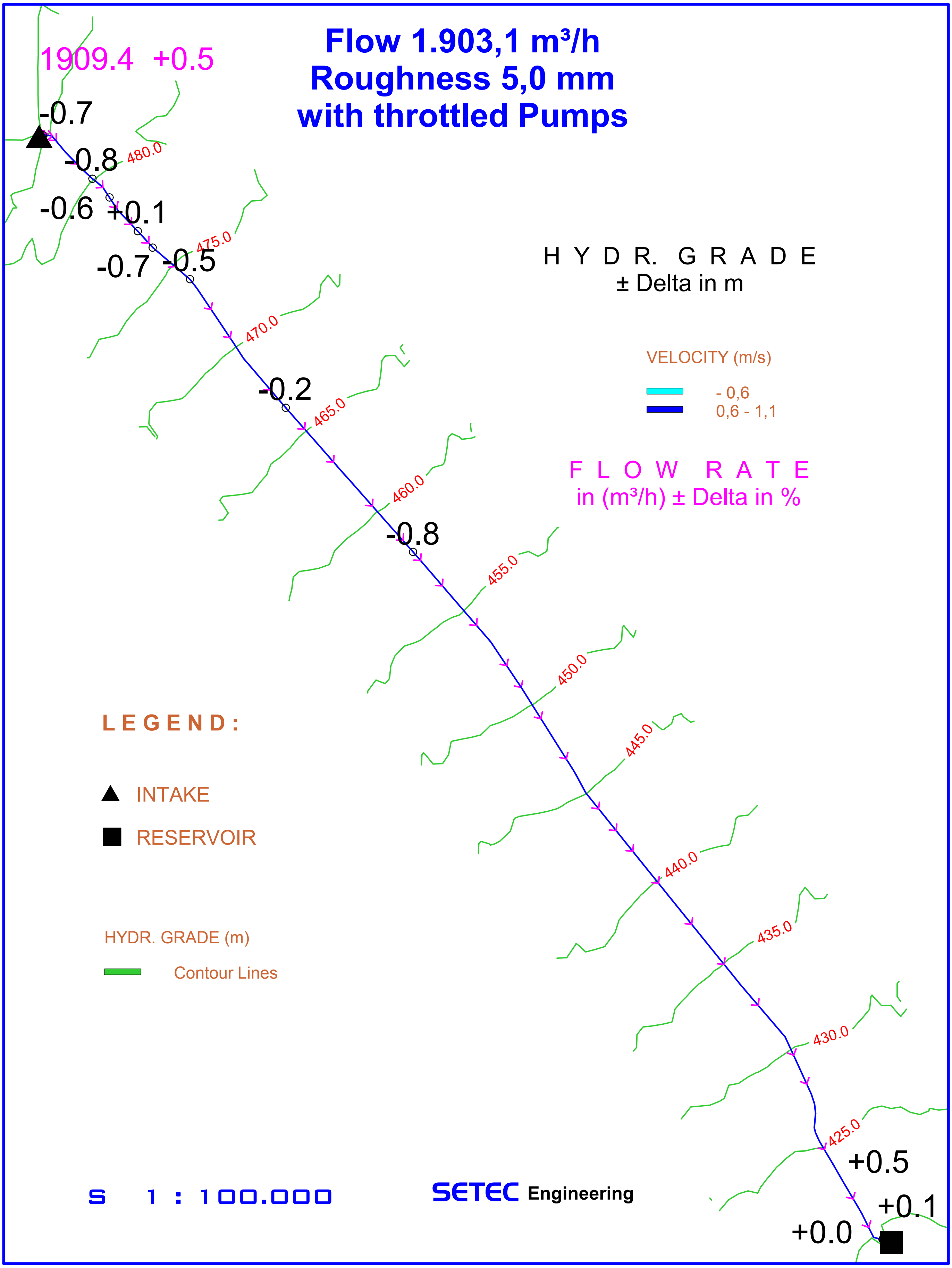
TM Ifraz II

Calibration Flow 1.909,4 m³/h



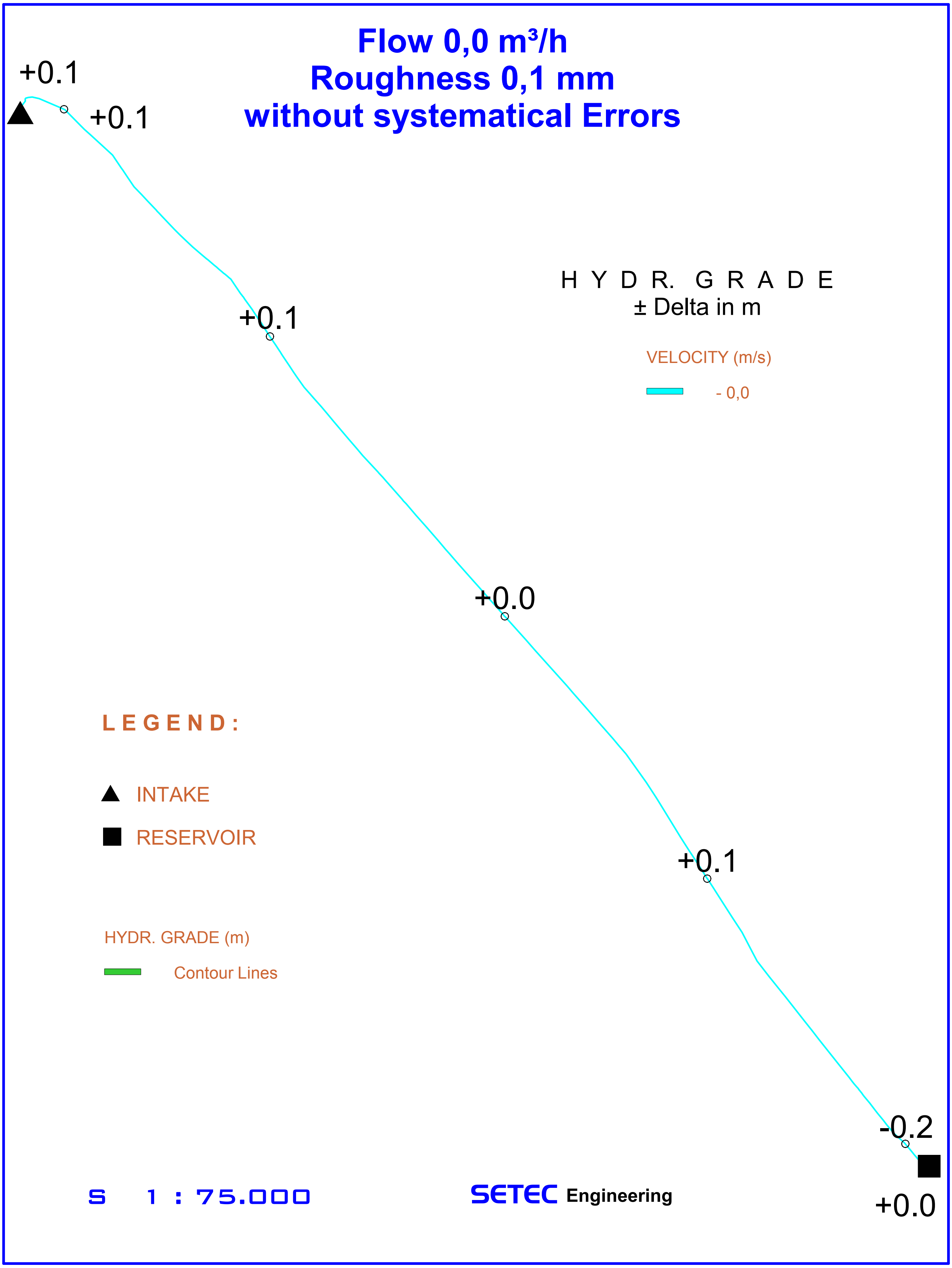
TM Ifraz II

Calibration Flow 1.909,4 m³/h



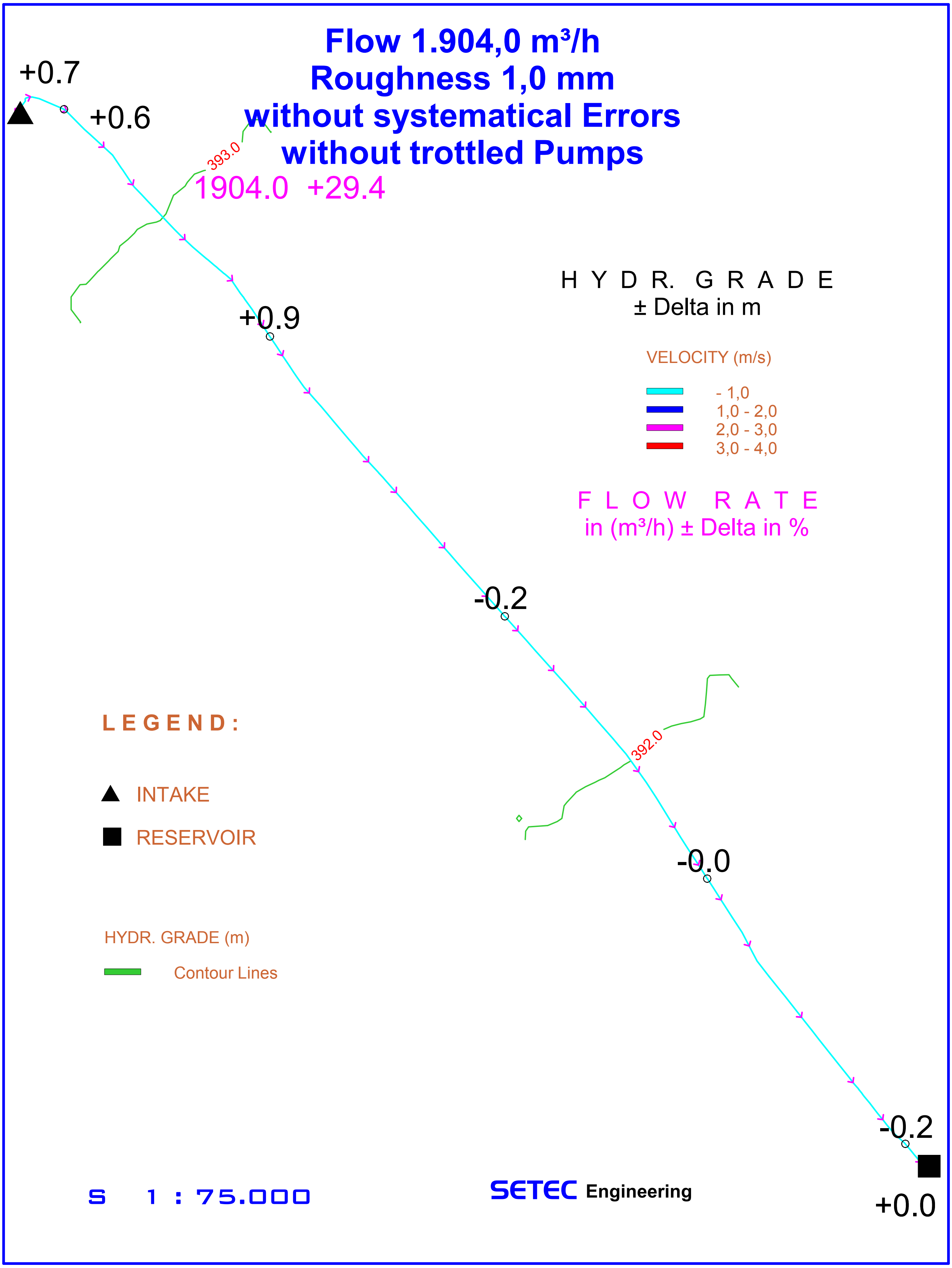
TM Ifraz III Part I

Calibration Load Case 1.0



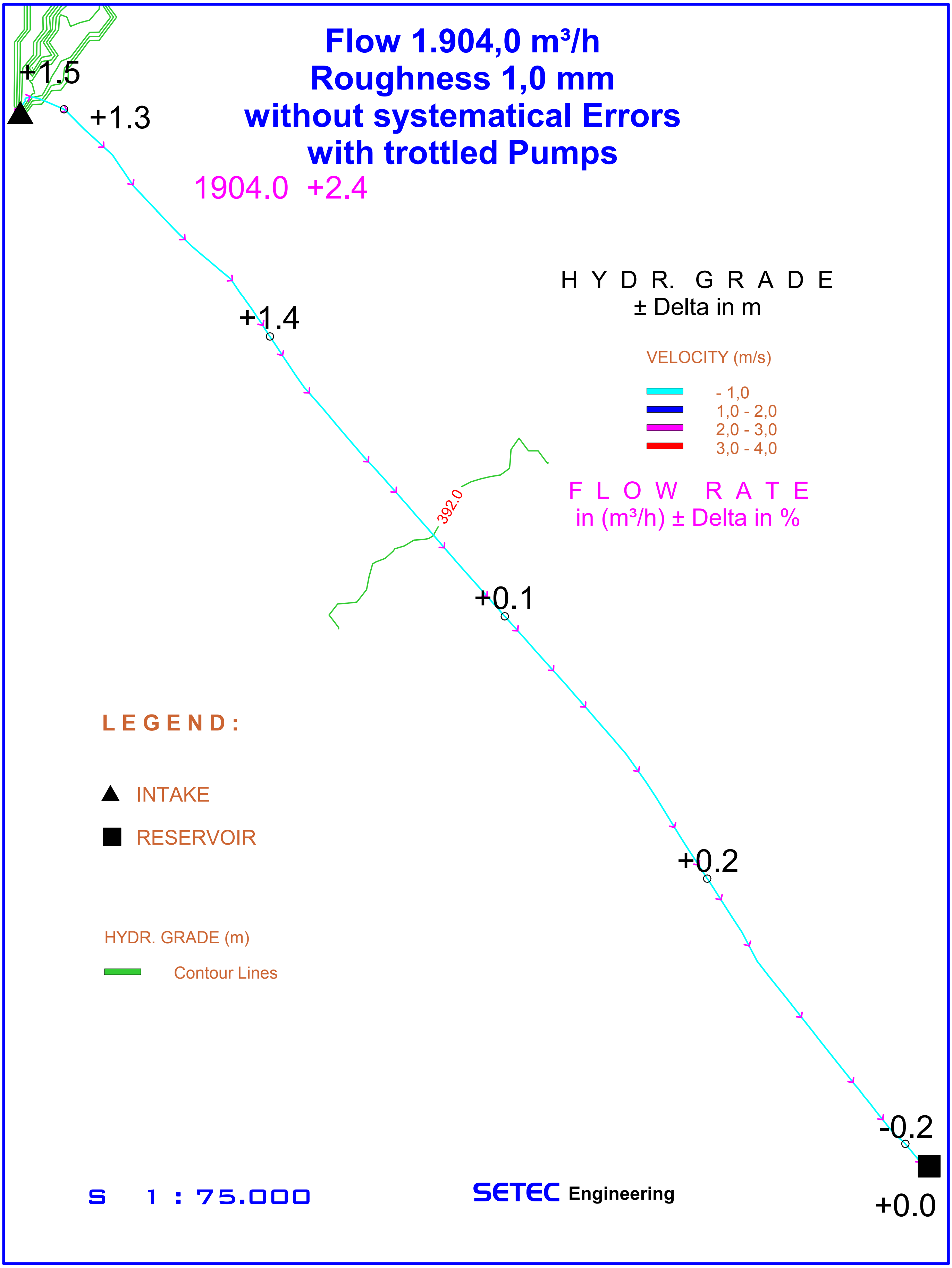
TM Ifraz III Part I

Calibration Load Case 2.10



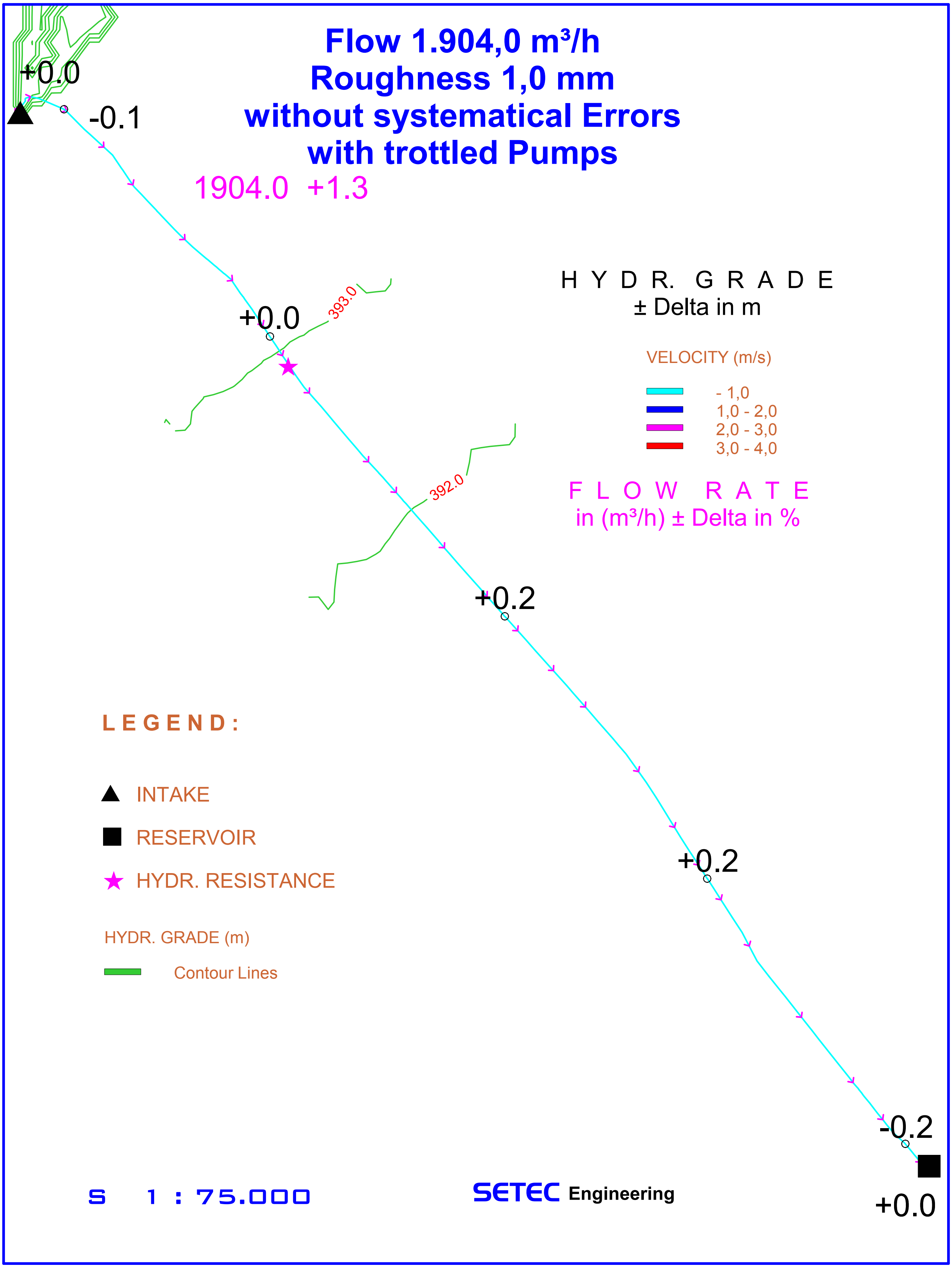
TM Ifraz III Part I

Calibration Load Case 2.11



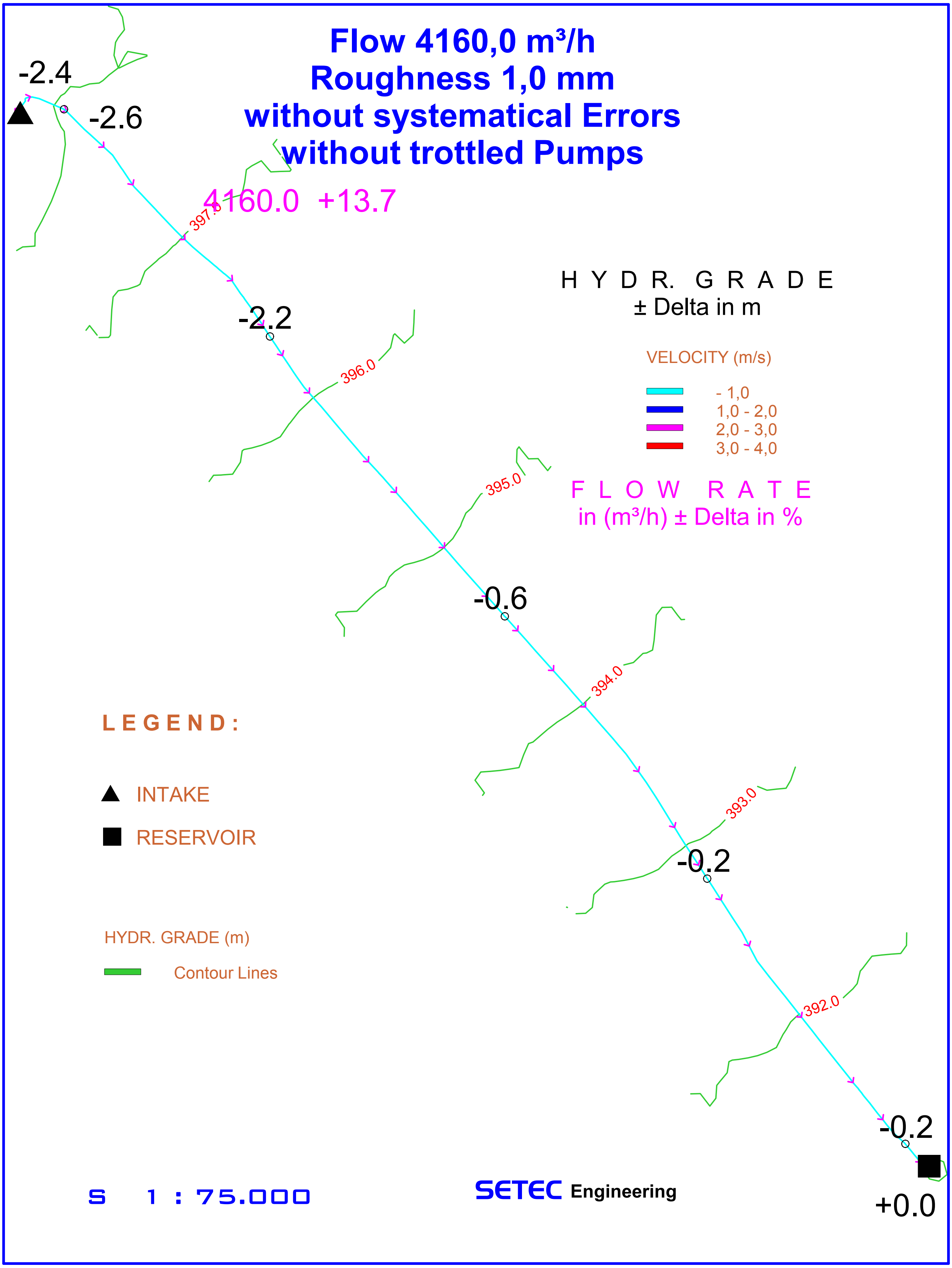
TM Ifraz III Part I

Calibration Load Case 2.12



TM Ifraz III Part I

Calibration Load Case 2.20

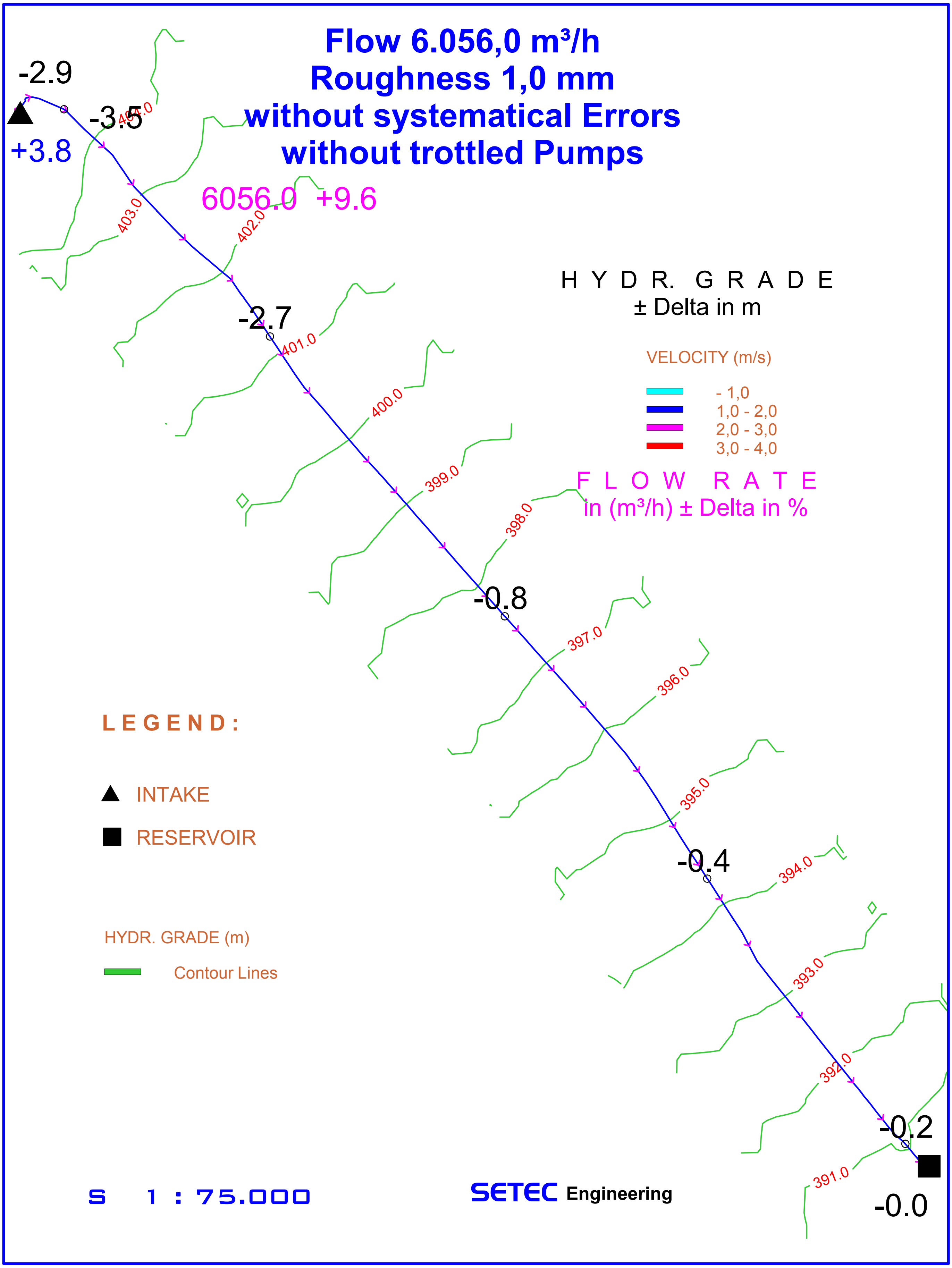


TM Ifraz III Part I

Calibration Load Case 2.21

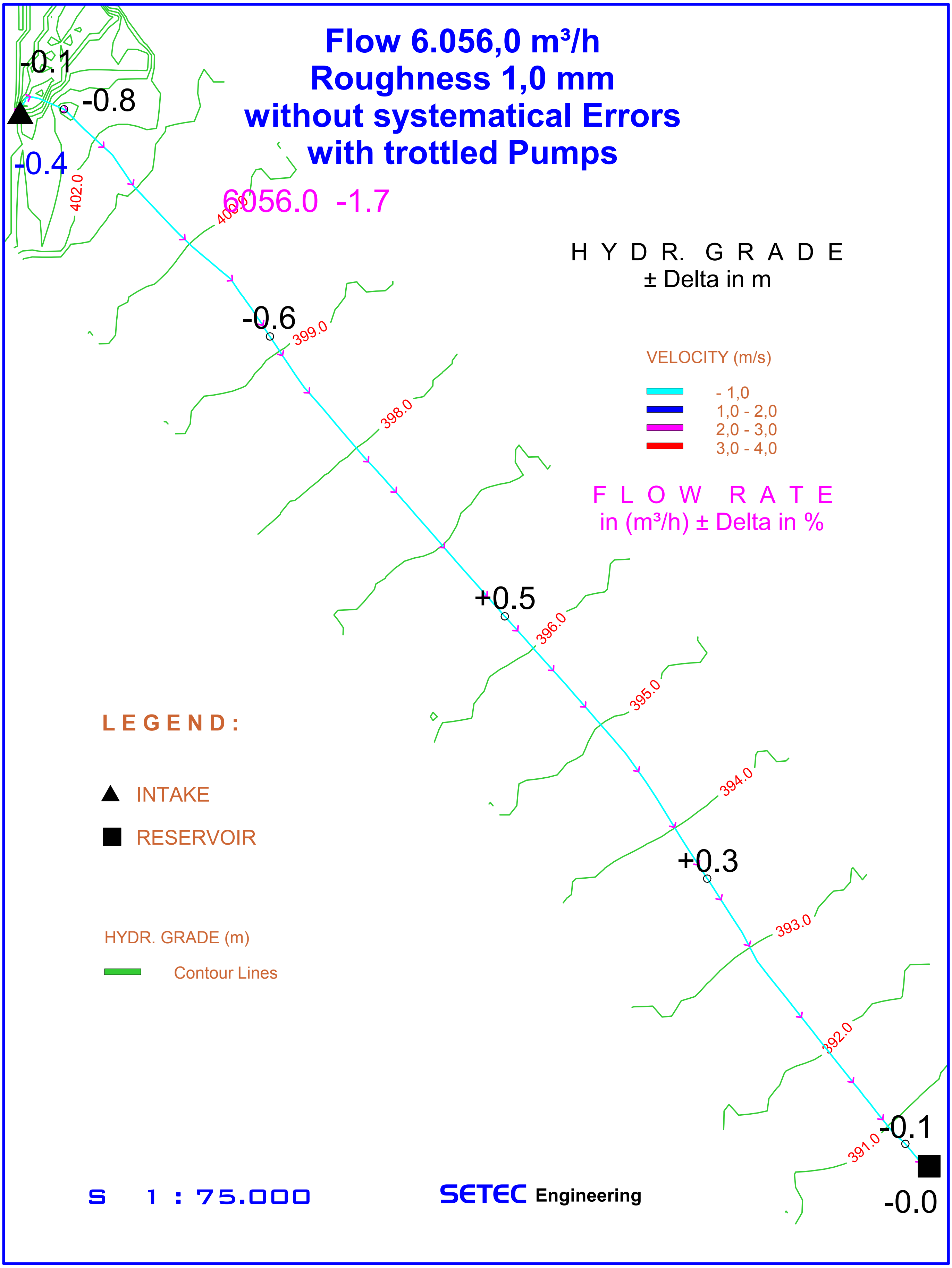
TM Ifraz III Part I

Calibration Load Case 2.30



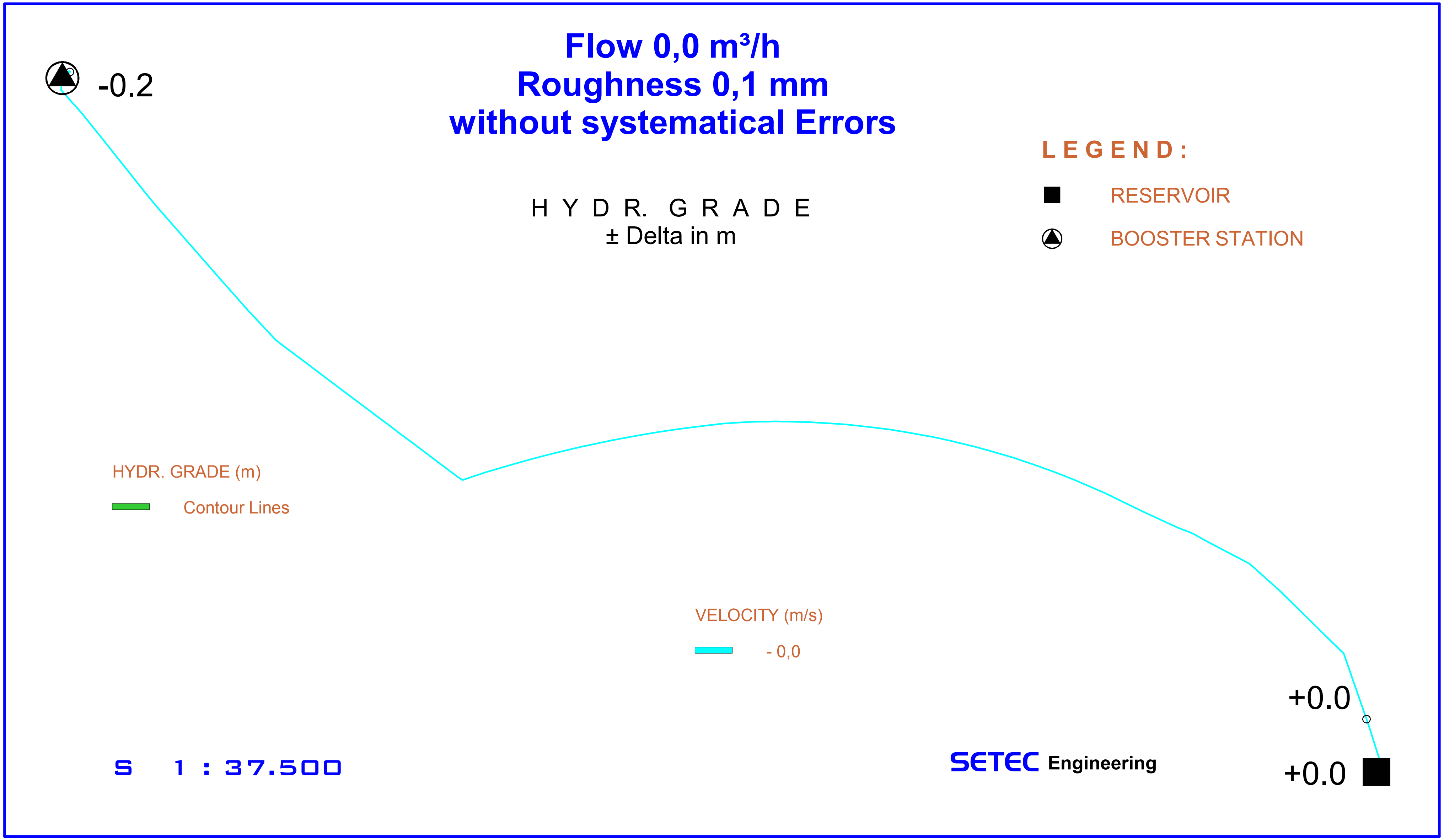
TM Ifraz III Part I

Calibration Load Case 2.31



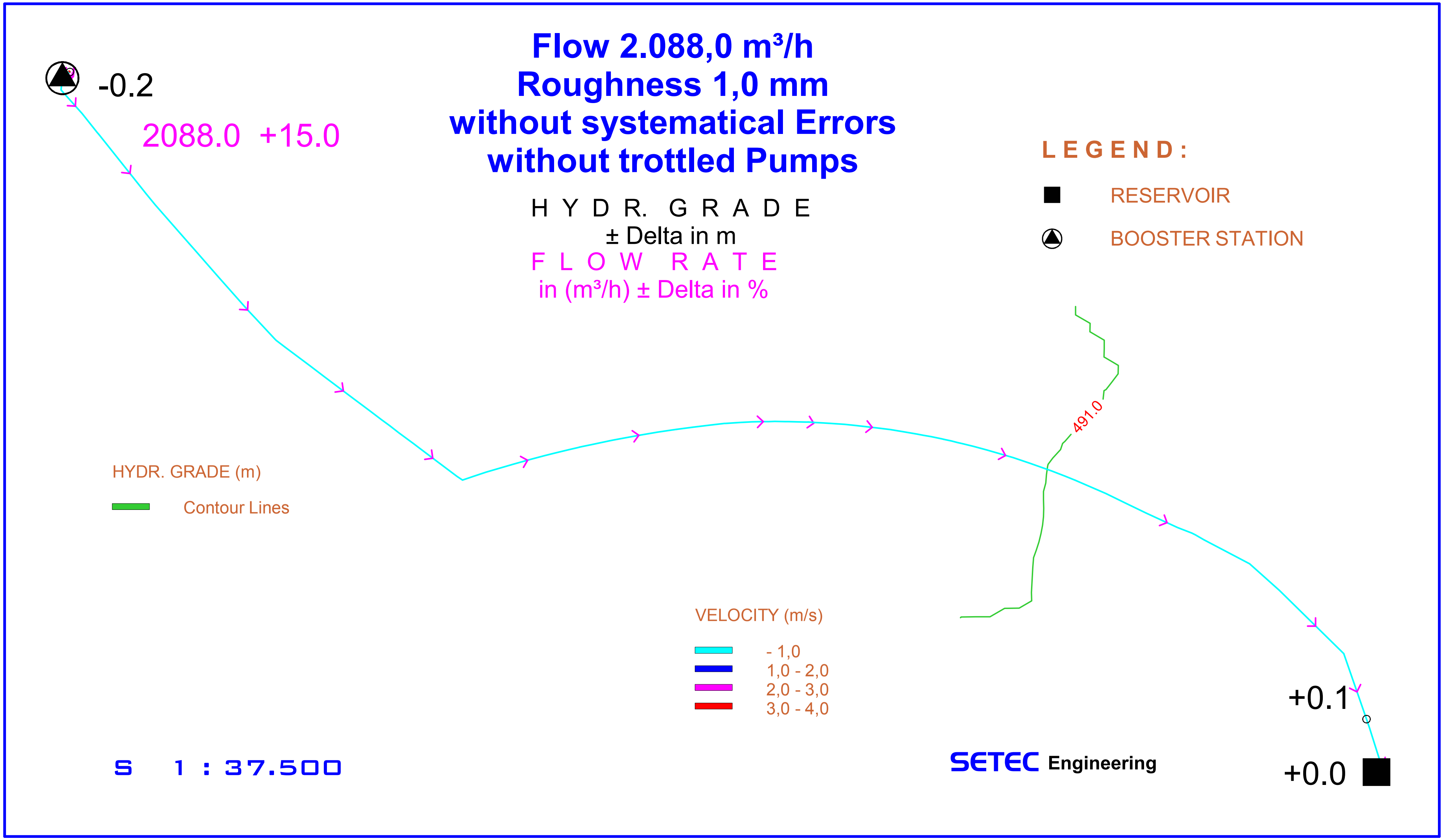
TM Ifraz III Part II

Calibration Load Case 1.0



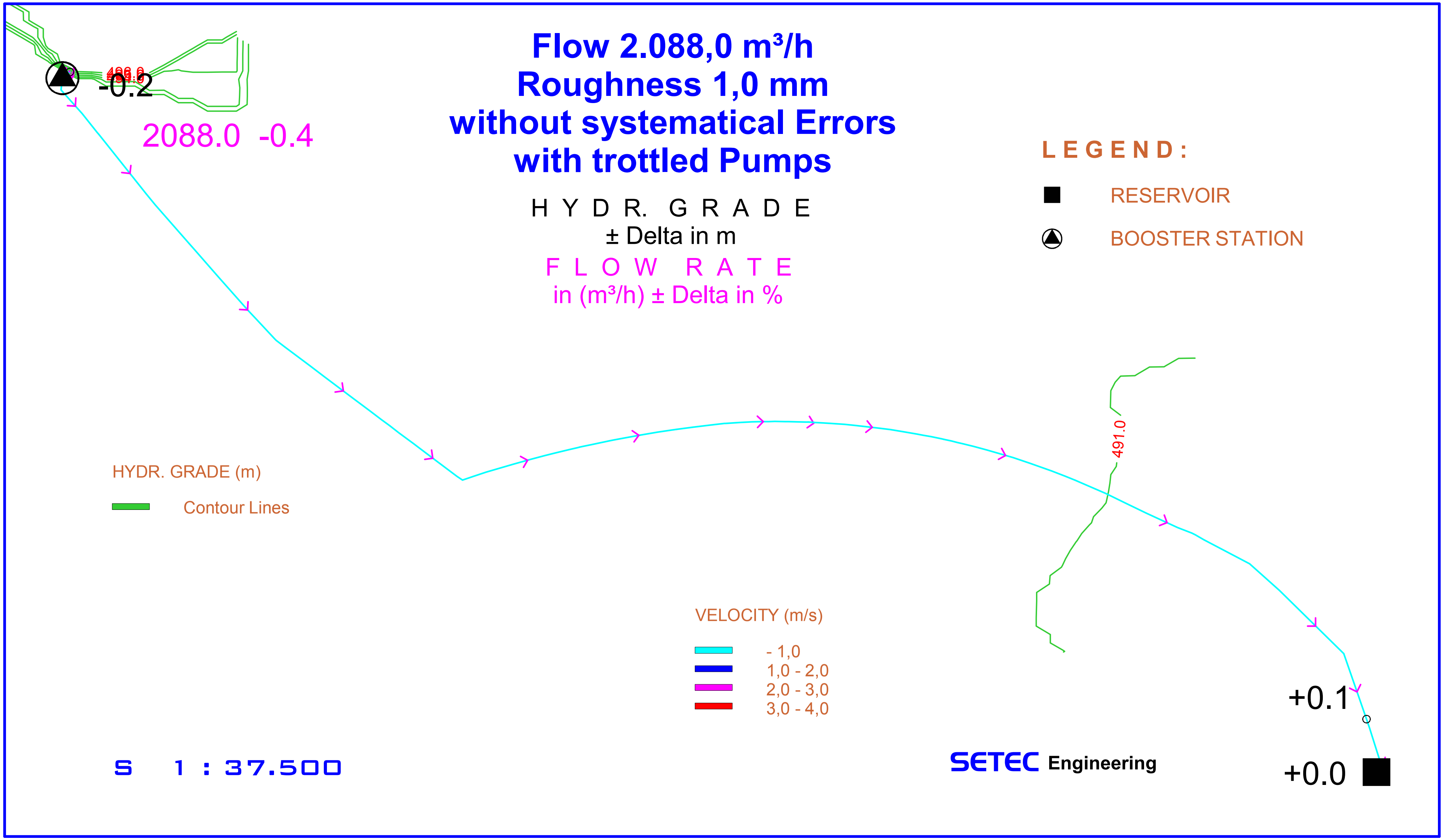
TM Ifraz III Part II

Calibration Load Case 2.10



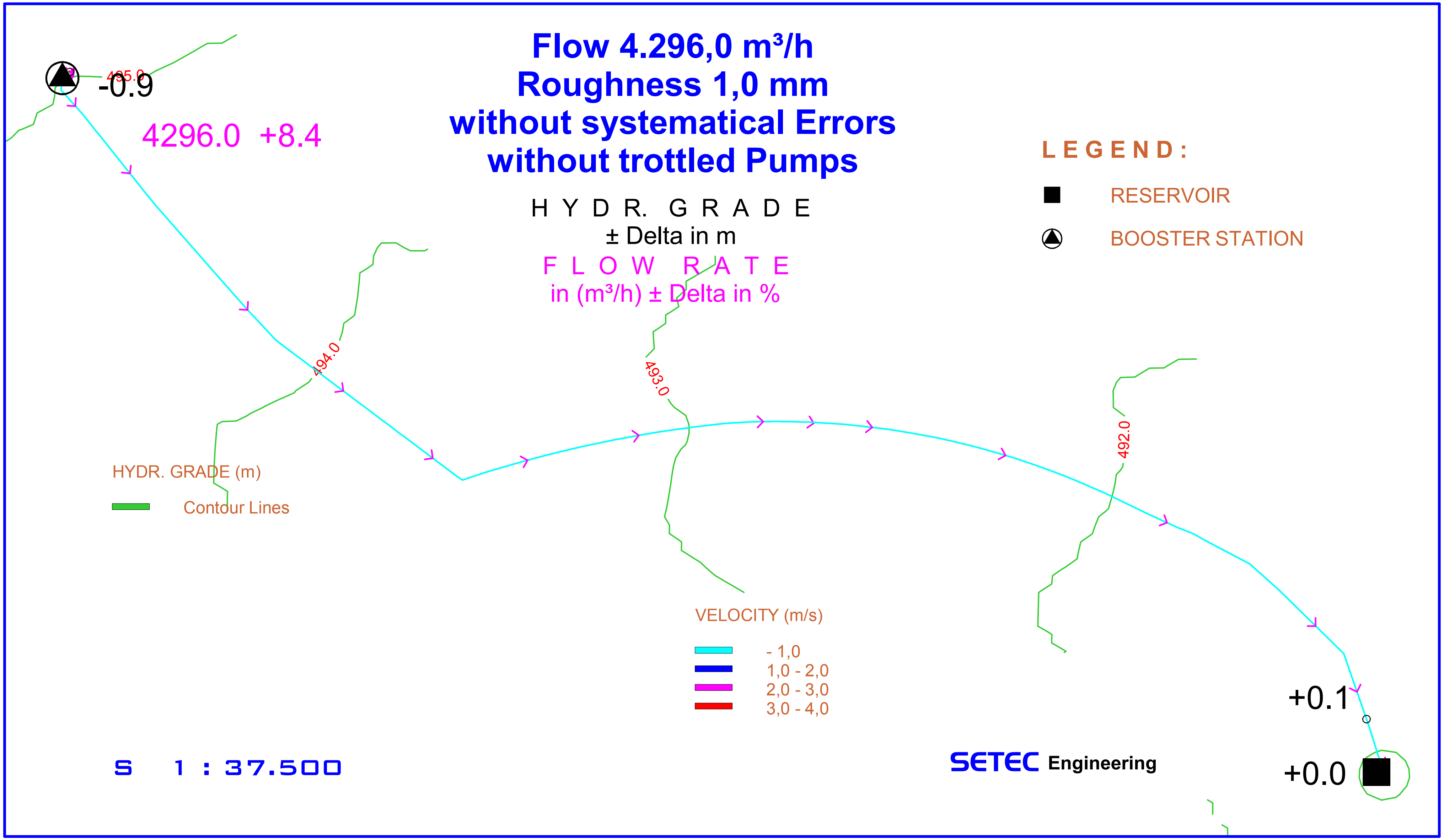
TM Ifraz III Part II

Calibration Load Case 2.11



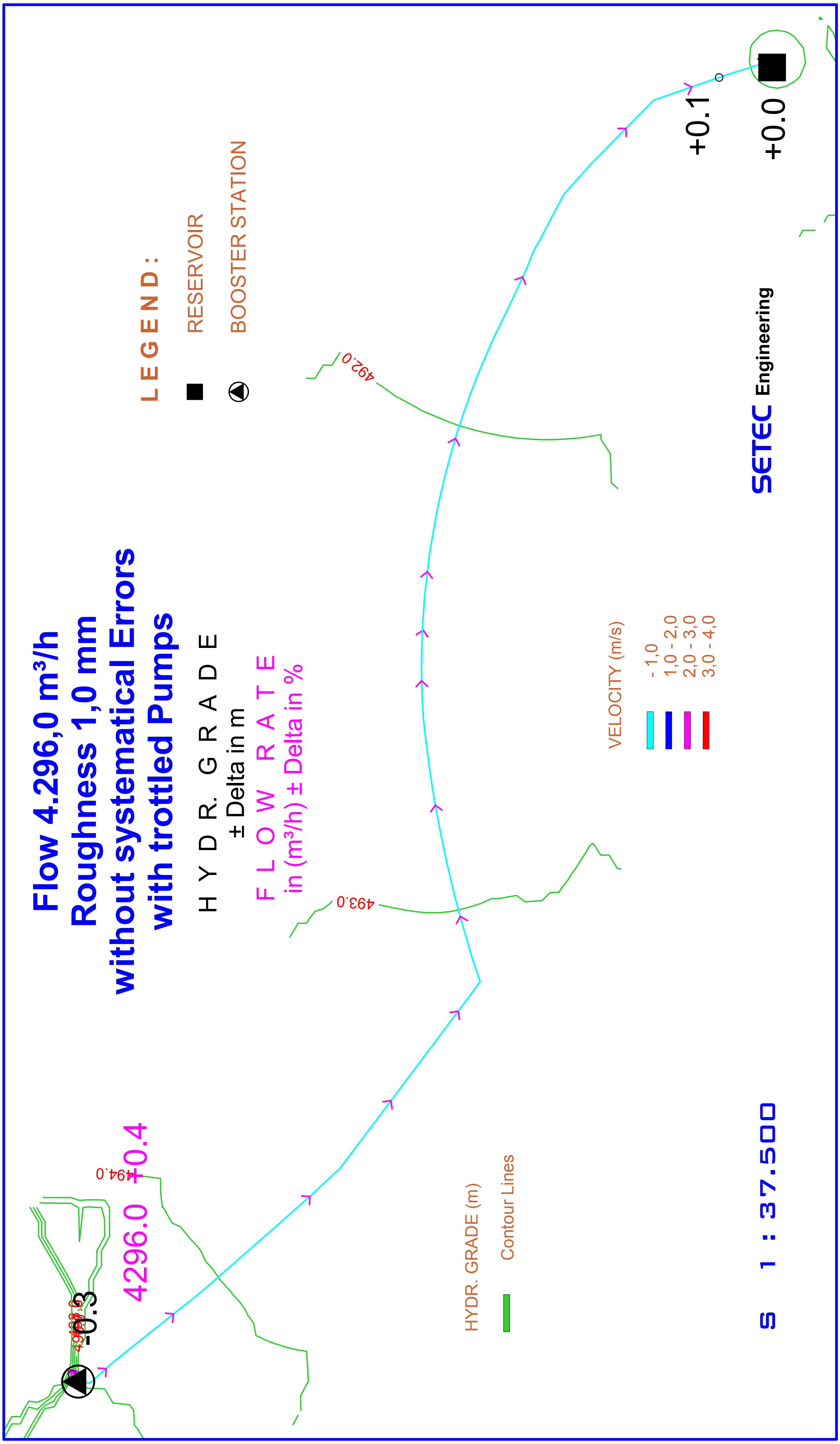
TM Ifraz III Part II

Calibration Load Case 2.20



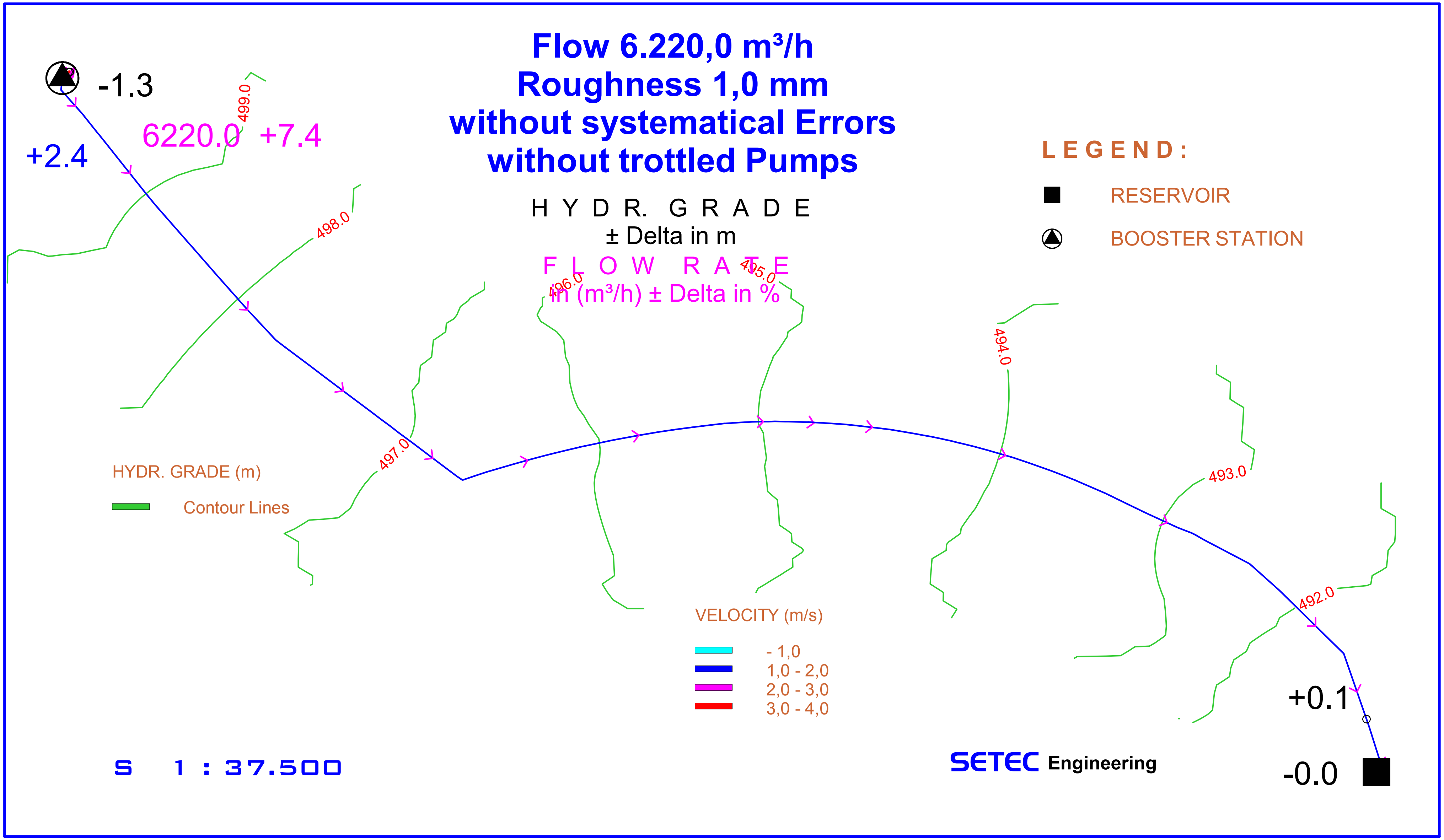
TM Ifraz III Part II

Calibration Load Case 2.21



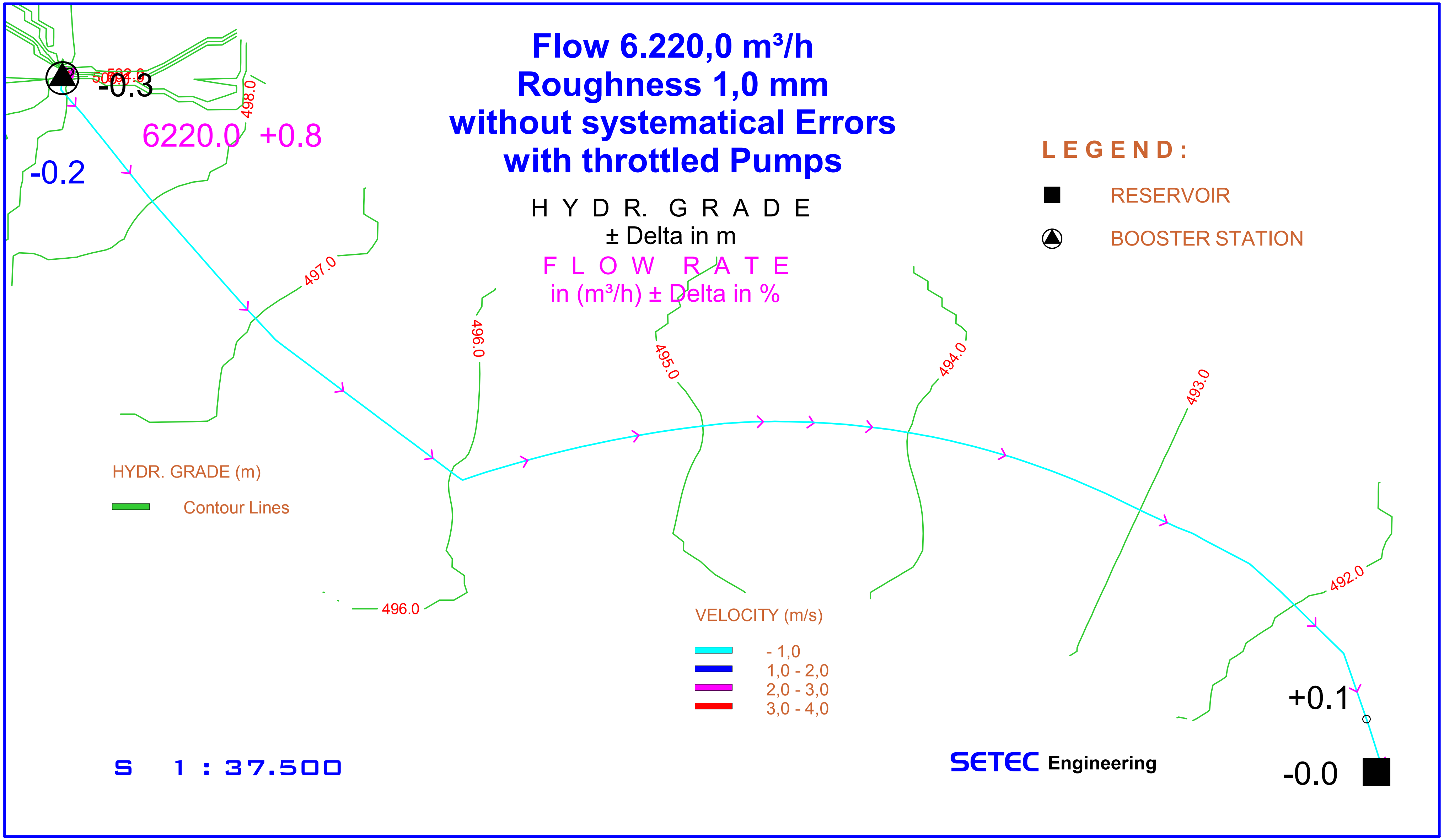
TM Ifraz III Part II

Calibration Load Case 2.30



TM Ifraz III Part II

Calibration Load Case 2.31



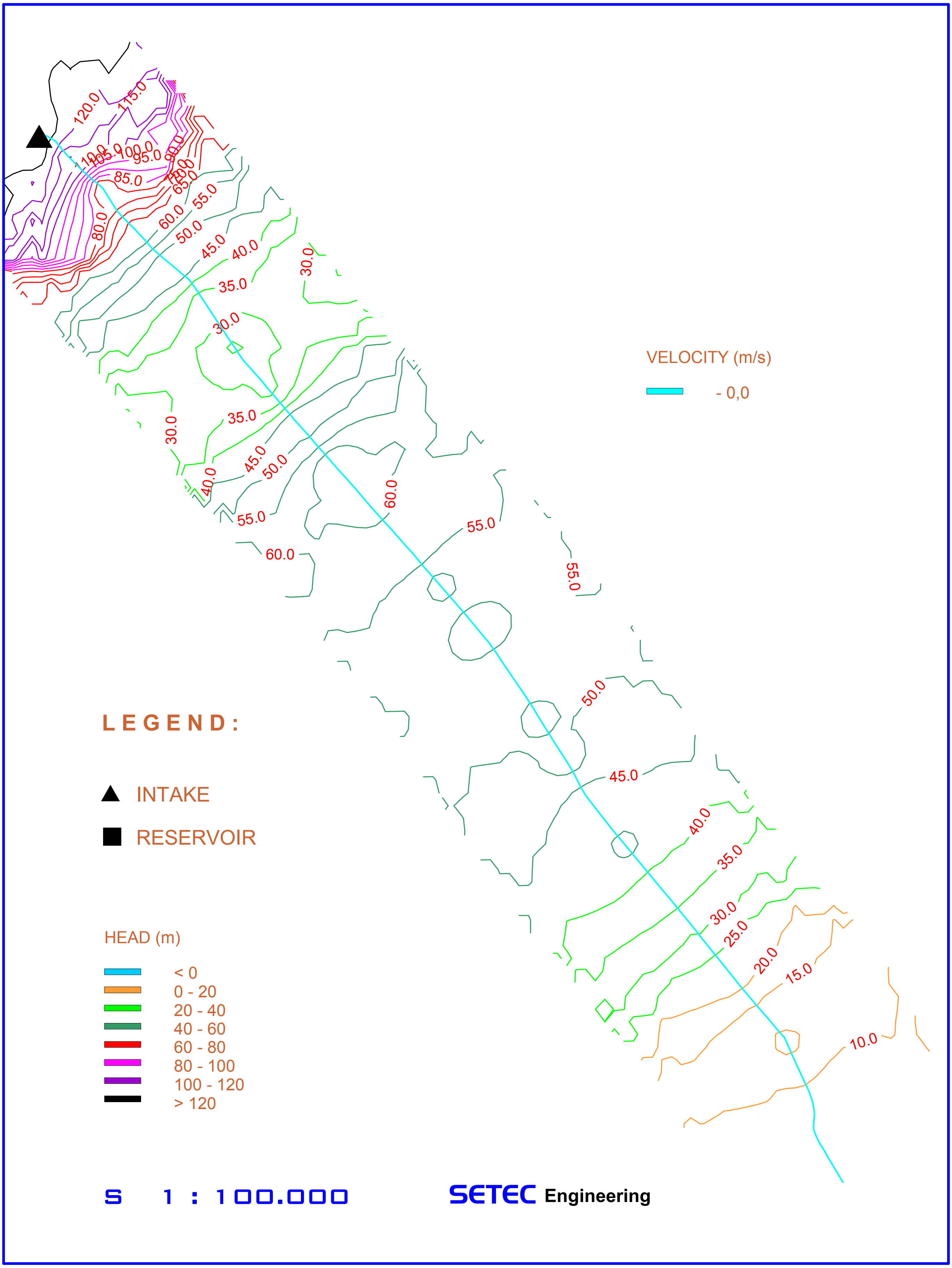
Graphic Presentation

Actual Conditions

Load Cases

TM Ifraz I

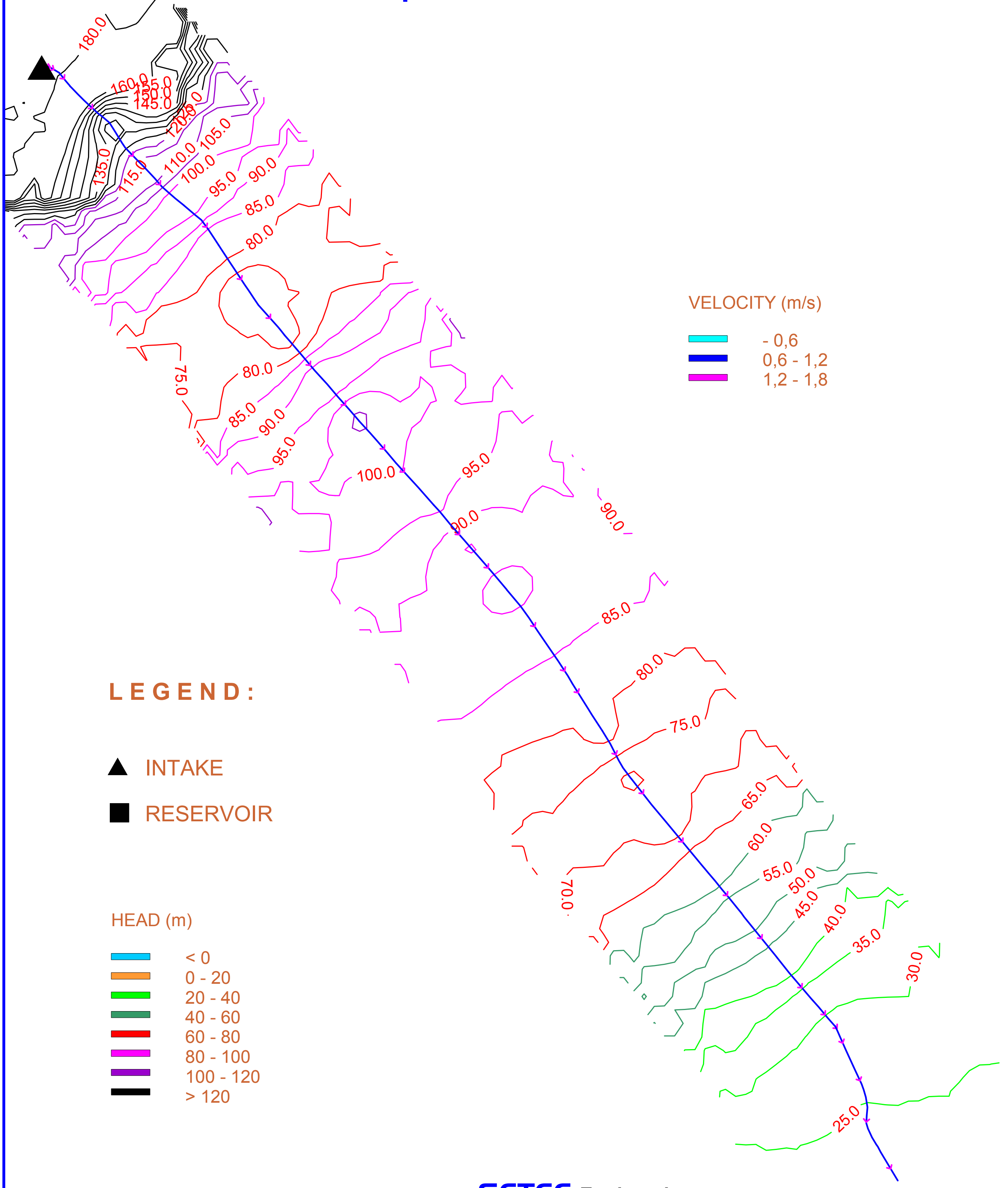
Actual 0P Flow 0,0 m³/h



TM Ifraz I

Actual 4P Flow 1.520 m³/h

Power Requirement 1.240 kW



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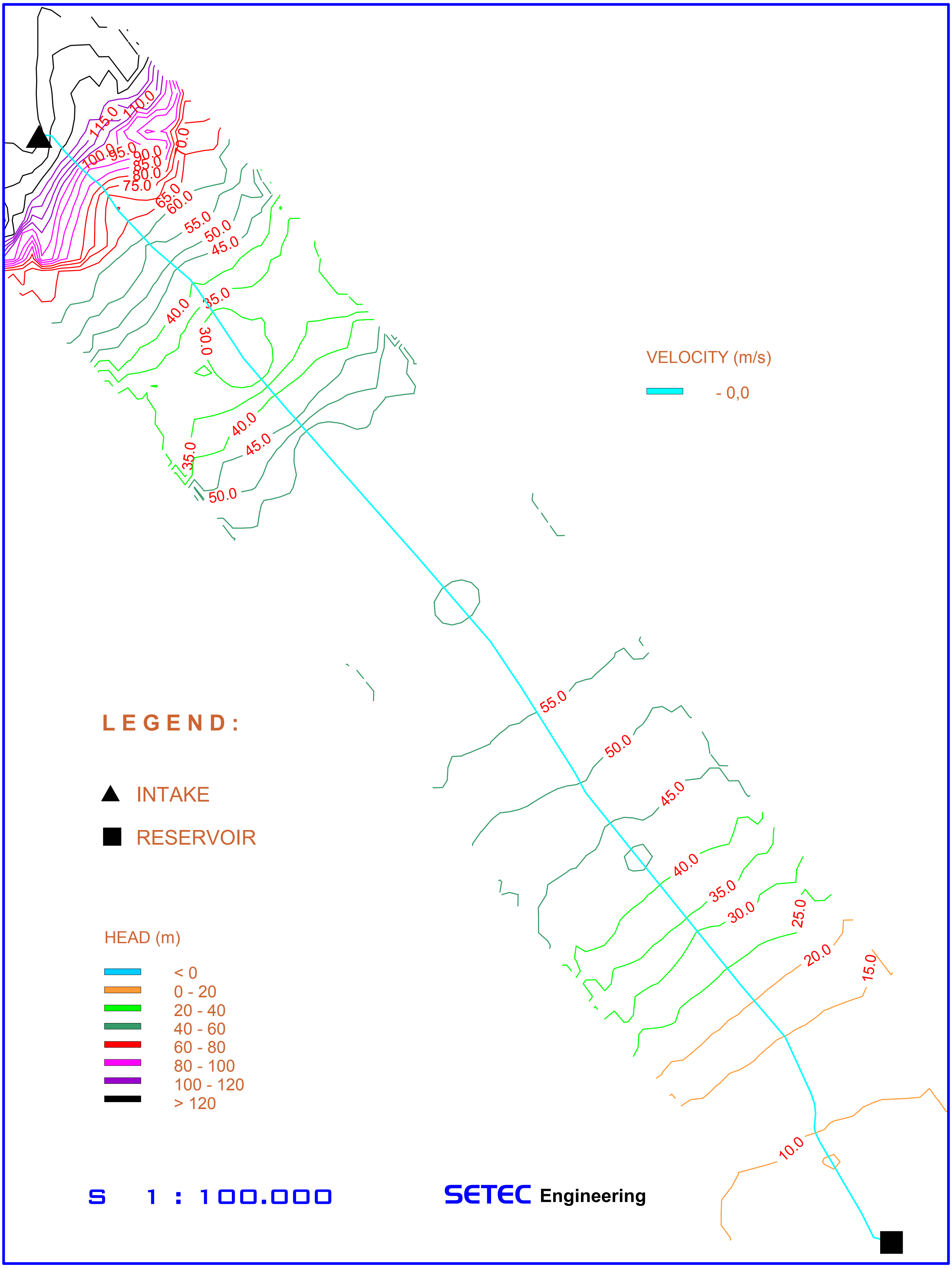
TM Ifraz II

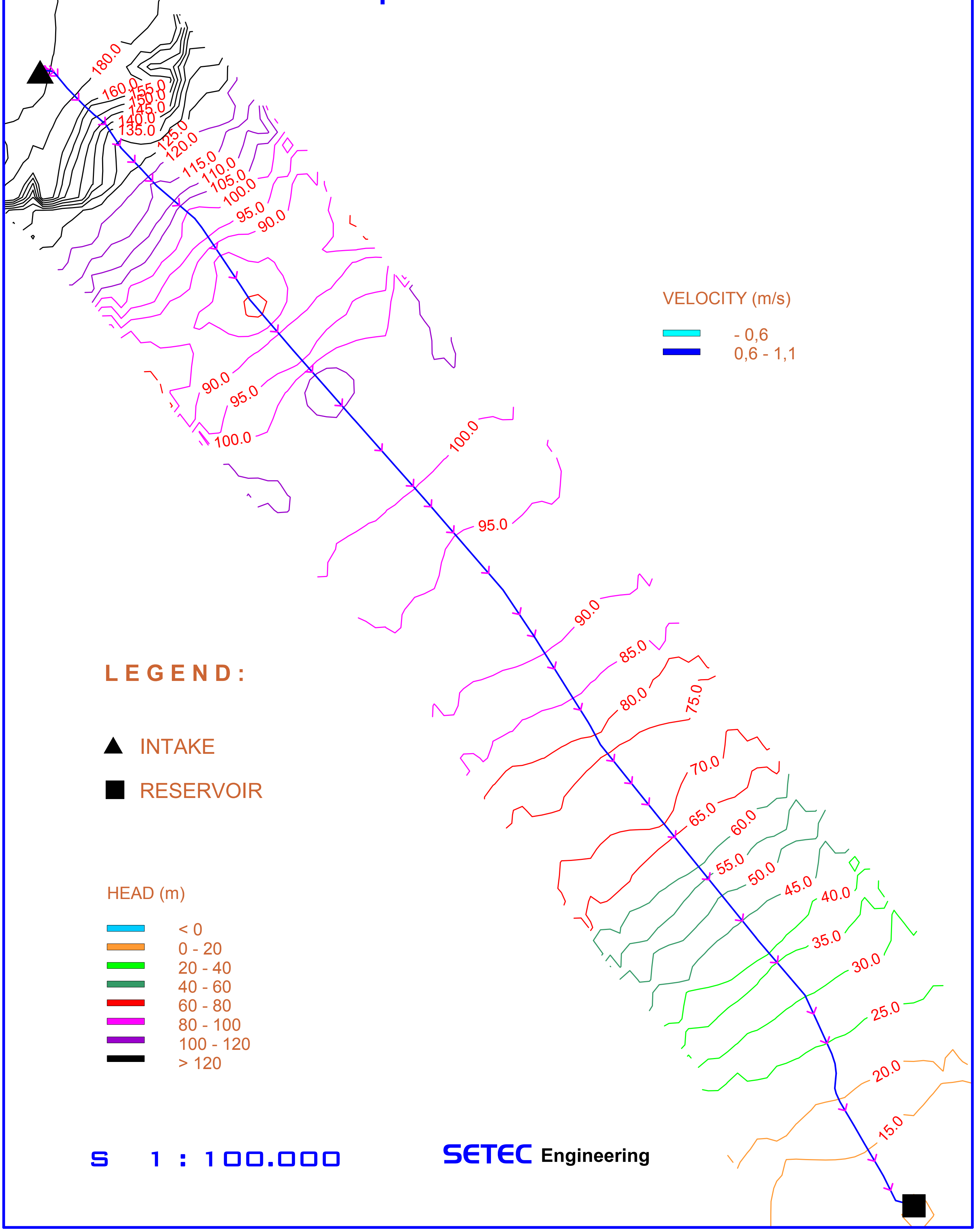
Actual 0P Flow 0,0 m³/h



TM Ifraz II

Actual 4P Flow 1.920 m³/h

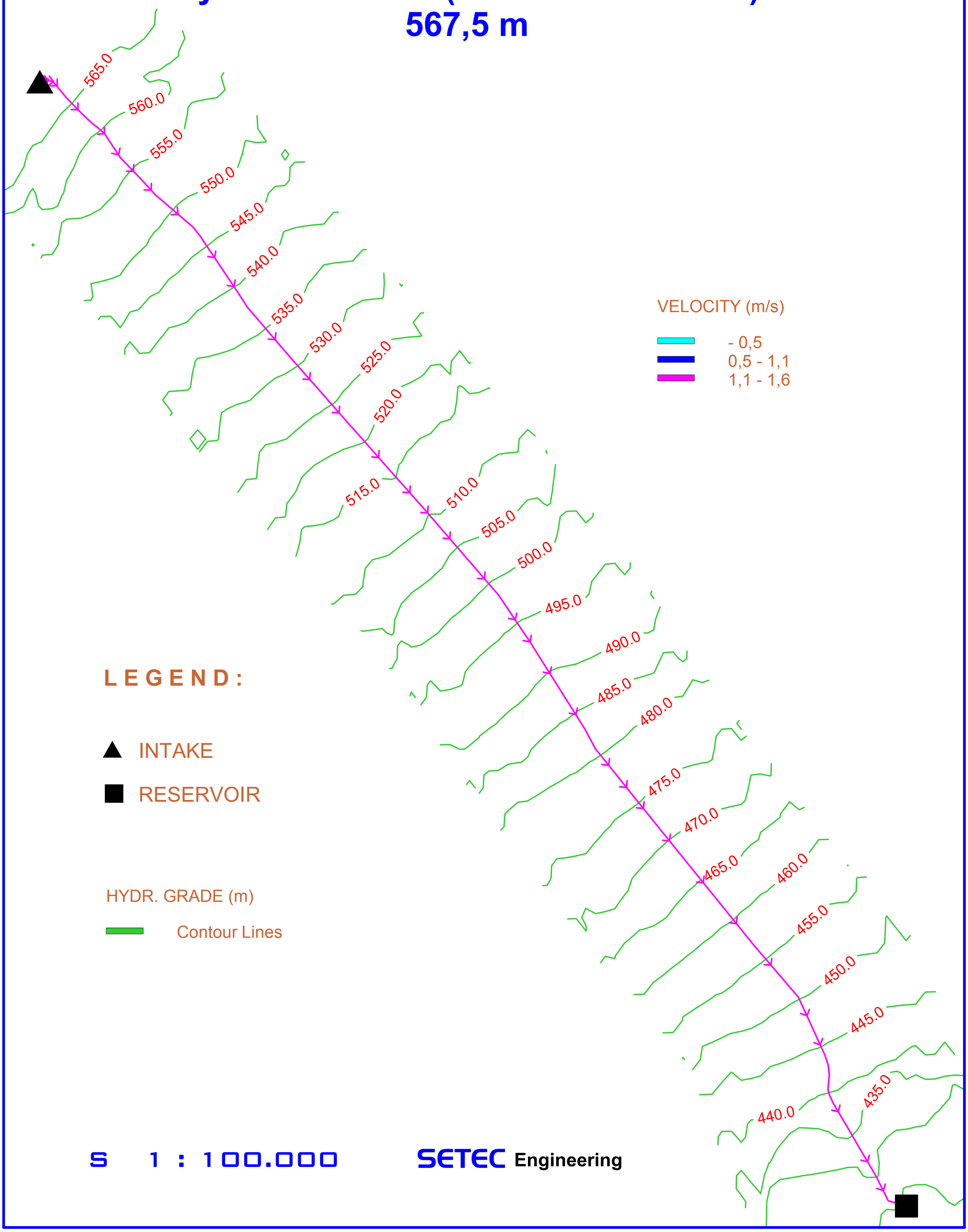
Power Requirement 1.240 kW



TM Ifraz II

Calibration Flow 2.880 m³/h

Hydraulic Grade (absolute Pressure)
567,5 m

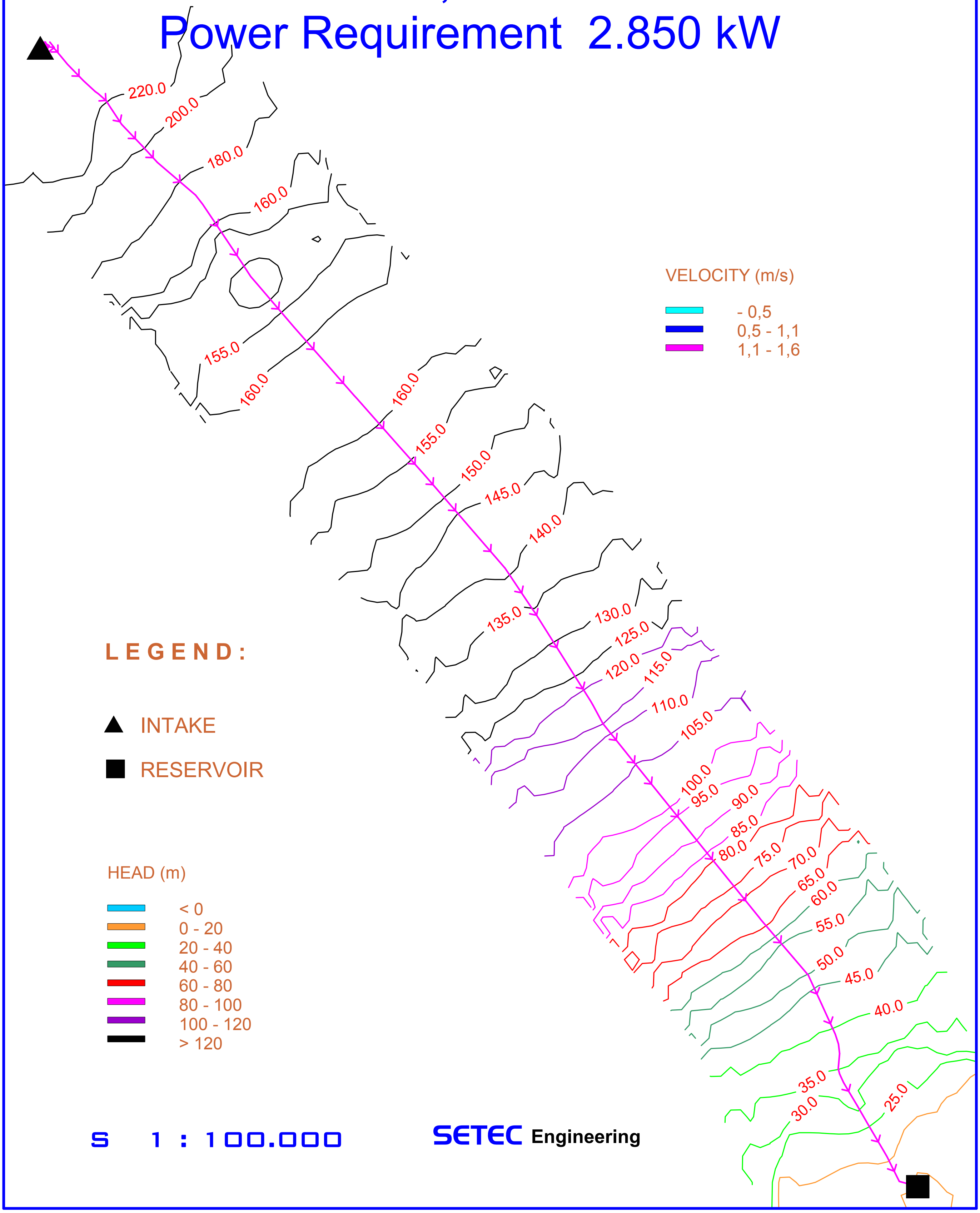


TM Ifraz II

Actual Flow 2.880 m³/h

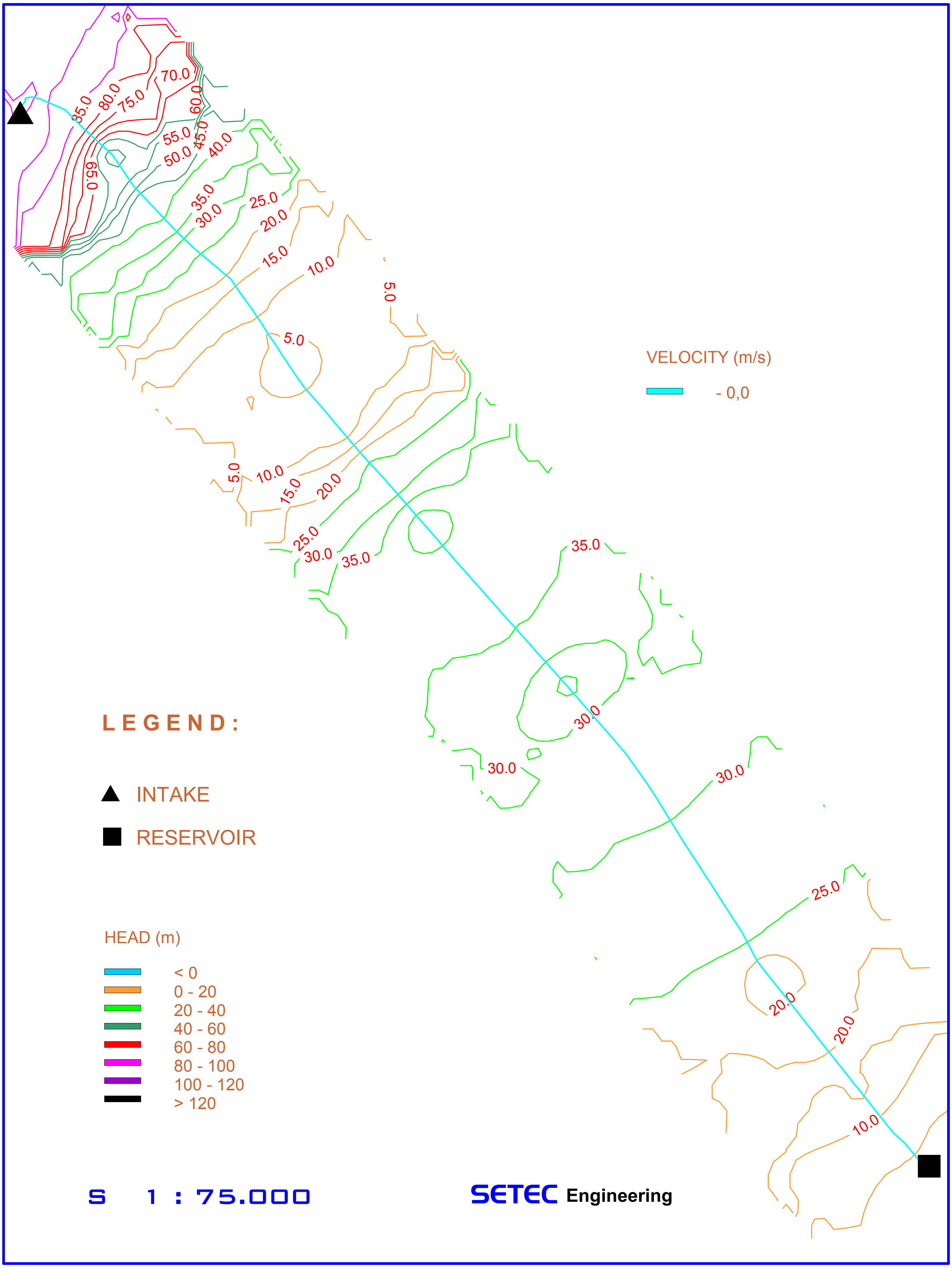
Pressure Head (relative Pressure)
28,3 bar

Power Requirement 2.850 kW



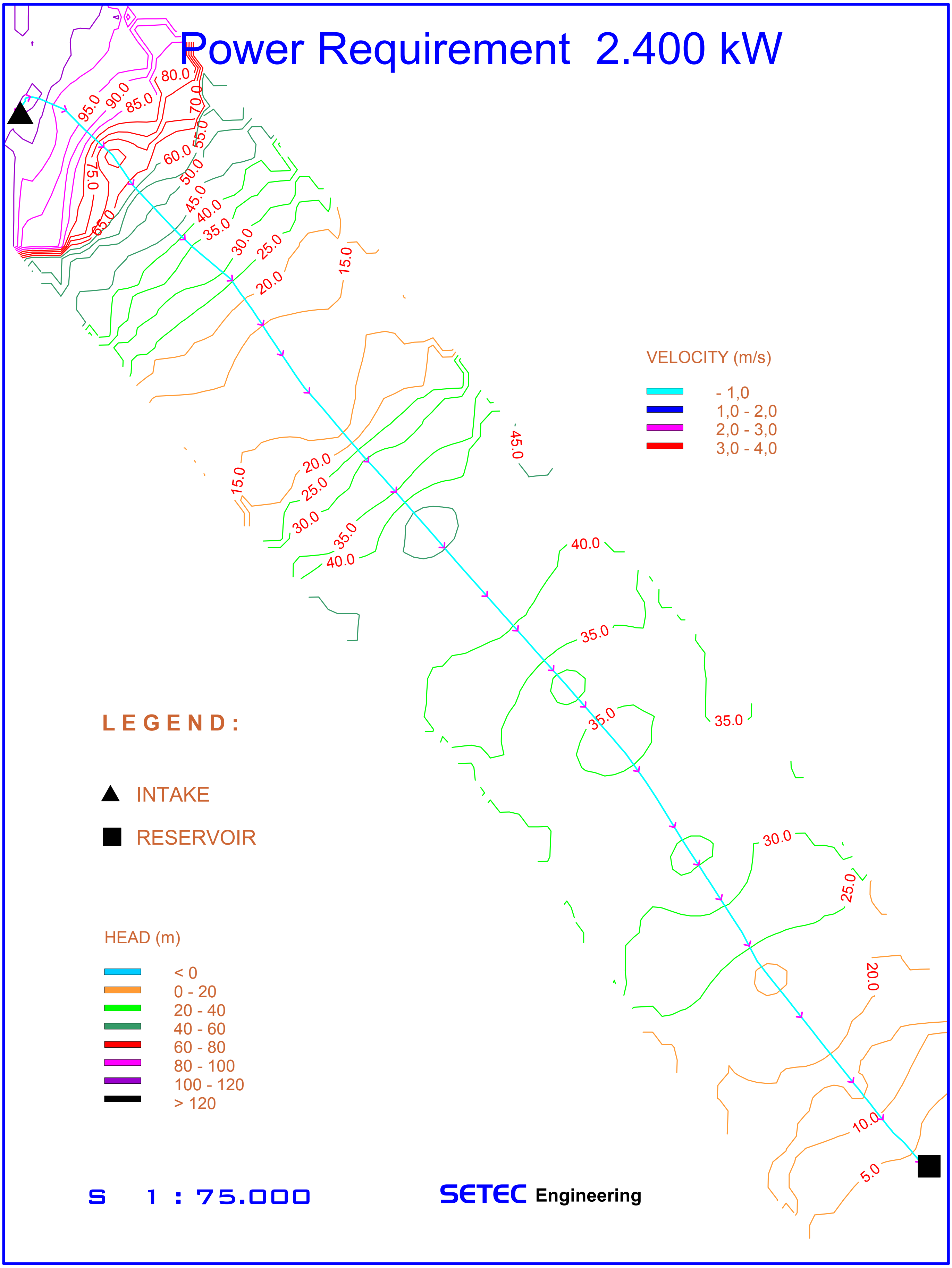
TM Ifraz III Part I

Actual 0P Flow 0,0 m³/h



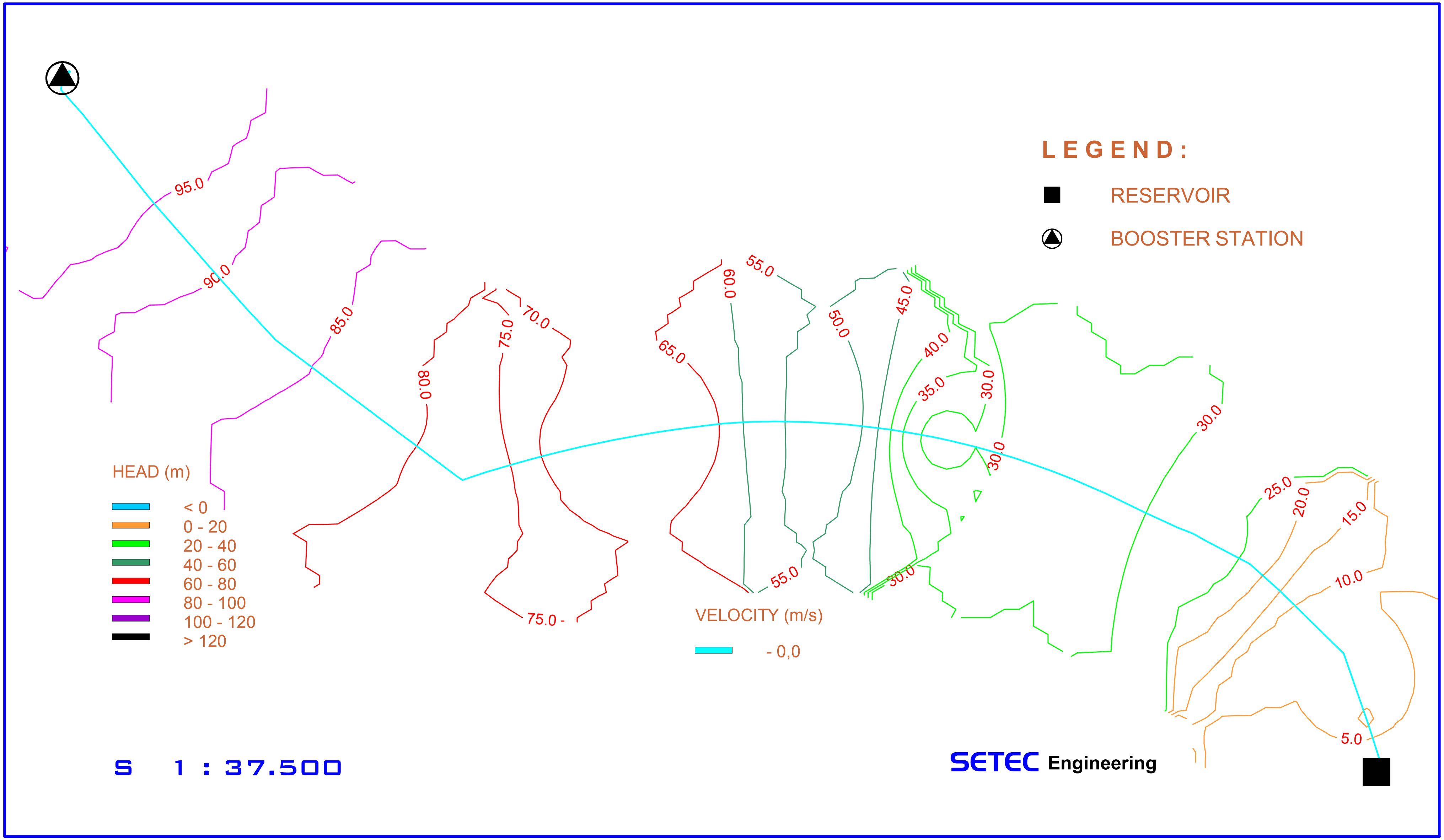
TM Ifraz III Part I

Actual 3P Flow 6.000 m³/h



TM Ifraz III Part II

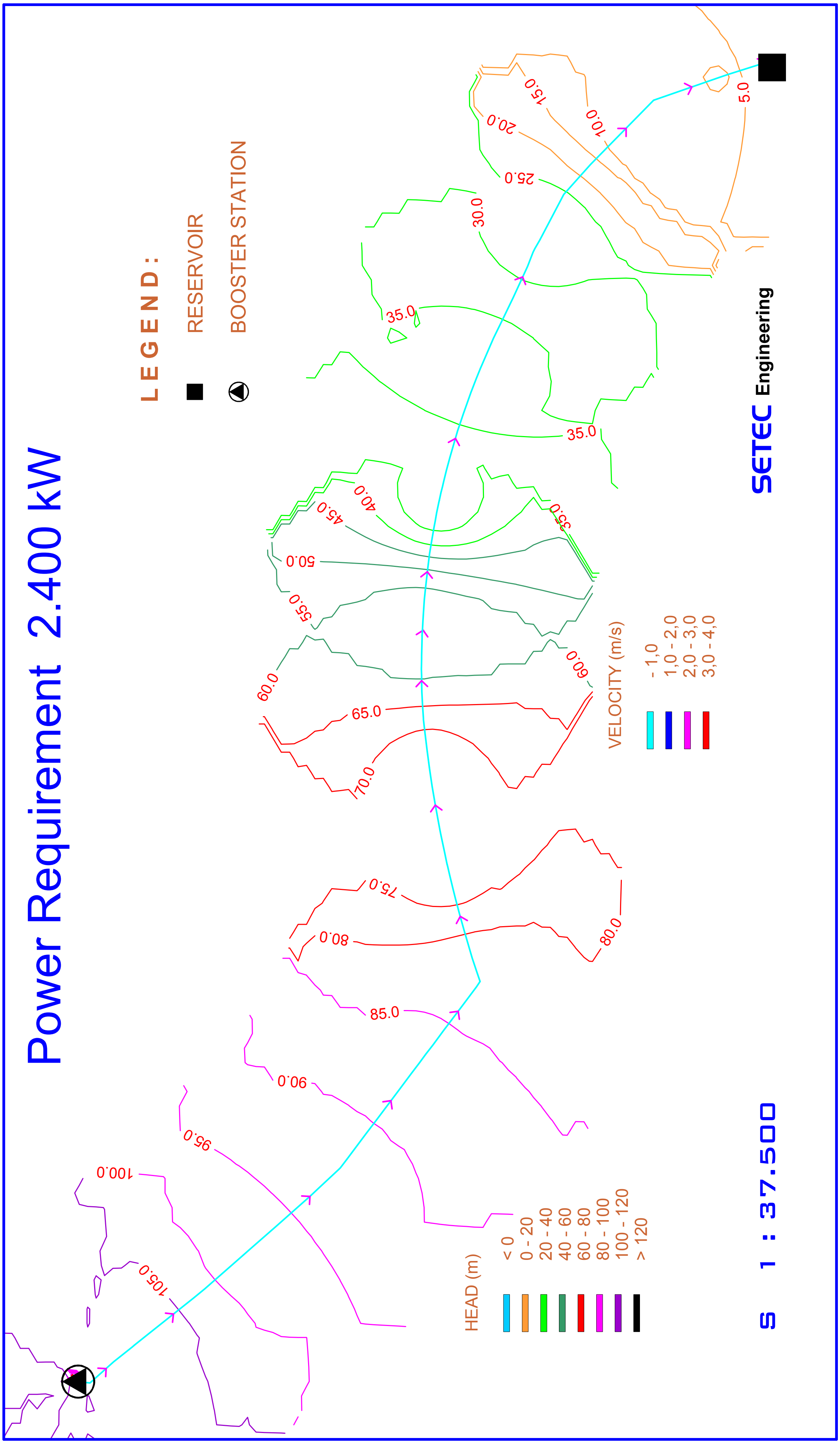
Actual 0P Flow 0,0 m³/h



TM Ifraz III Part II

Actual 3P Flow 6.100 m³/h

Power Requirement 2.400 kW



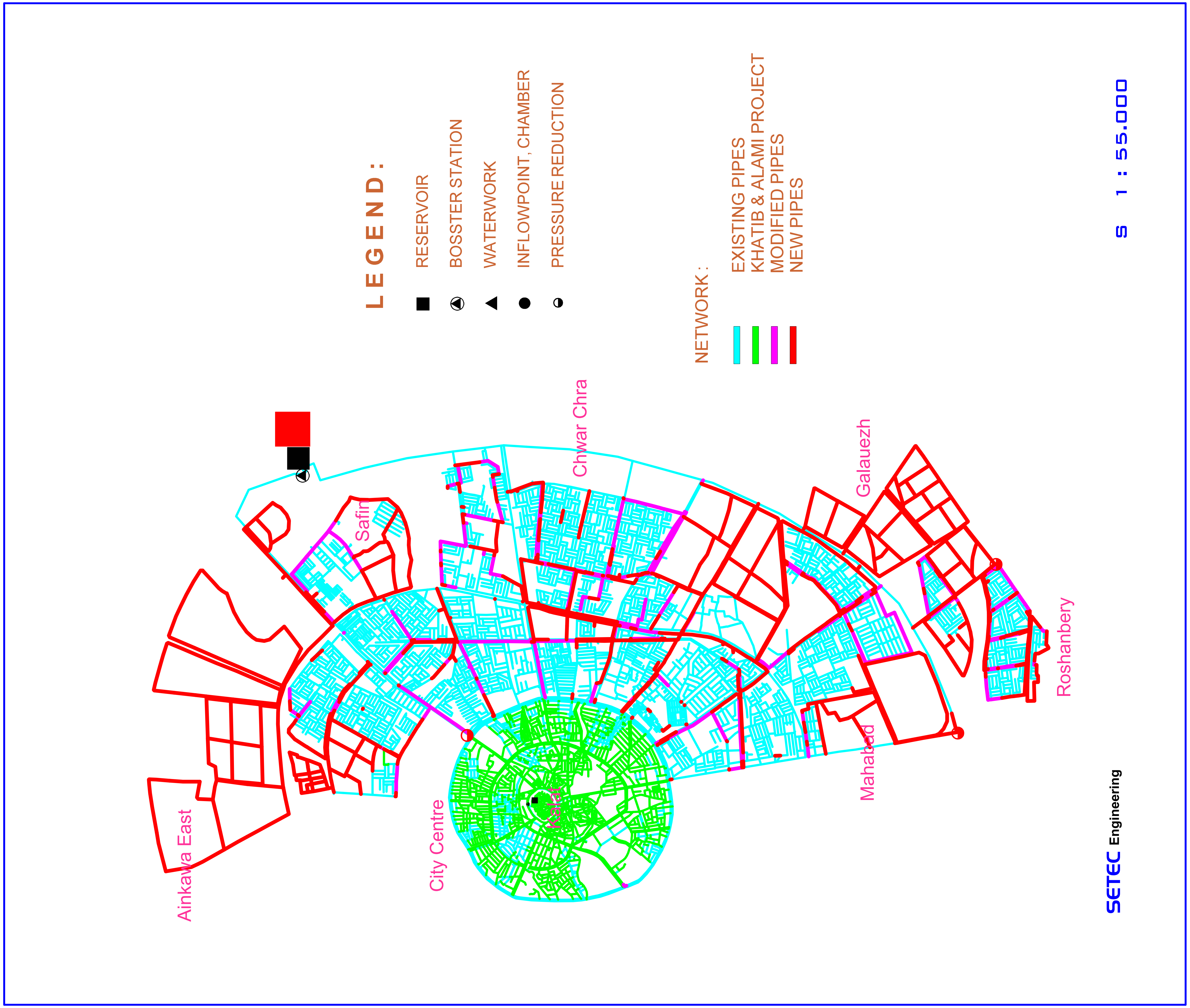
Graphic Presentation

Design

Load Cases

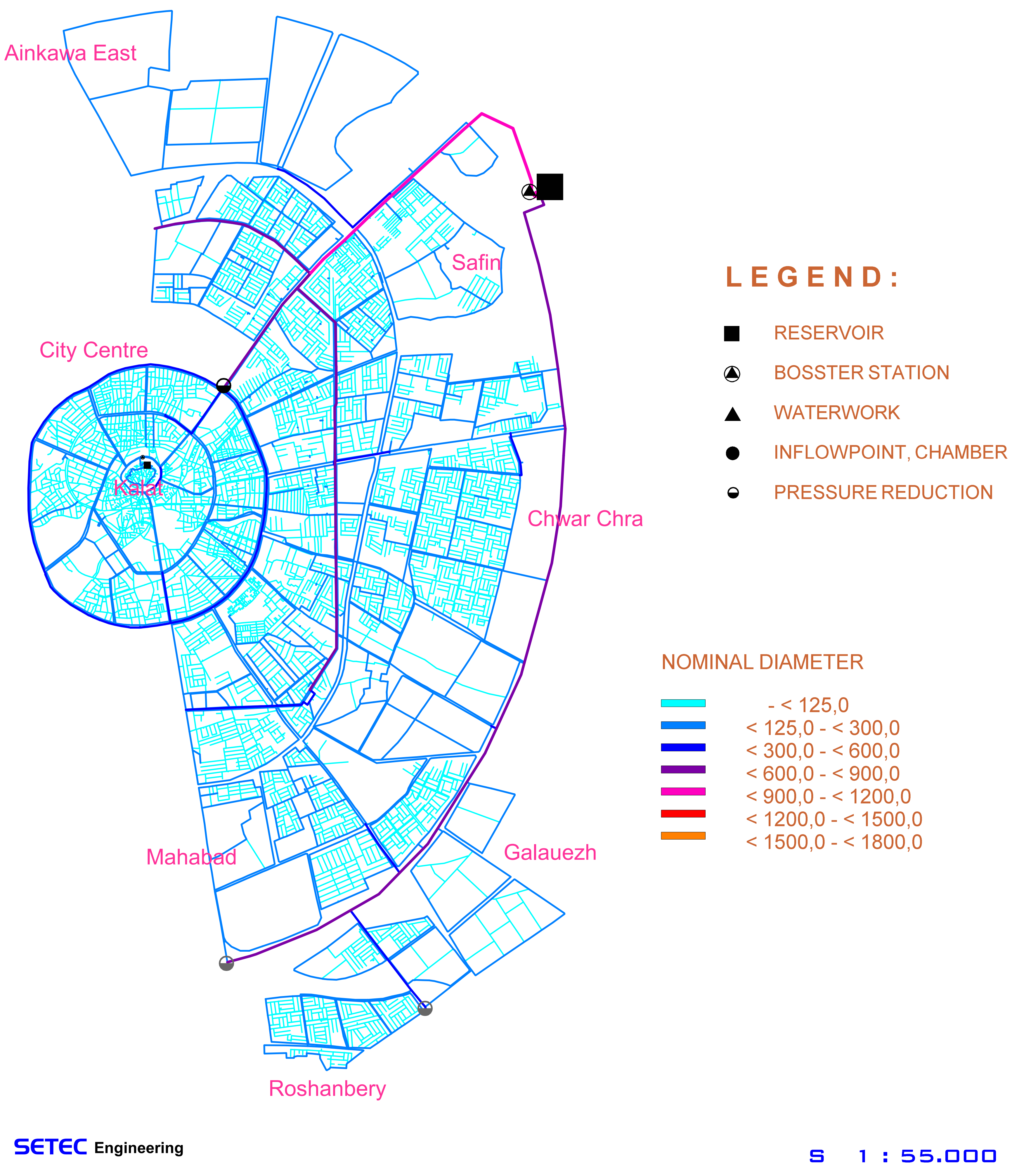
SA Dawajin

Design 2032 Measures



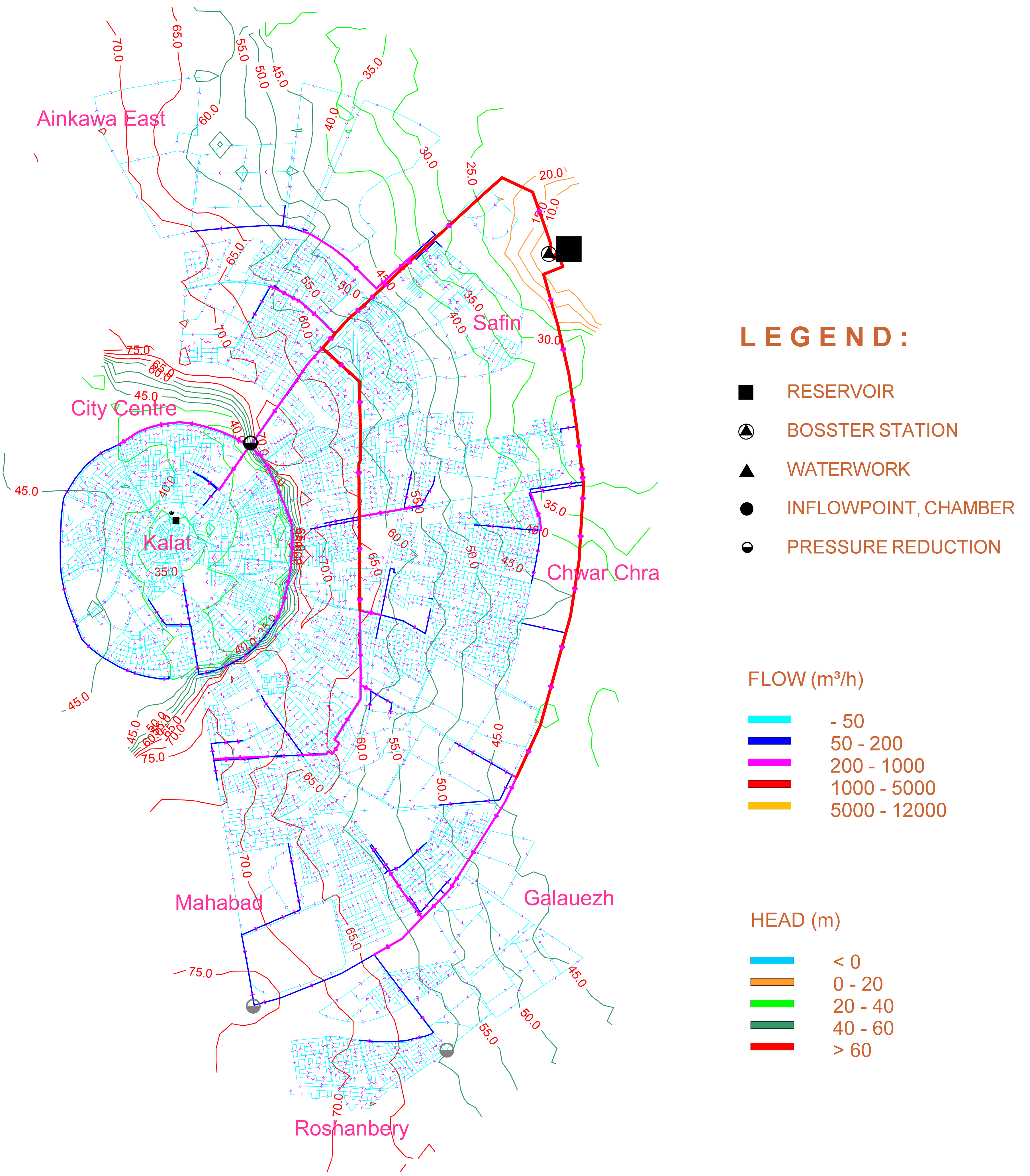
SA Dawajin

Design 2032 Dimensions



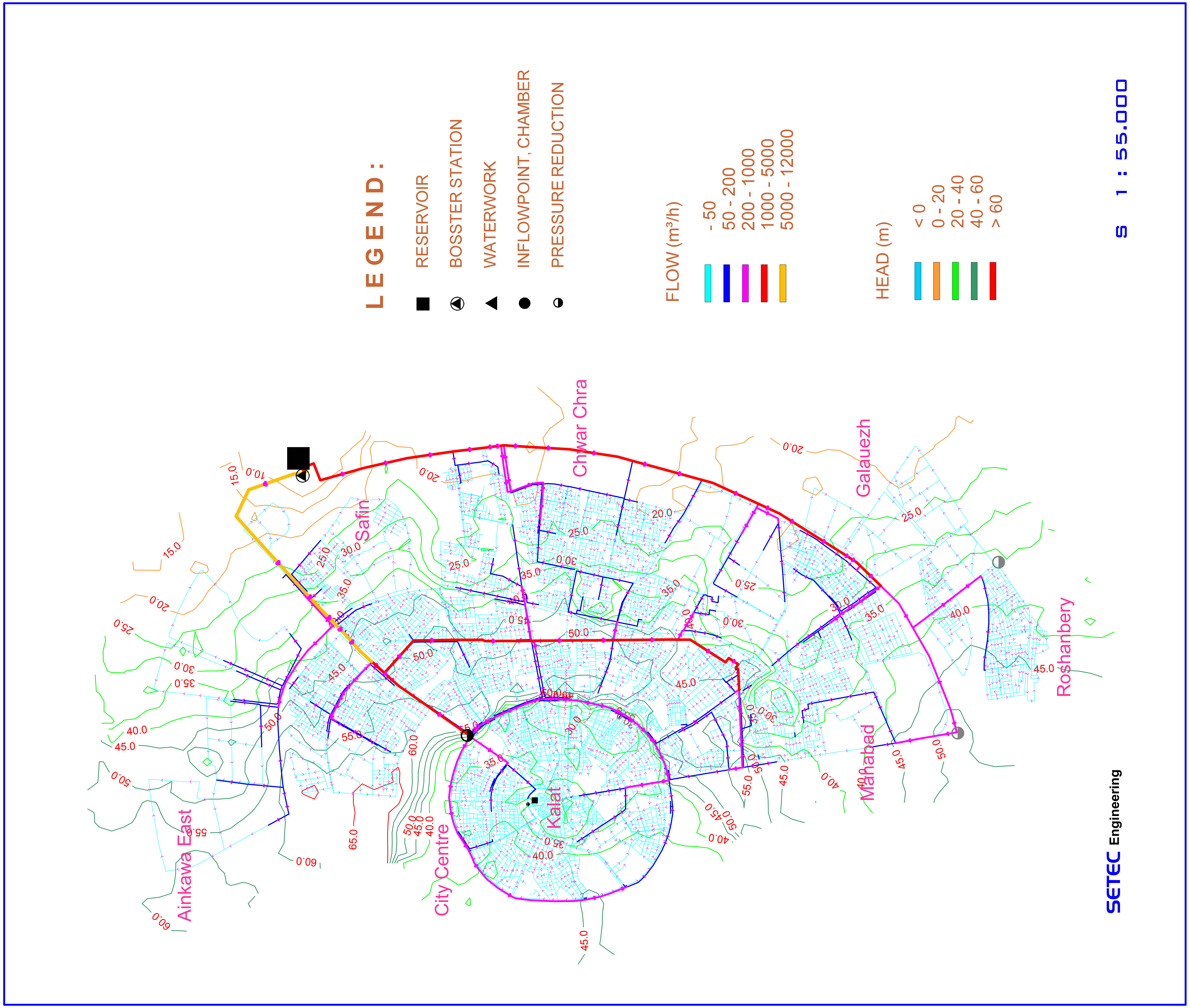
SA Dawajin

Design 2032 Minimum hourly Demand 5.664,8 m/h



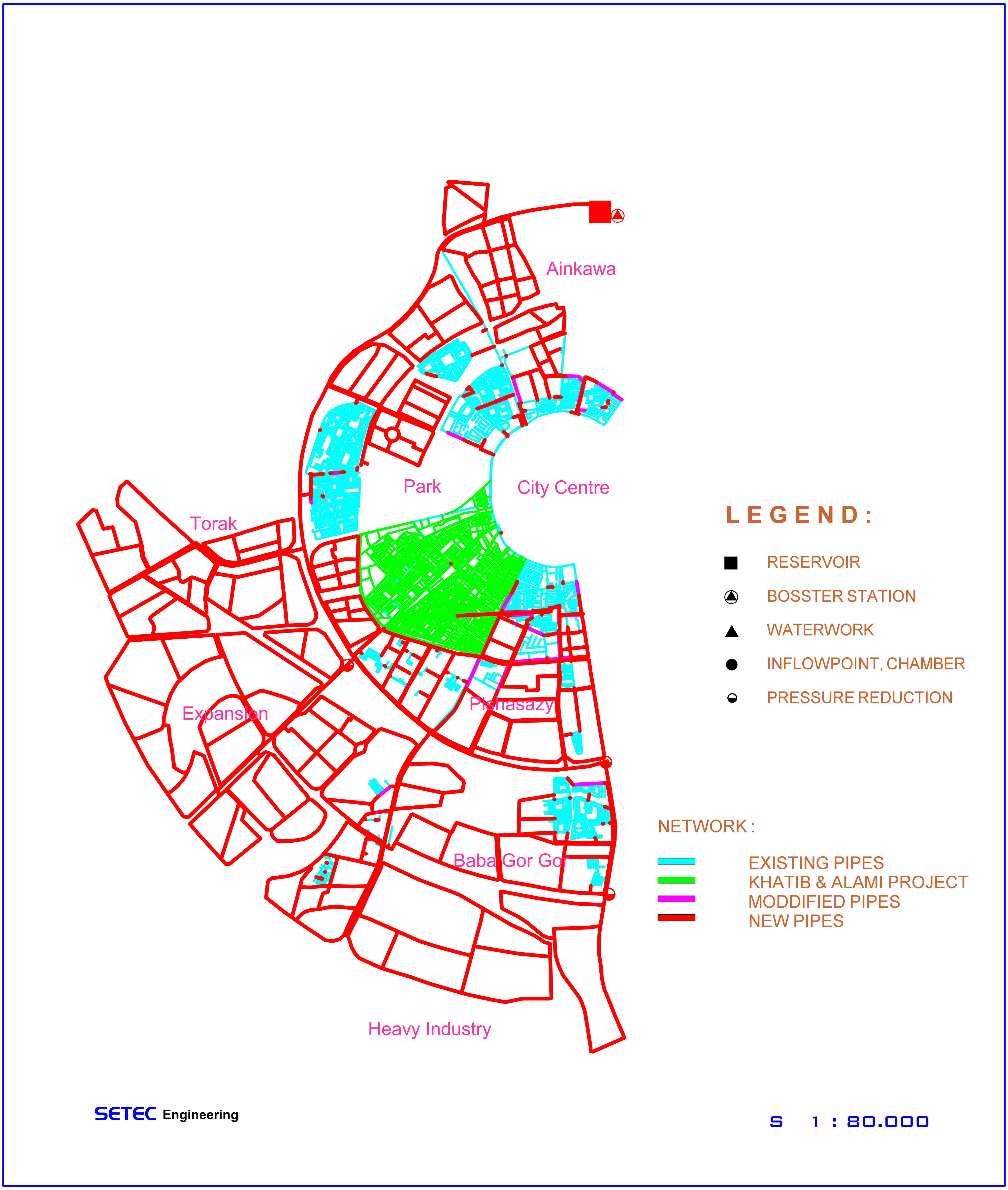
SA Dawajin

Design 2032 Peak hourly Demand 11.329,6 m/h



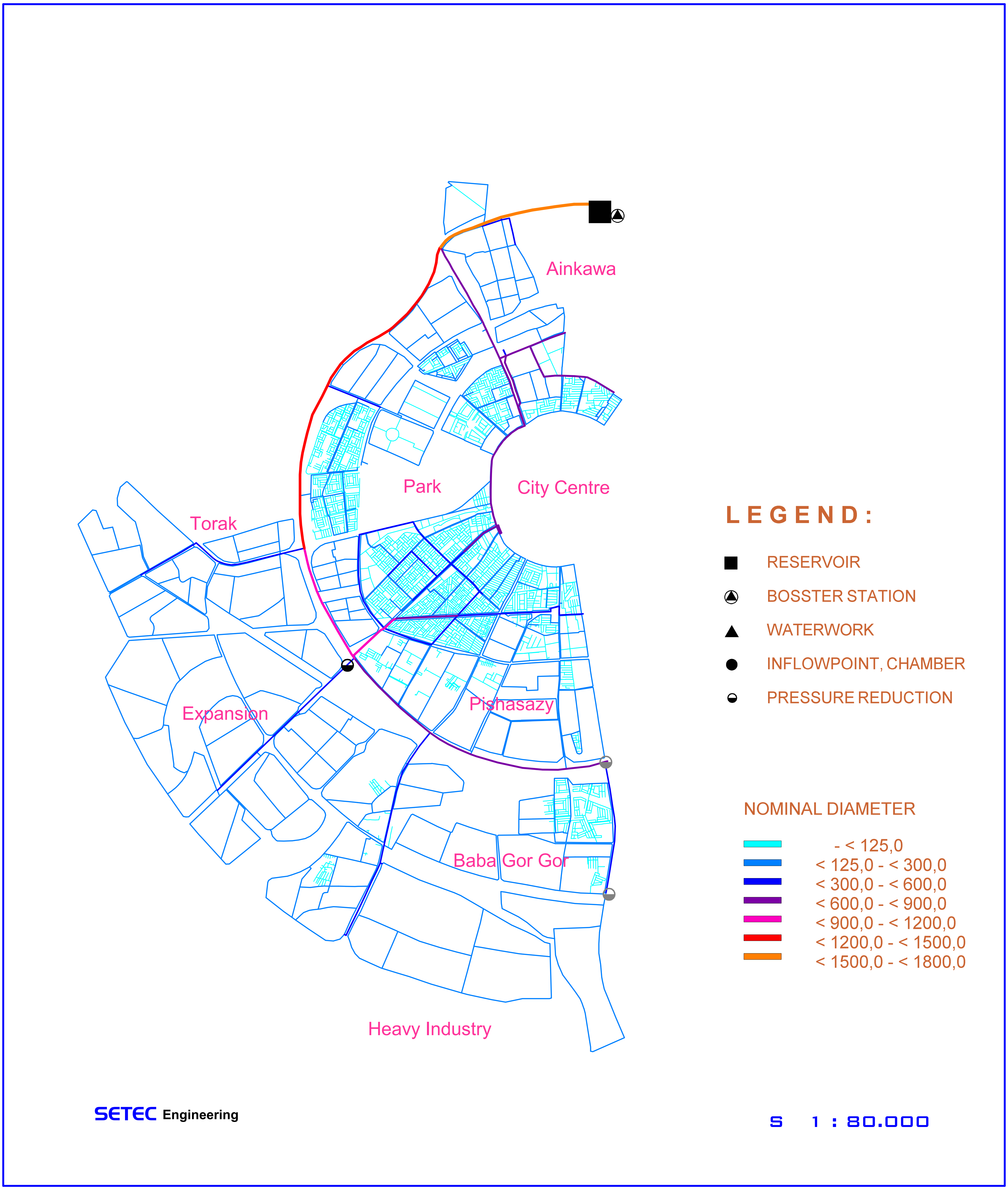
SA Berkot

Design 2032 Measures



SA Berkot

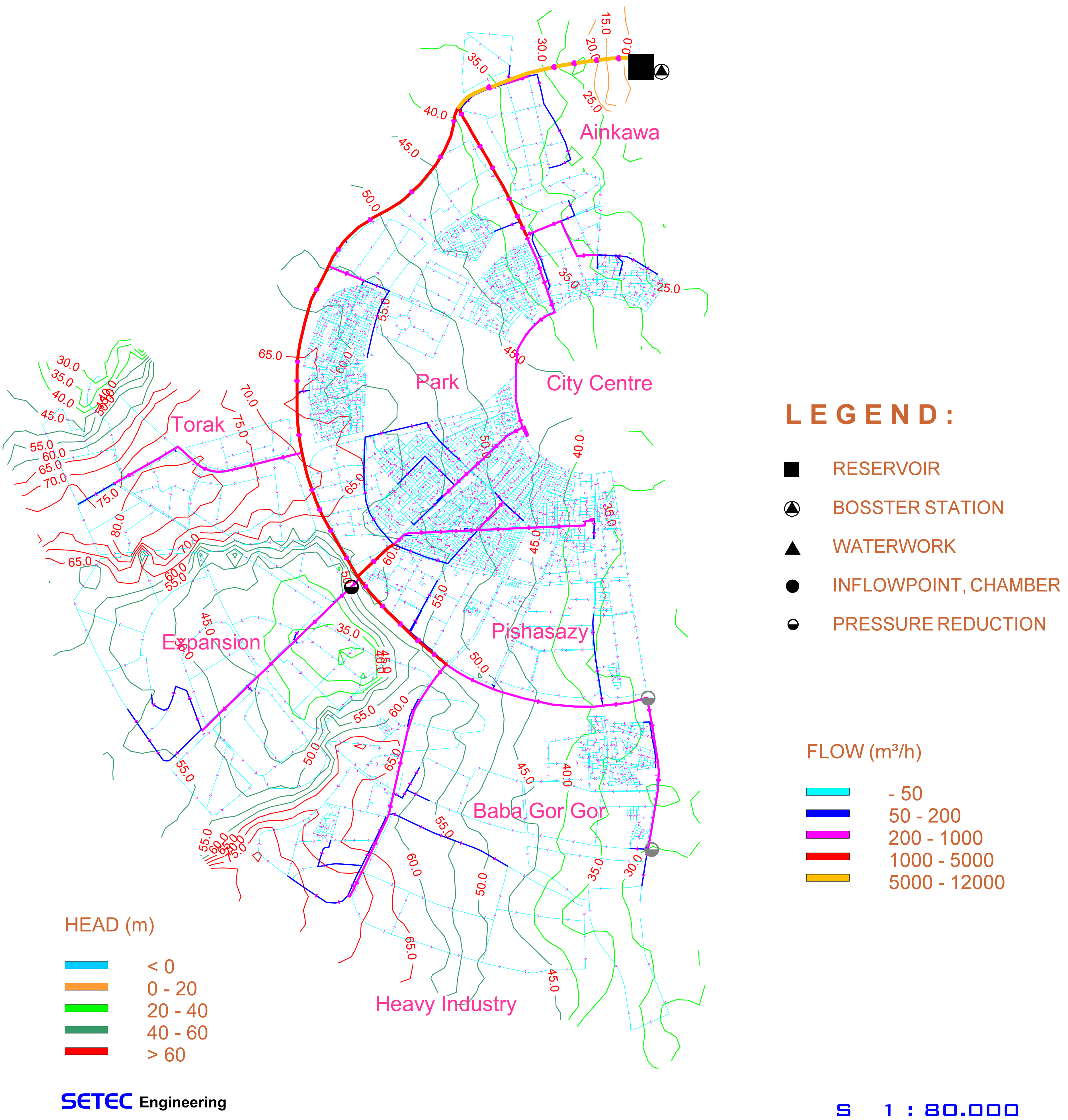
Design 2032 Dimensions



SA Berkot

Design 2032 Minimum hourly Demand 5.754,1 m³/h

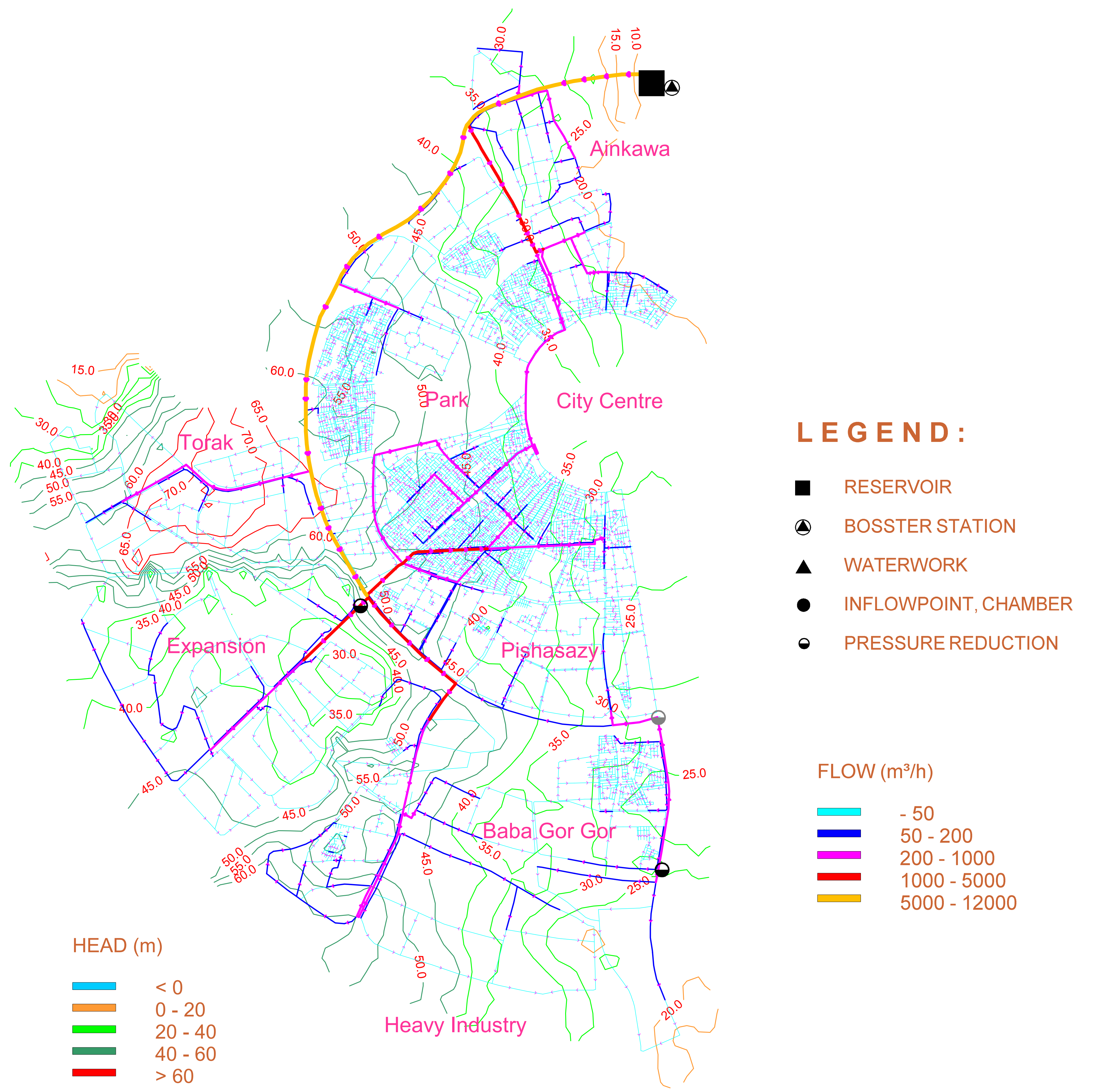
Input R Berkot 5.754,1 m³/h



SA Berkot

Design 2032 Peak hourly Demand 11.508,2 m³/h

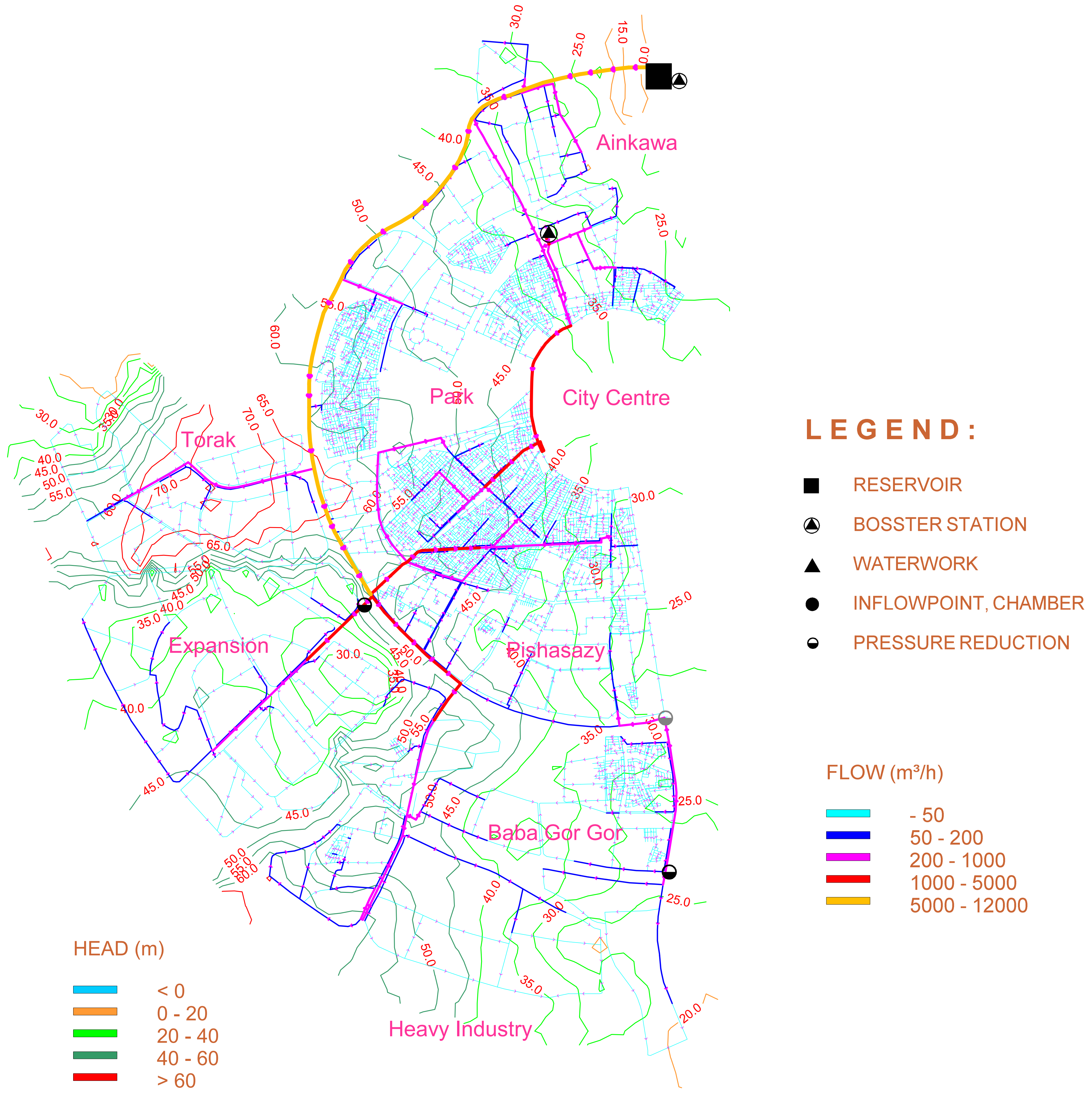
Input R Berkot 10.508,2 m³/h
Input SA Pirzeen 1.000,0 m³/h



SA Berkot

Design 2032 Peak hourly Demand 11.508,2 m³/h +BS1

Input R Berkot 8.397,4 m³/h
Input SA Pirzeen 1.000,0 m³/h
BS Ainkawa P1-P3 2.085,7 m³/h



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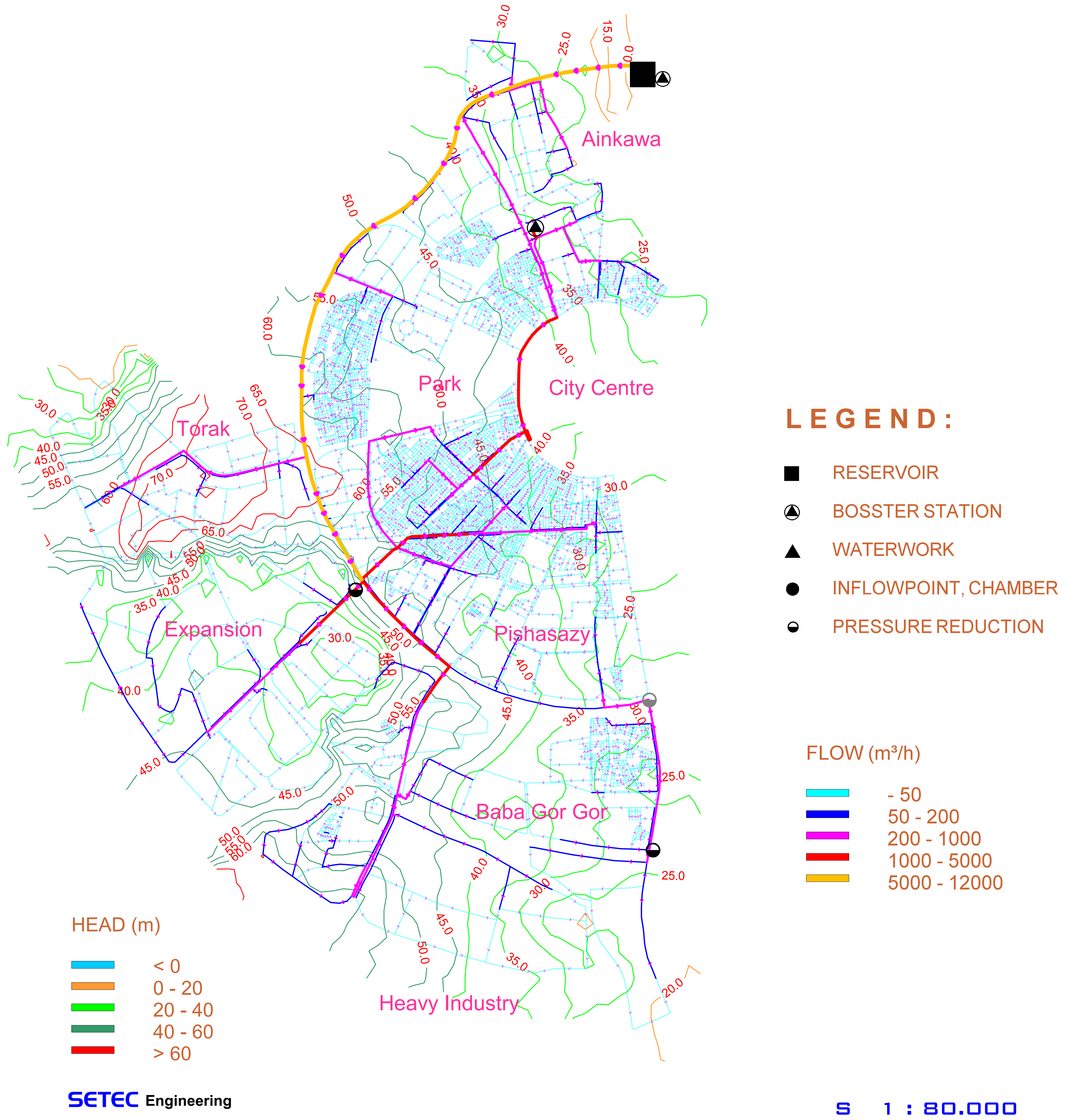
S 1 : 80.000

SA Berkot

Design 2032 Peak hourly Demand 11.508,2 m³/h +BS2

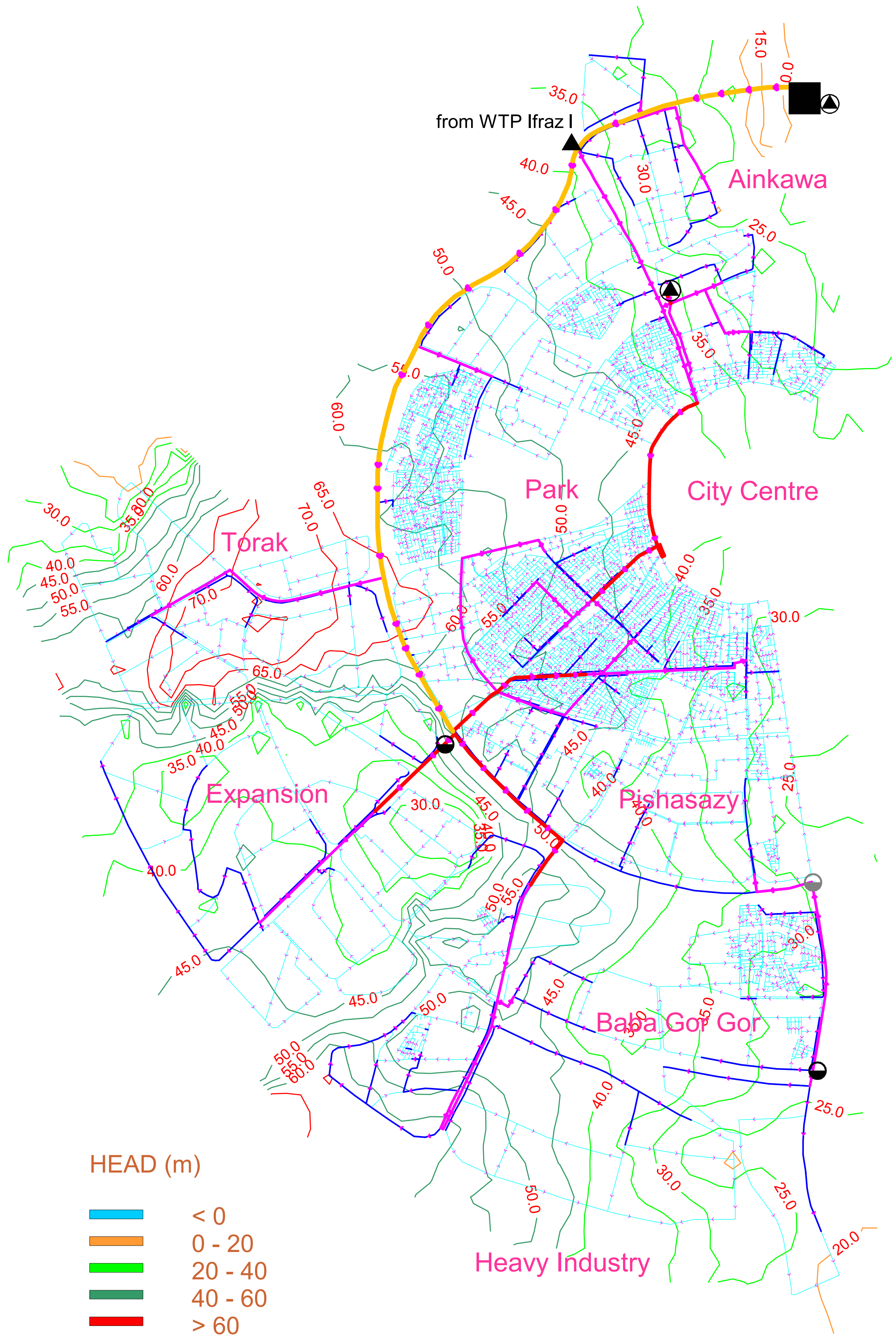
Input R Berkot 8.762,6 m³/h
Input SA Pirzeen 1.000,0 m³/h
BS Ainkawa P4-P6 1.745,6 m³/h



SA Berkot

Design 2032 Peak hourly Demand 11.508,2 m³/h +BS+IF1

Input R Berkot 6.853,2 m³/h
Input SA Pirzeen 1.000,0 m³/h
BS Ainkawa P1-P3 2.064,5 m³/h
TM Ifraz 1 1.590,5 m³/h



LEGEND:

- RESERVOIR
- BOSSTER STATION
- WATERWORK
- INFLOWPOINT, CHAMBER
- PRESSURE REDUCTION

FLOW (m³/h)

- - 50
- 50 - 200
- 200 - 1000
- 1000 - 5000
- 5000 - 12000

HEAD (m)

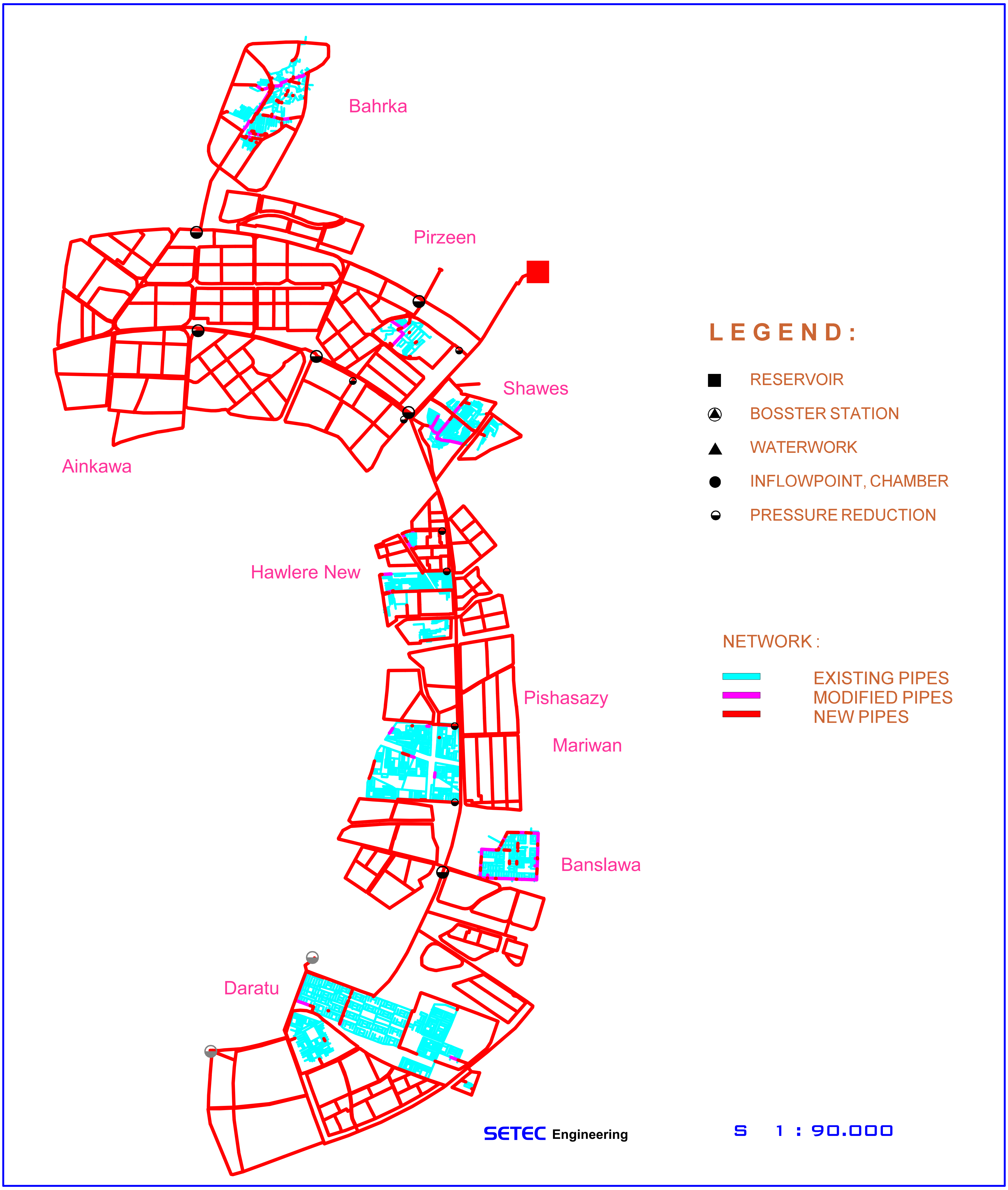
- < 0
- 0 - 20
- 20 - 40
- 40 - 60
- > 60

SETEC Engineering

S 1 : 80.000

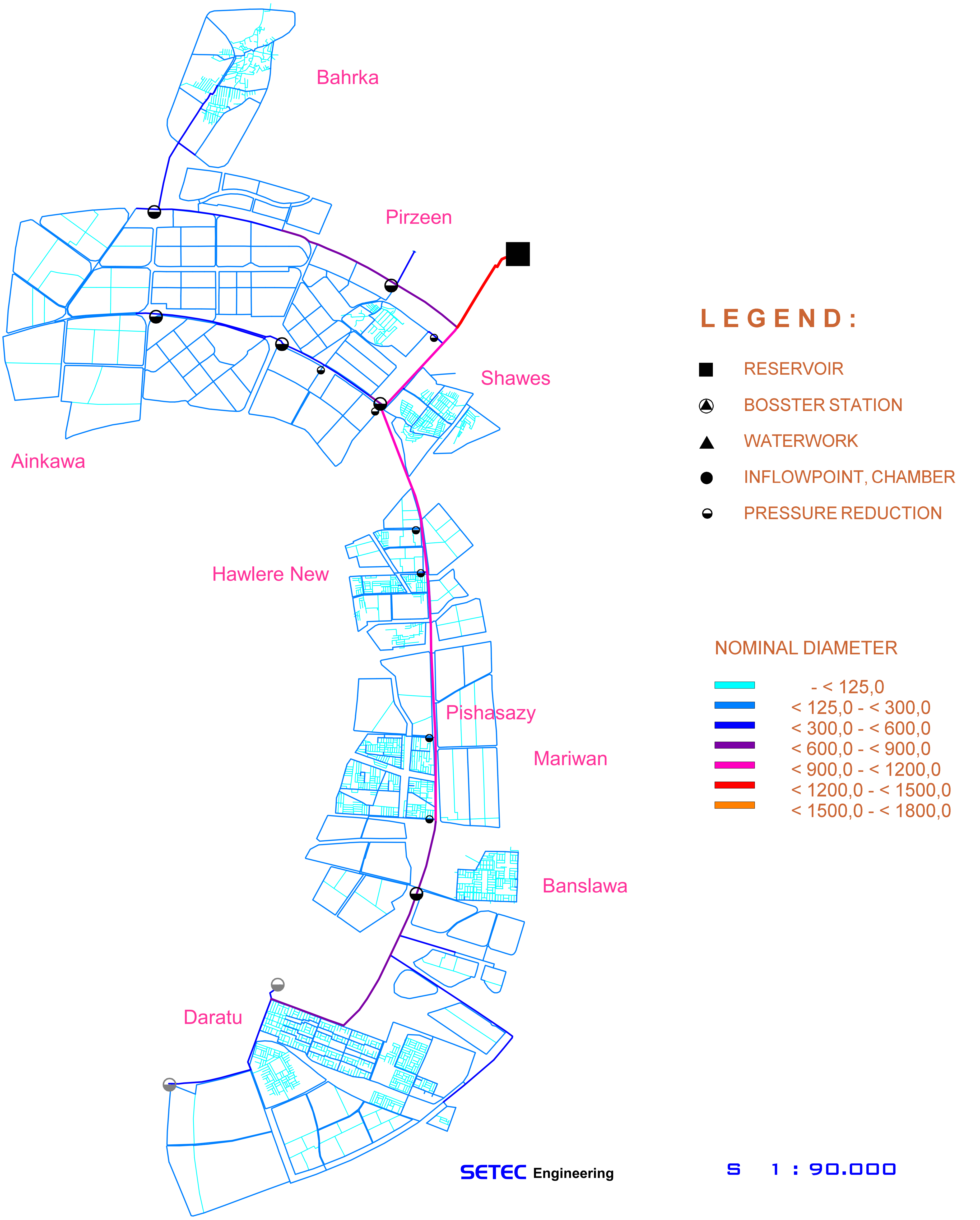
SA Pirzeen

Design 2032 Measures



SA Pirzeen

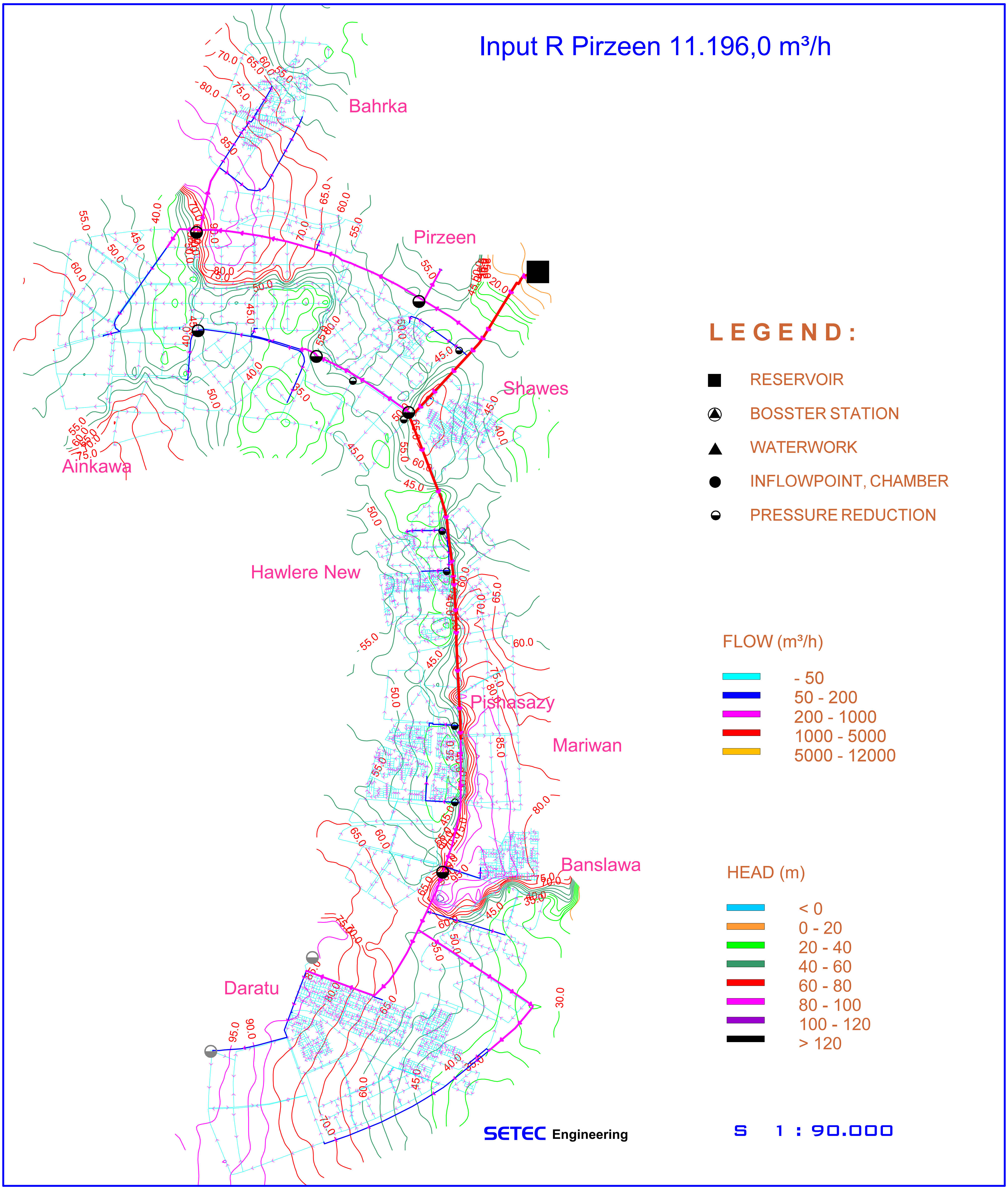
Design 2032 Dimensions



SA Pirzeen

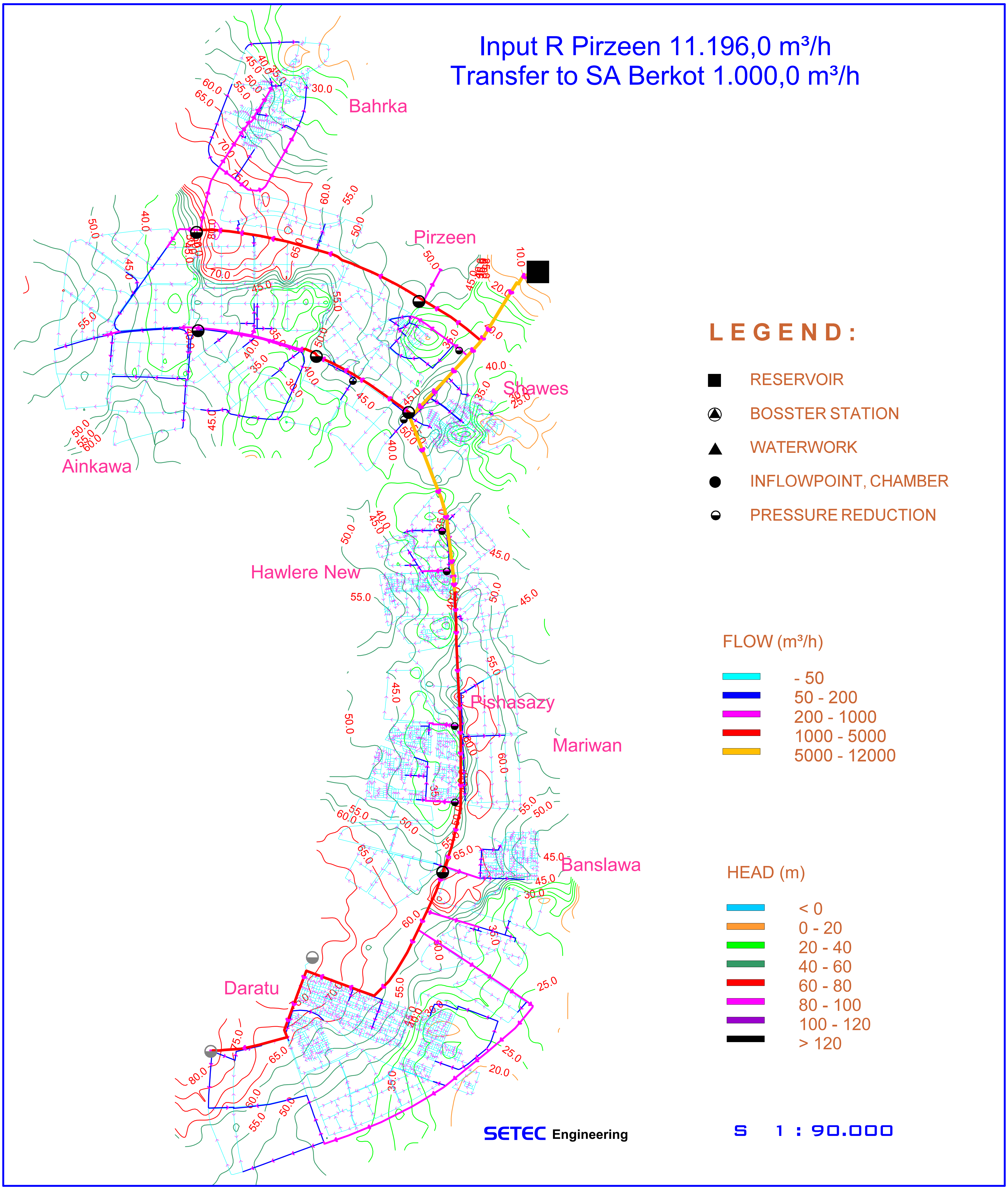
Design 2032 Minimum hourly Demand 3.336,9 m³/h

Input R Pirzeen 11.196,0 m³/h



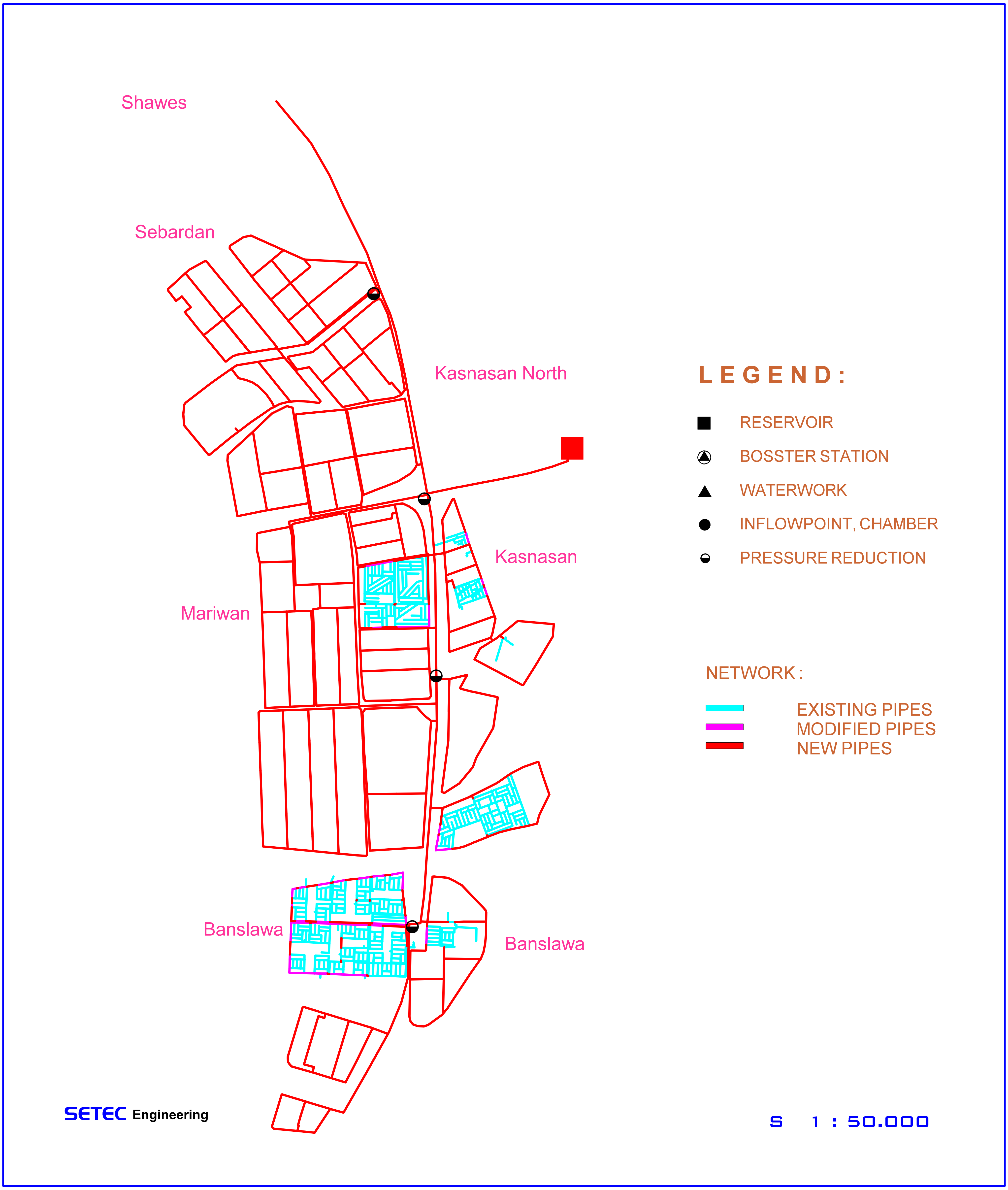
SA Pirzeen

Design 2032 Peak hourly Demand 10.196,0 m³/h



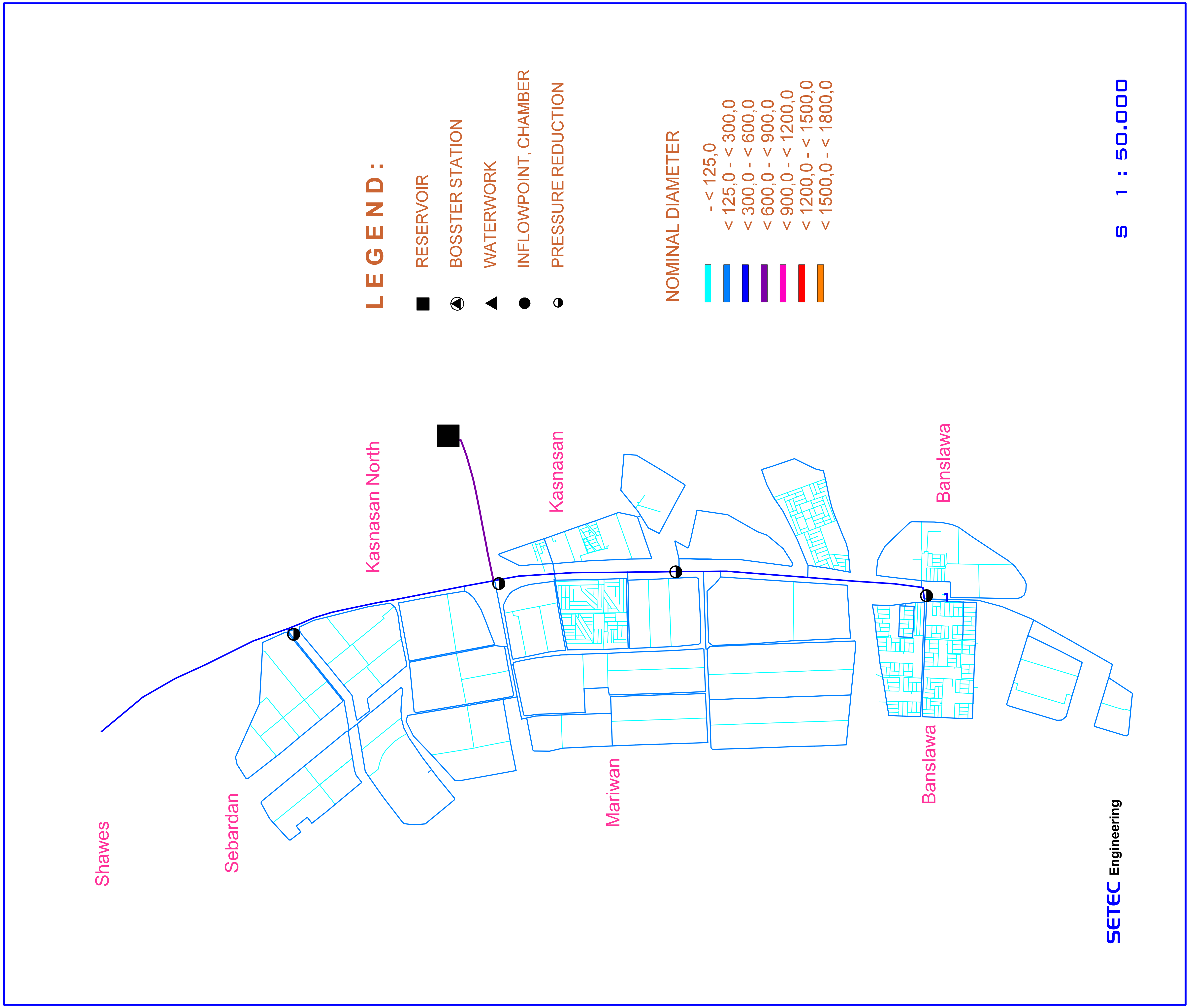
SA Kasnasan

Design 2032 Measures



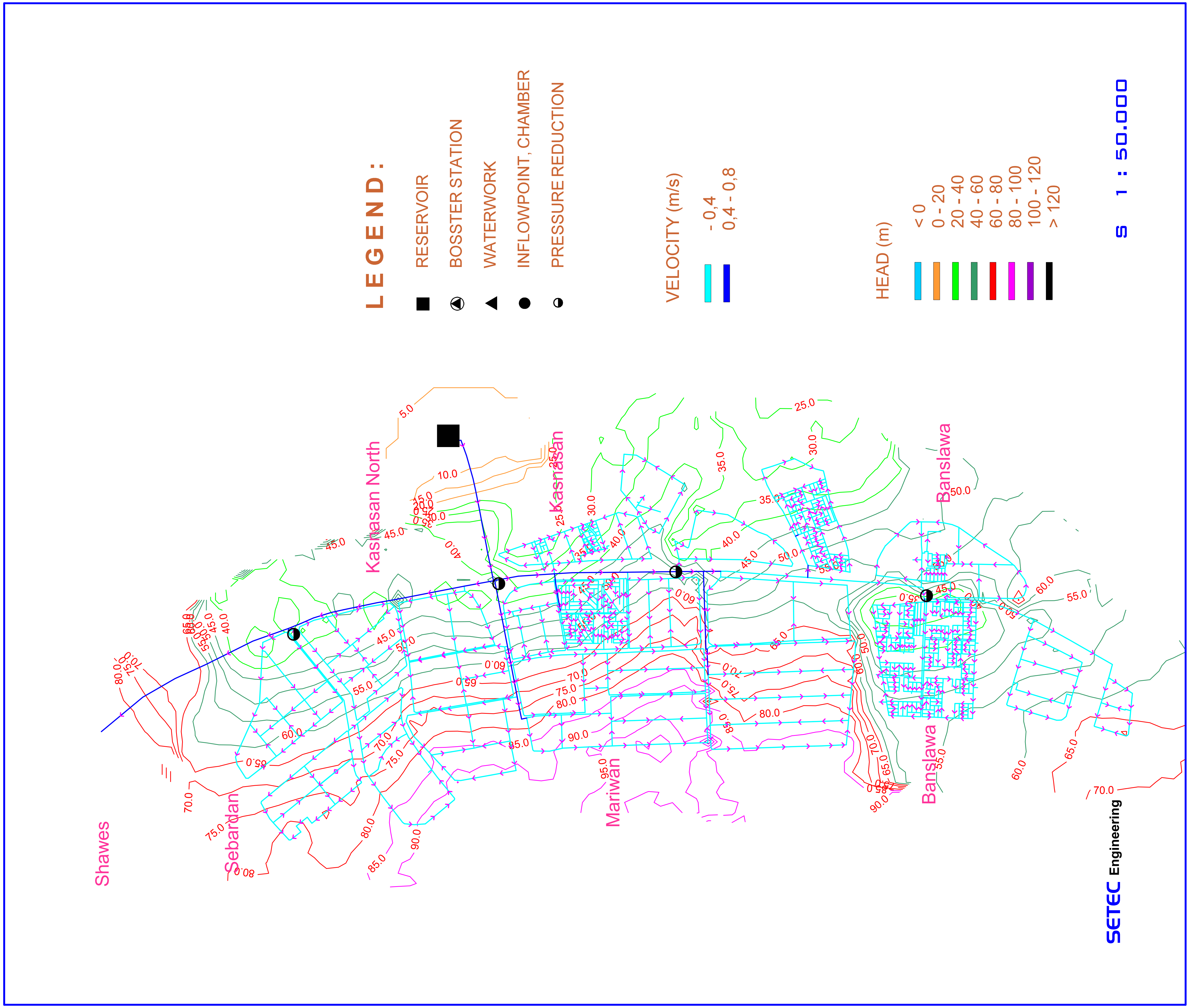
SA Kasnasan

Design 2032 Dimensions



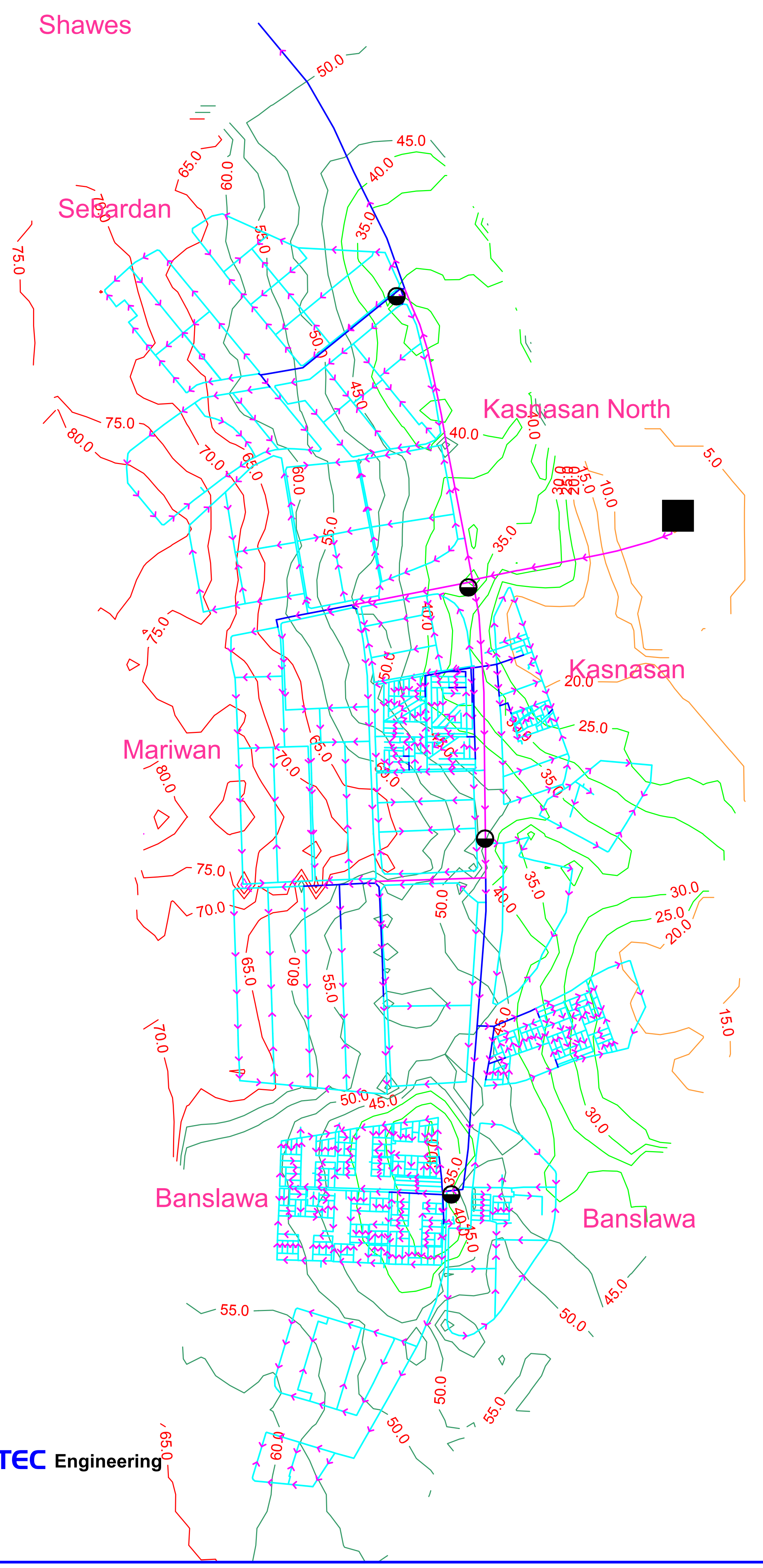
SA Kasnasan

Design 2032 Minimum hourly Demand 1.133,9 m³/h



SA Kasnasan

Design 2032 Peak hourly Demand 3.560,0 m³/h



LEGEND:

- RESERVOIR
- BOSSTER STATION
- WATERWORK
- INFLOWPOINT, CHAMBER
- PRESSURE REDUCTION

VELOCITY (m/s)

- - 0,8
- 0,8 - 1,7
- 1,7 - 2,5

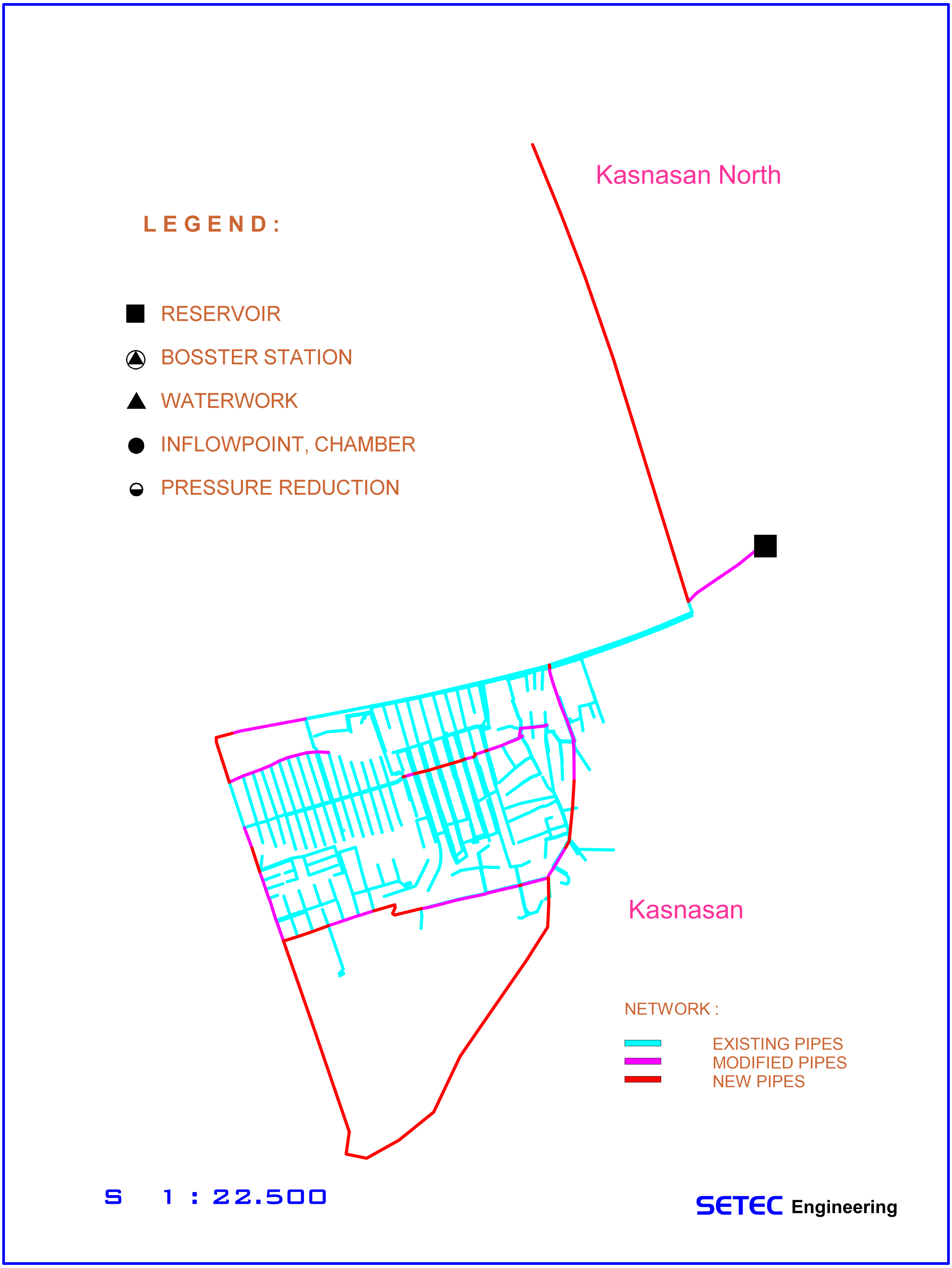
HEAD (m)

- < 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- > 120

S 1 : 50.000

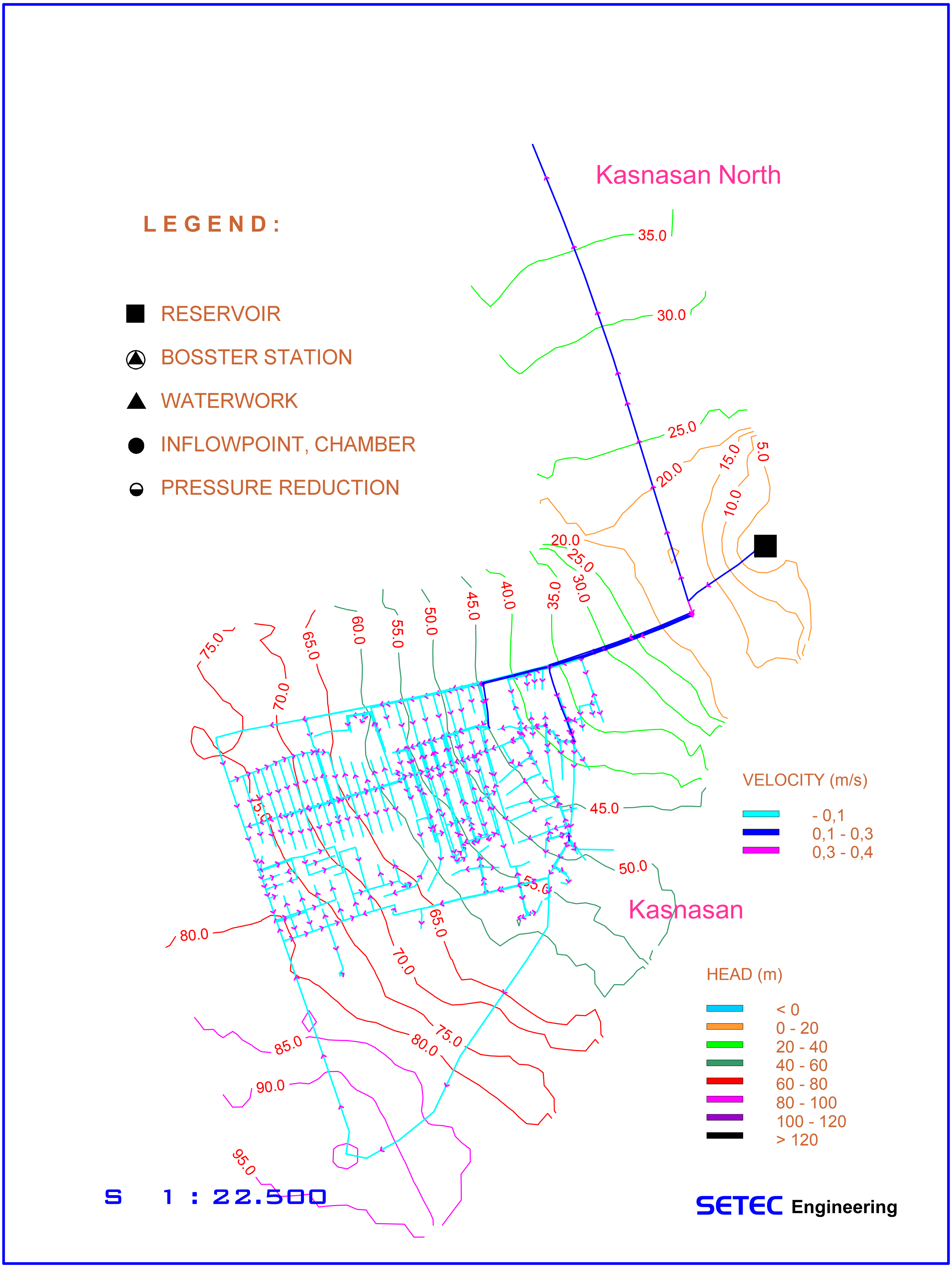
SA Kasnasan Town

Design 2032 Measures



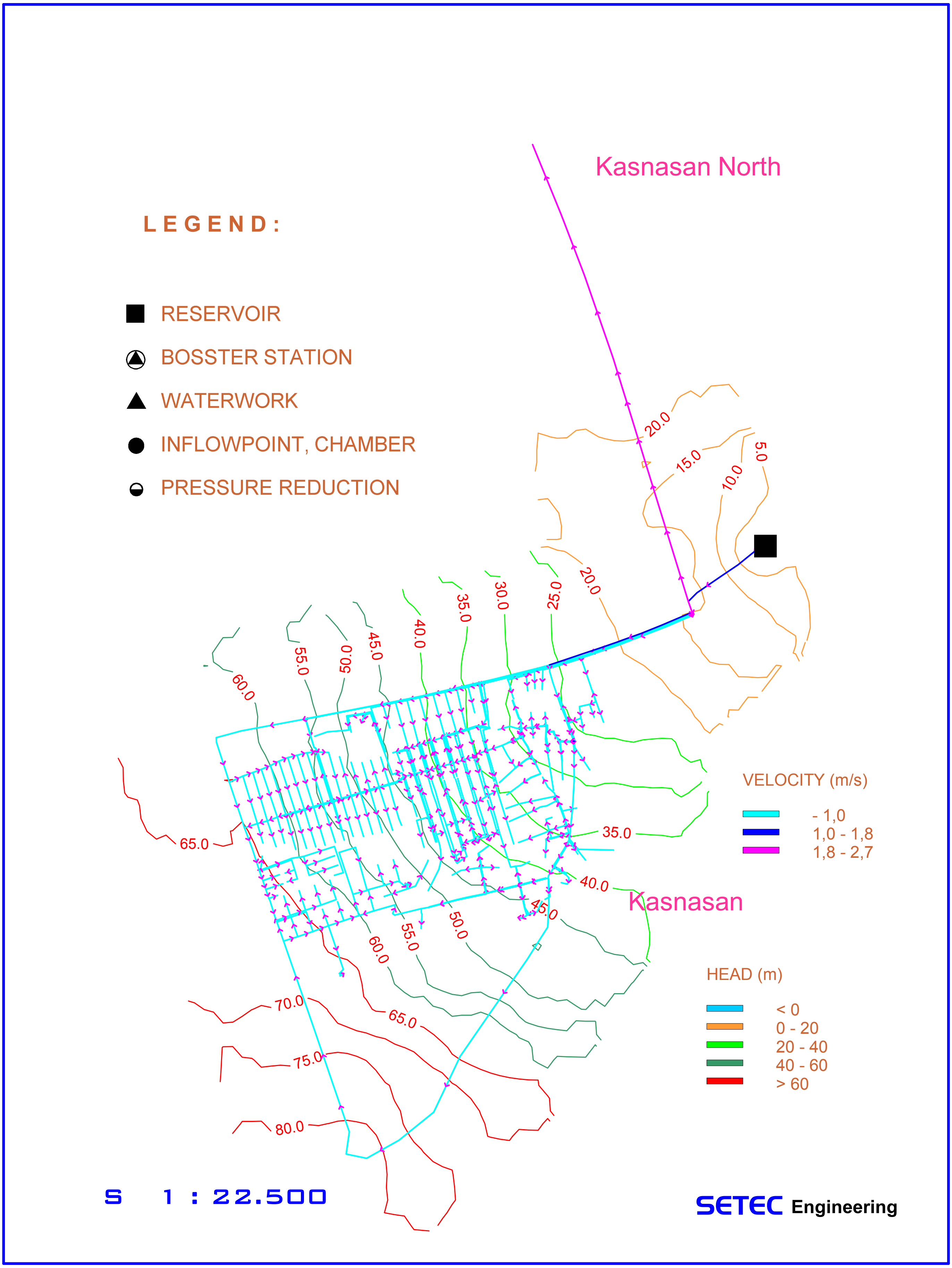
SA Kasnasan Town

Design 2032 Minimum hourly Demand 167,0 m³/h



SA Kasnasan Town

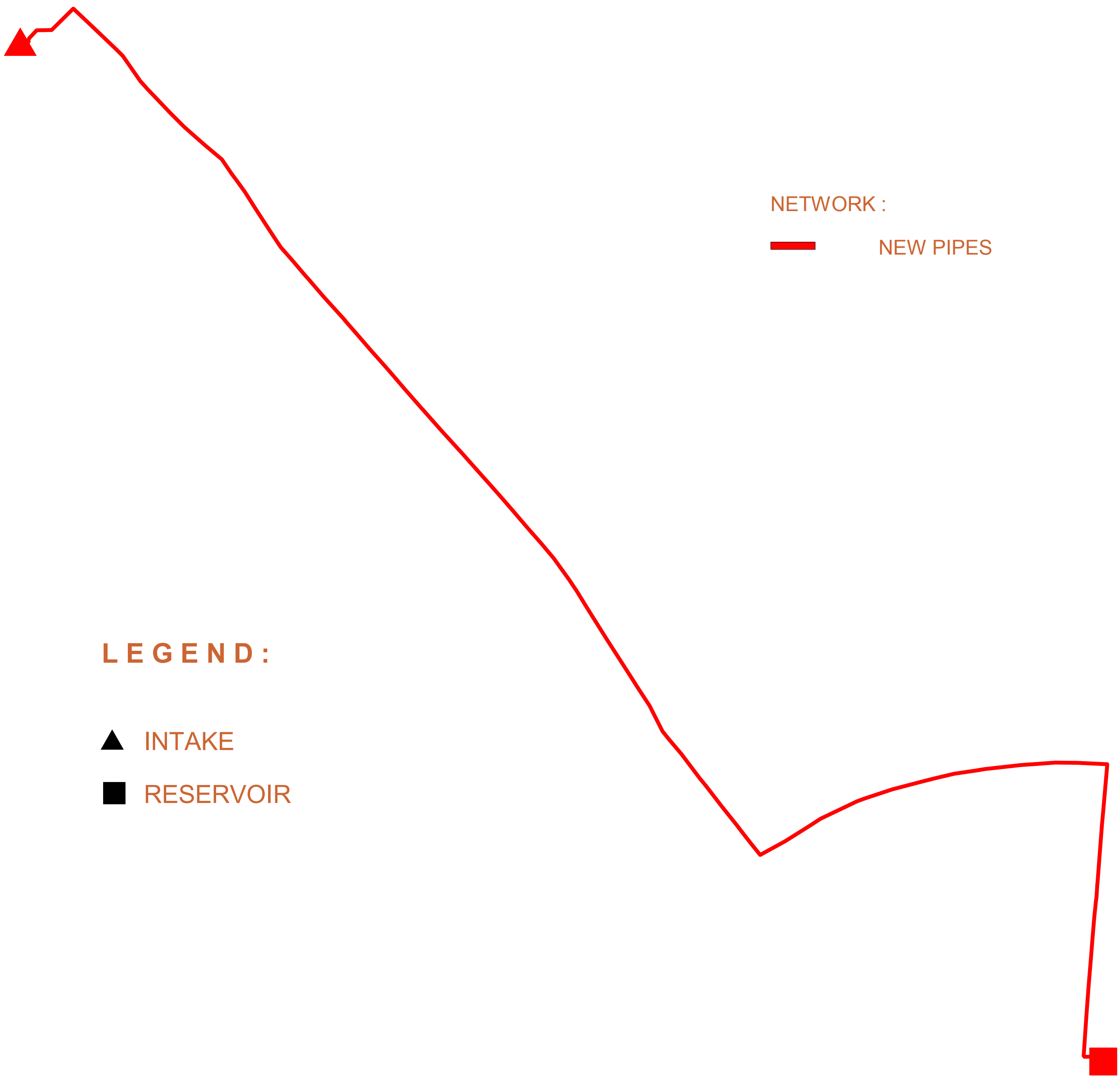
Design 2032 Peak hourly Demand 1.093,2 m³/h



TM Ifraz IV

Design 2032 Measures

Capacity TM Ifraz IV 20.000 m³/h DN 1.800
Power Requirement 16.000 kW
inclusive total Efficiency of 70 %



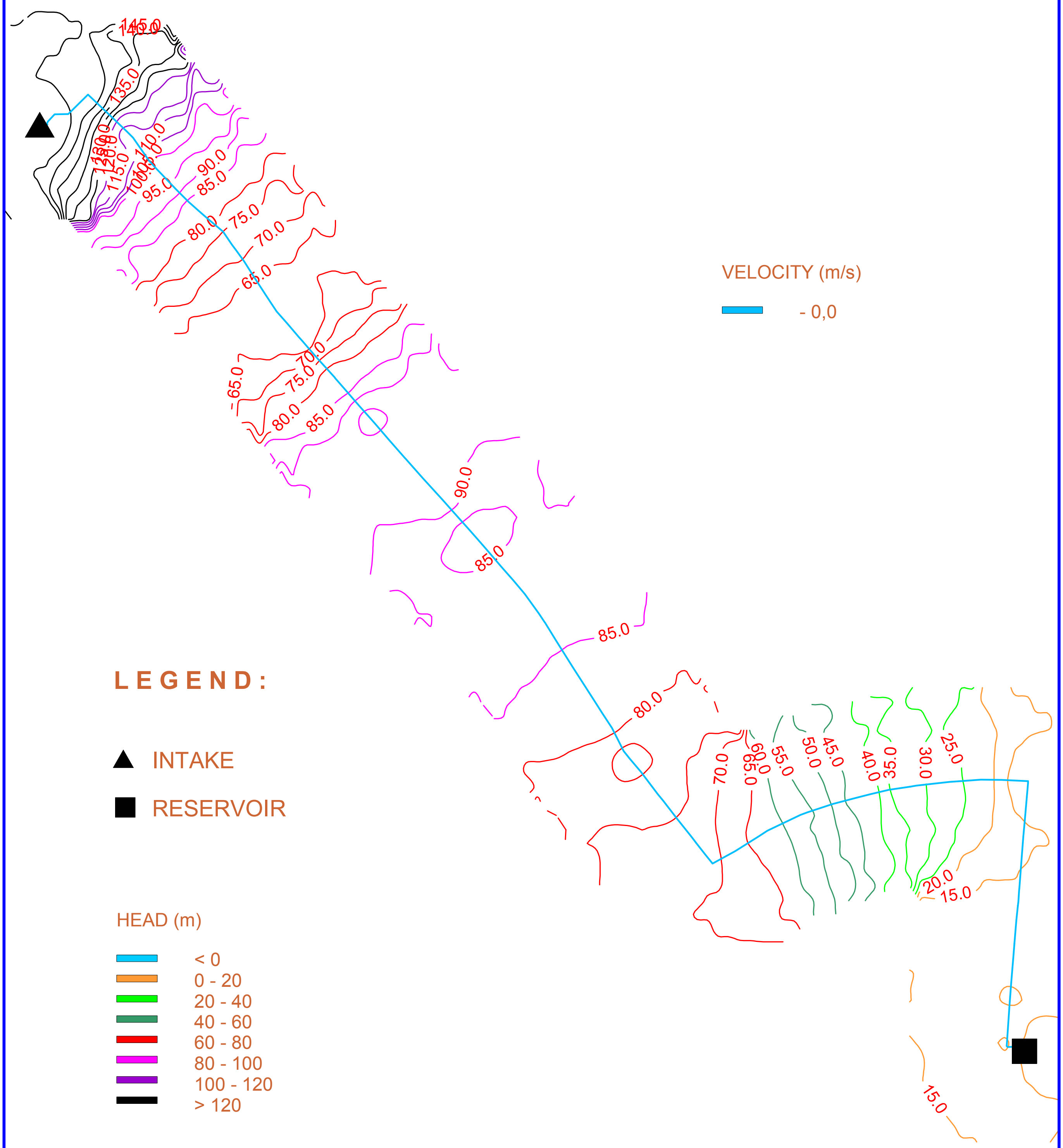
S 1 : 110.000

SETEC Engineering

TM Ifraz IV

Design 2032 Flow 0,0 m³/h

Pressure after Pumps 15,3 bar



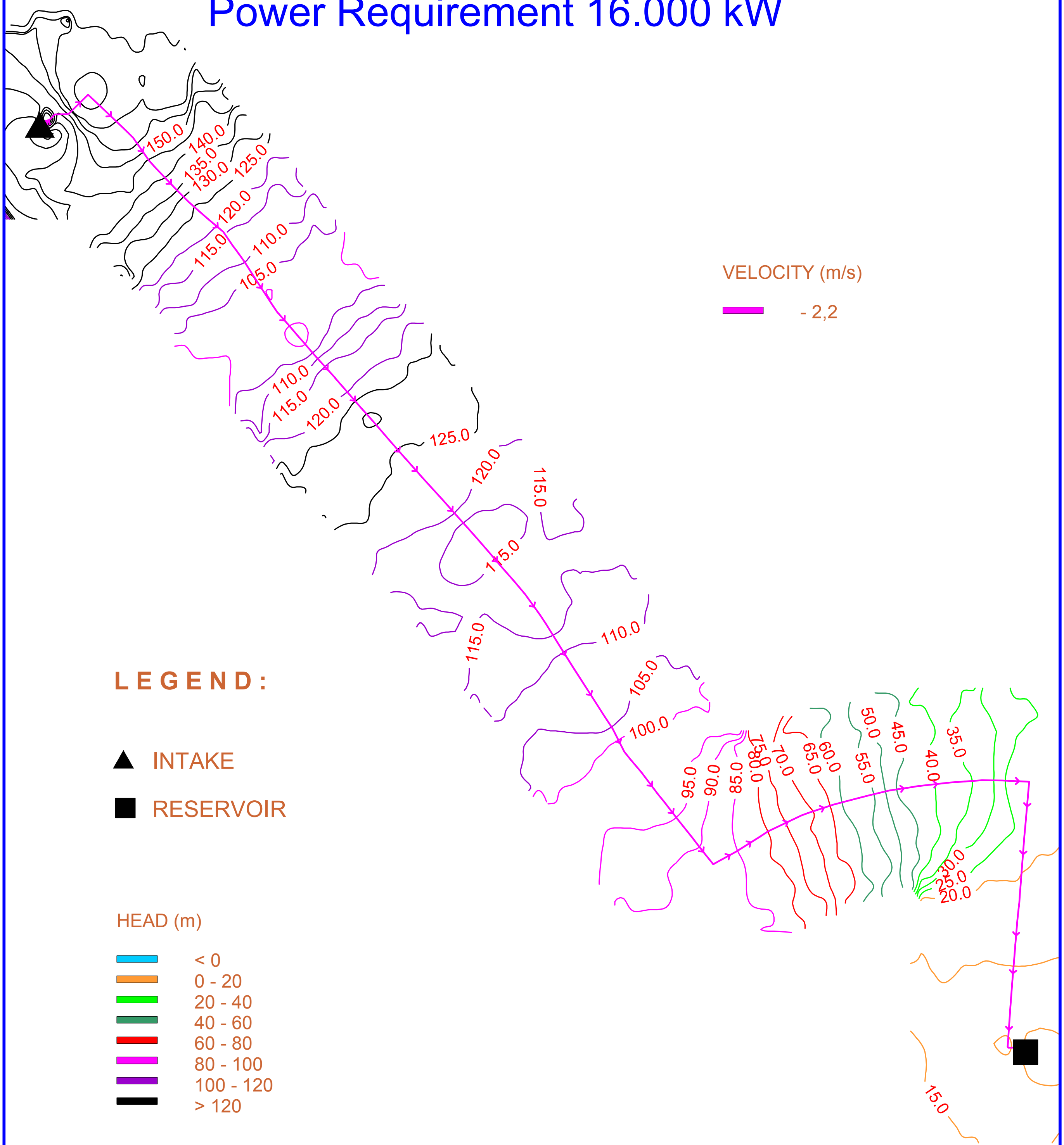
S 1 : 110.000

SETEC Engineering

TM Ifraz IV

Design 2032 Flow 20.000 m³/h

Pressure after Pumps 20,1 bar
DN 1.800
Power Requirement 16.000 kW



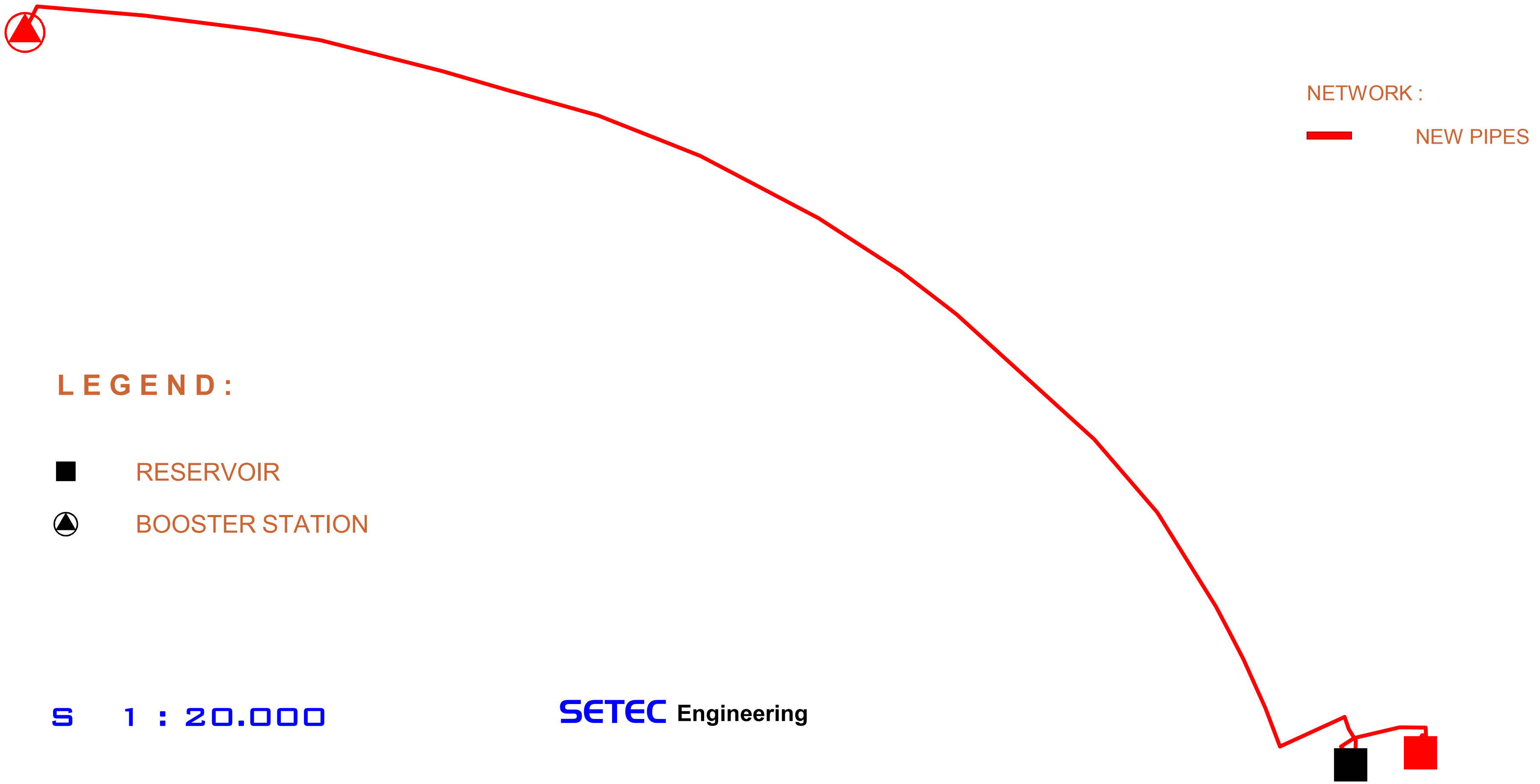
S 1 : 110.000

SETEC Engineering

TM Perkot-Dawajin

Design 2032 Measures

Capacity 14.000 m³/h DN 1.500
Power Requirement 3.200 kW
inclusive total Efficiency of 70 %

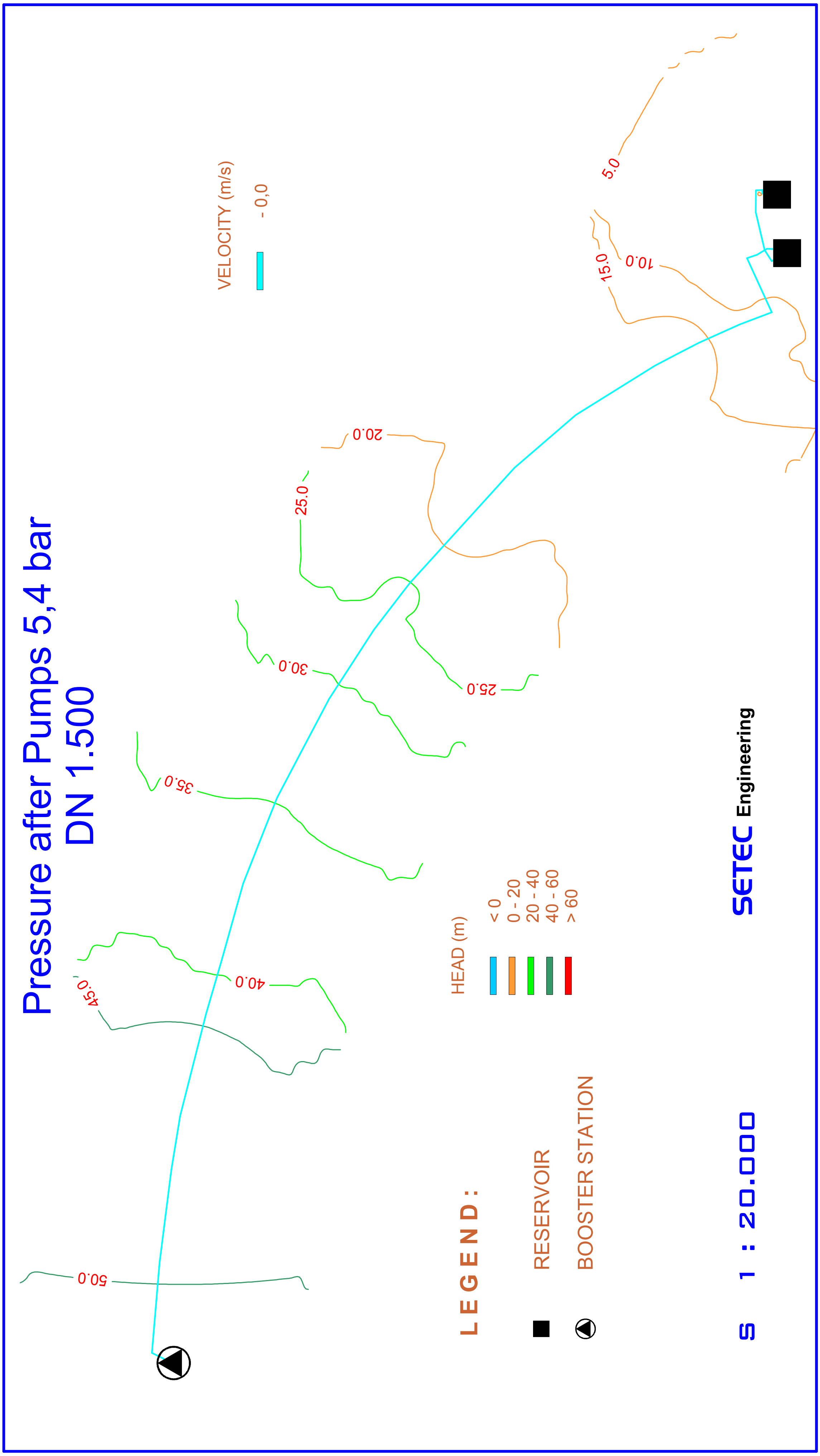


S 1 : 20.000

SETEC Engineering

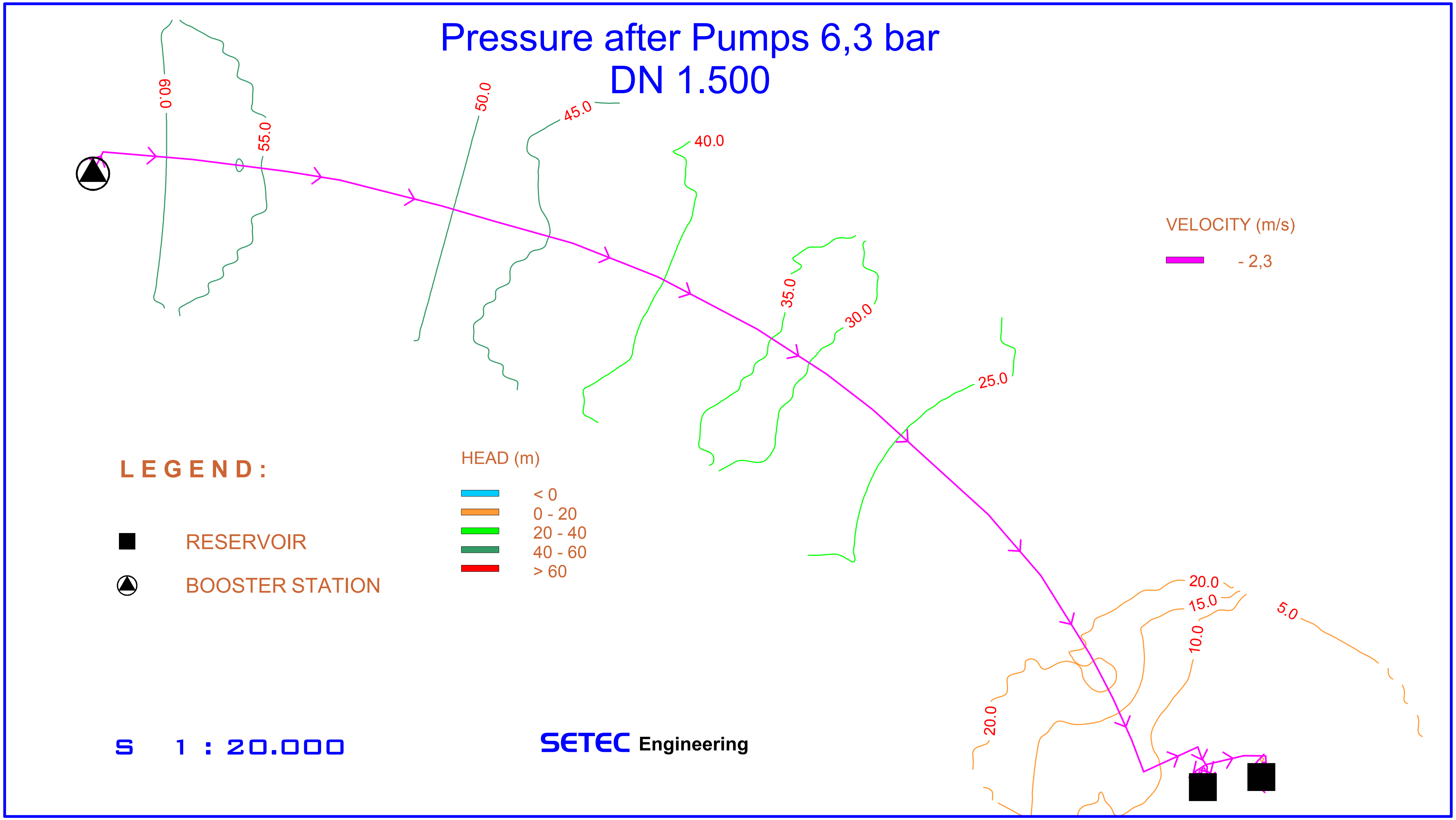
TM Perkot-Dawajin

Design 2032 Flow 0,0 m³/h



TM Perkot-Dawajin

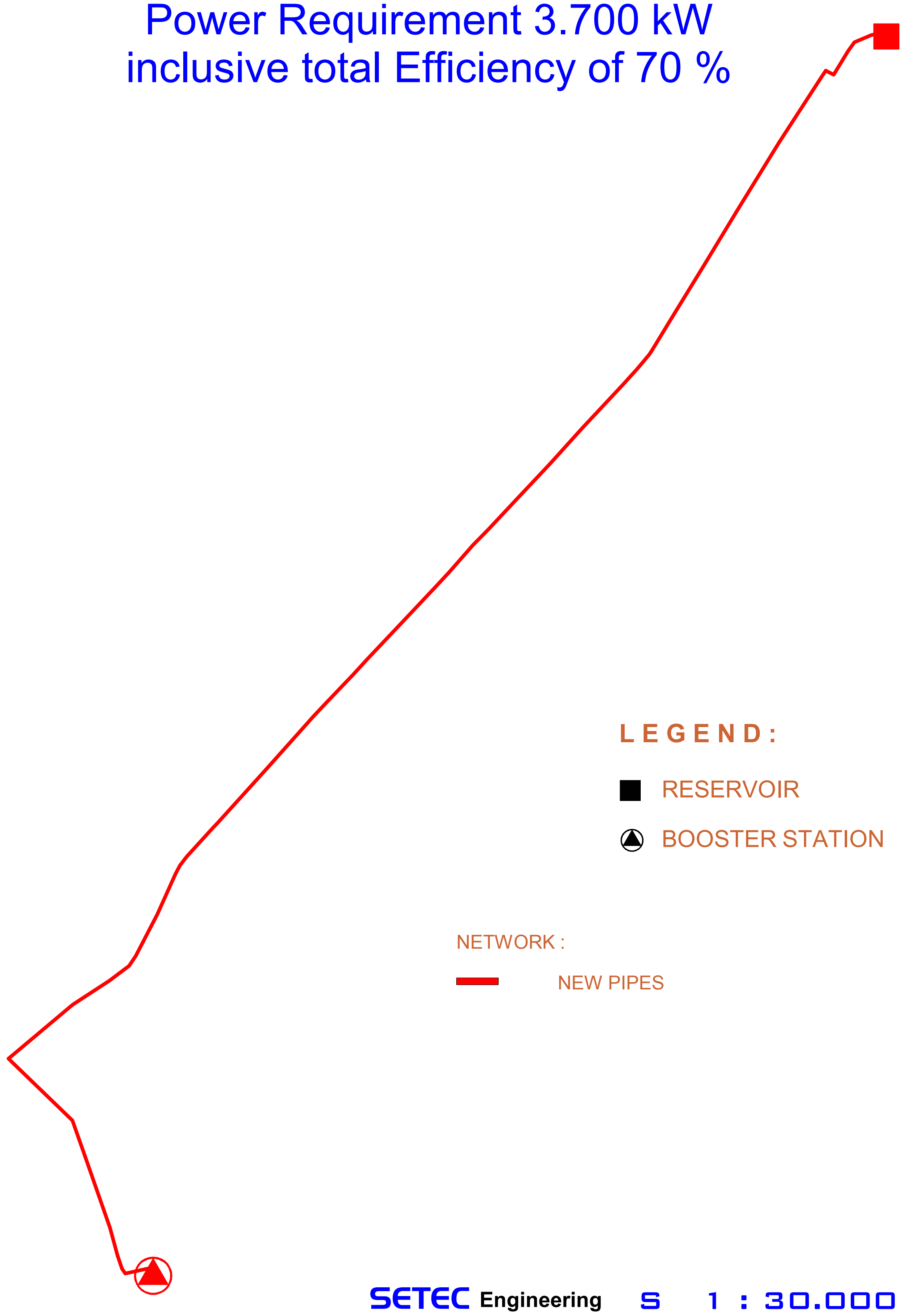
Design 2032 Flow 14.000 m³/h



TM Dawajin-Pirzeen

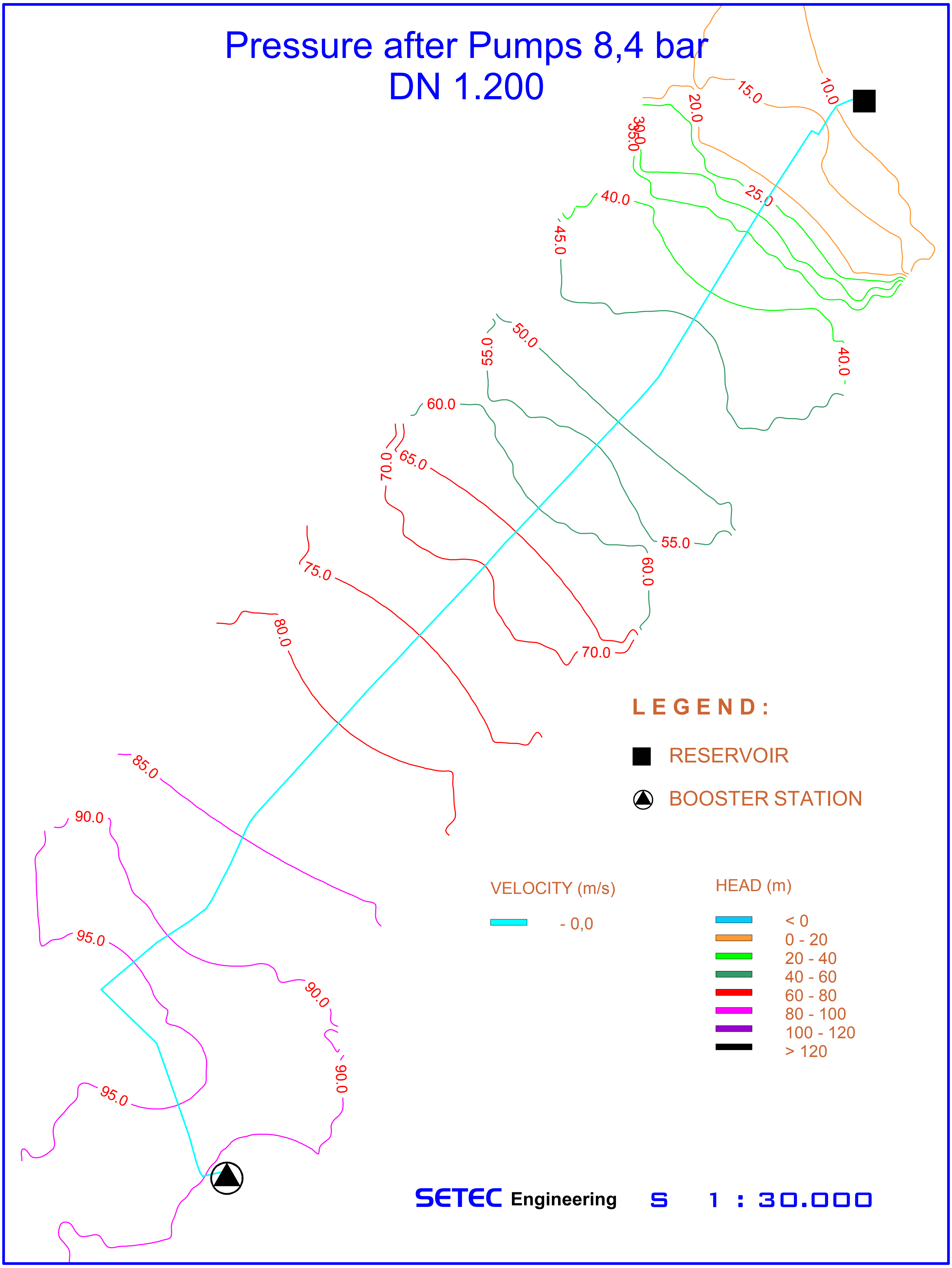
Design 2032 Measures

Capacity 9.000 m³/h DN 1.200
Power Requirement 3.700 kW
inclusive total Efficiency of 70 %



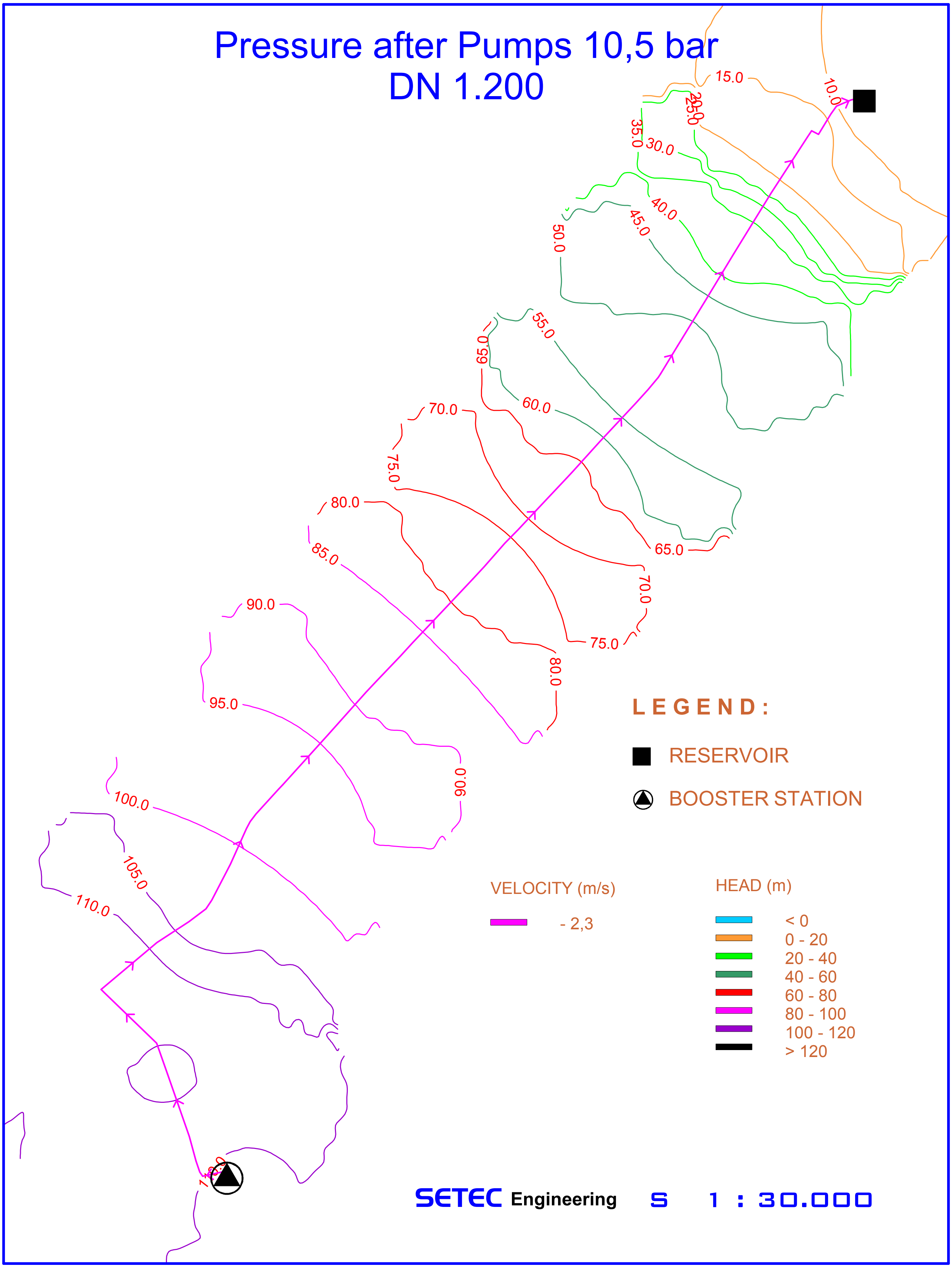
TM Dawajin-Pirzeen

Design 2032 Flow 0,0 m³/h



TM Dawajin-Pirzeen

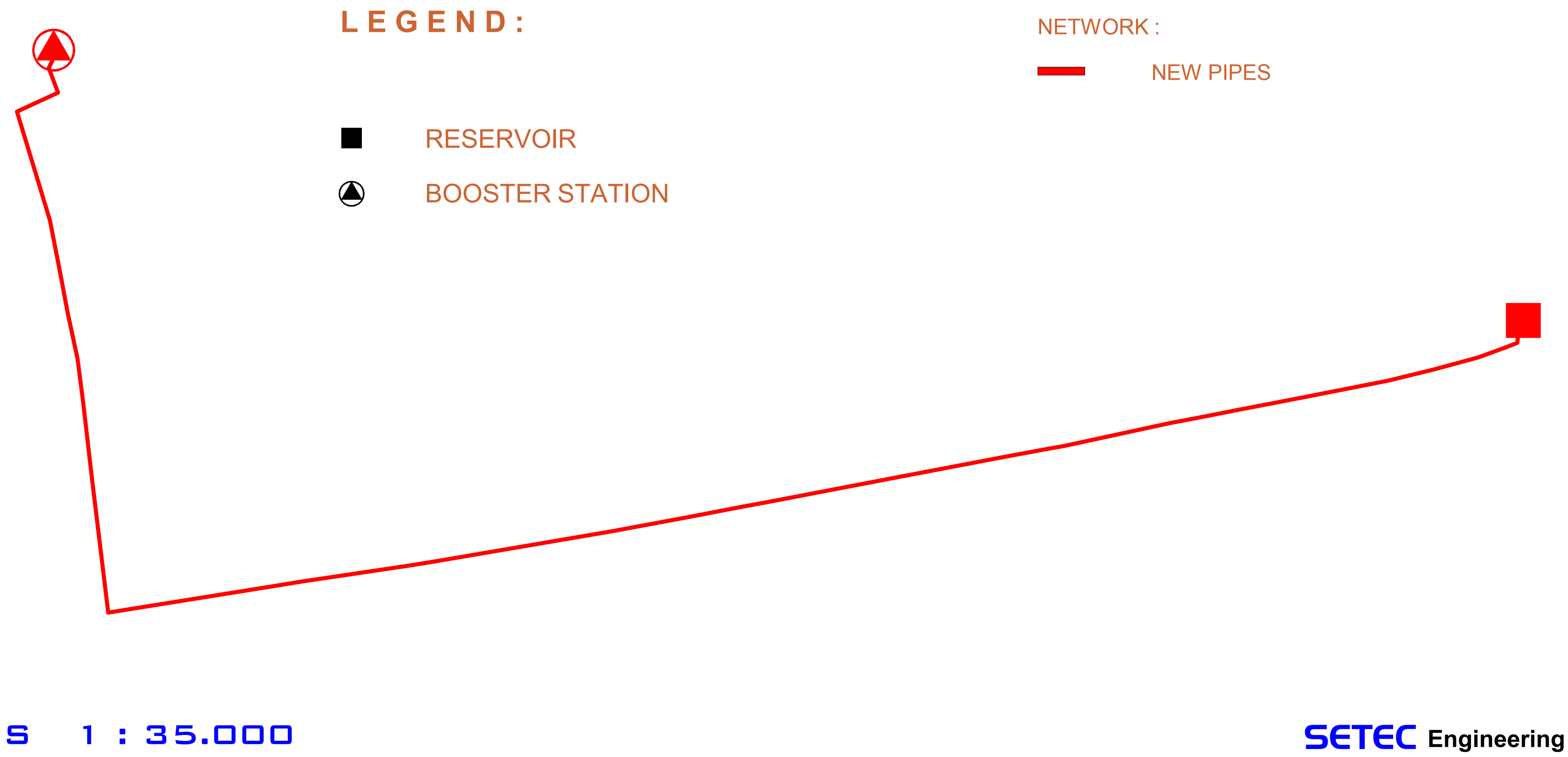
Design 2032 Flow 9.000 m³/h



TM Dawajin-Kasnasan

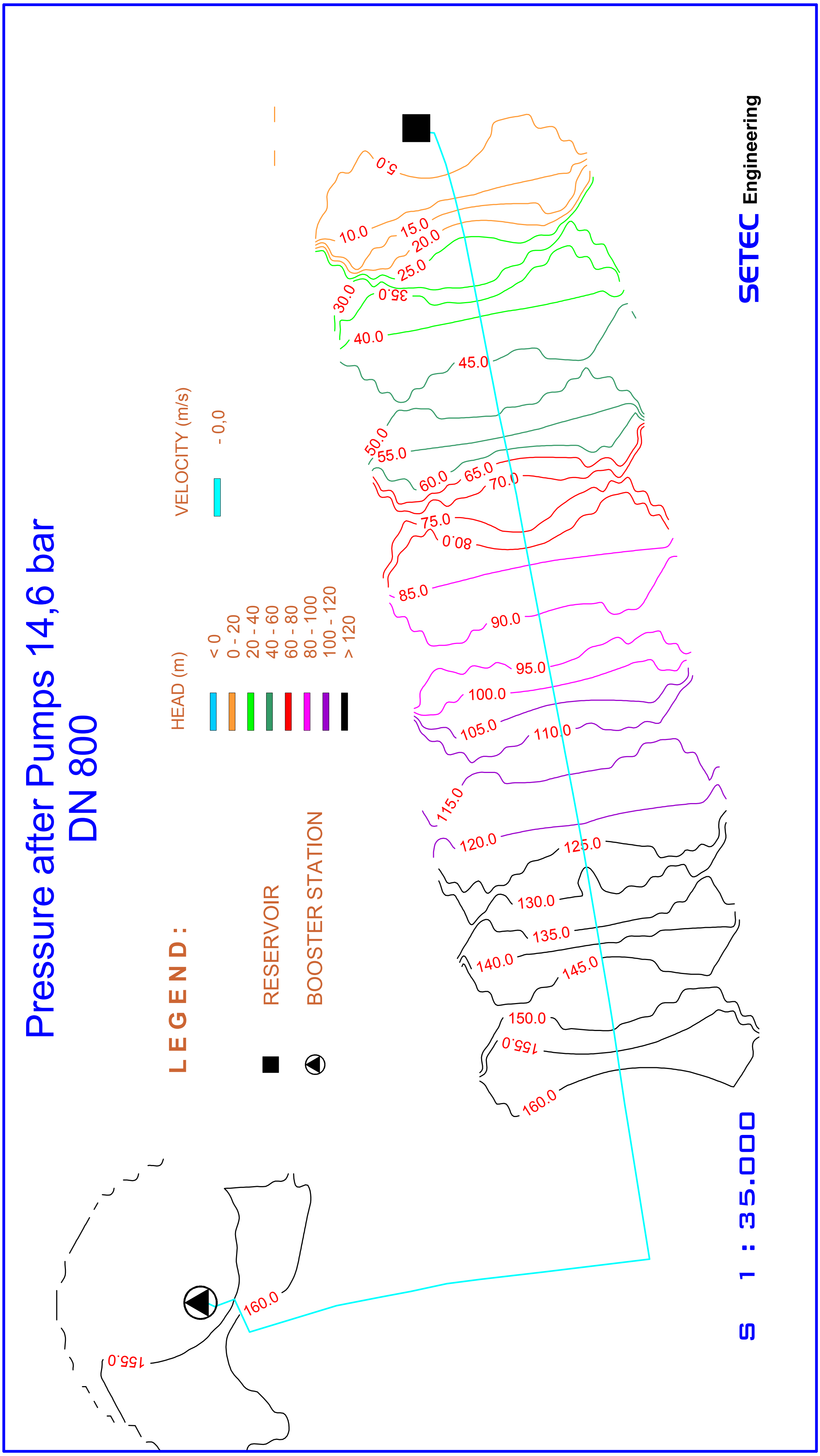
Design 2032 Measures

Capacity 3.500 m^3/h DN 800
Power Requirement 2.500 kW
inclusive total Efficiency of 70 %



TM Dawajin-Kasnasan

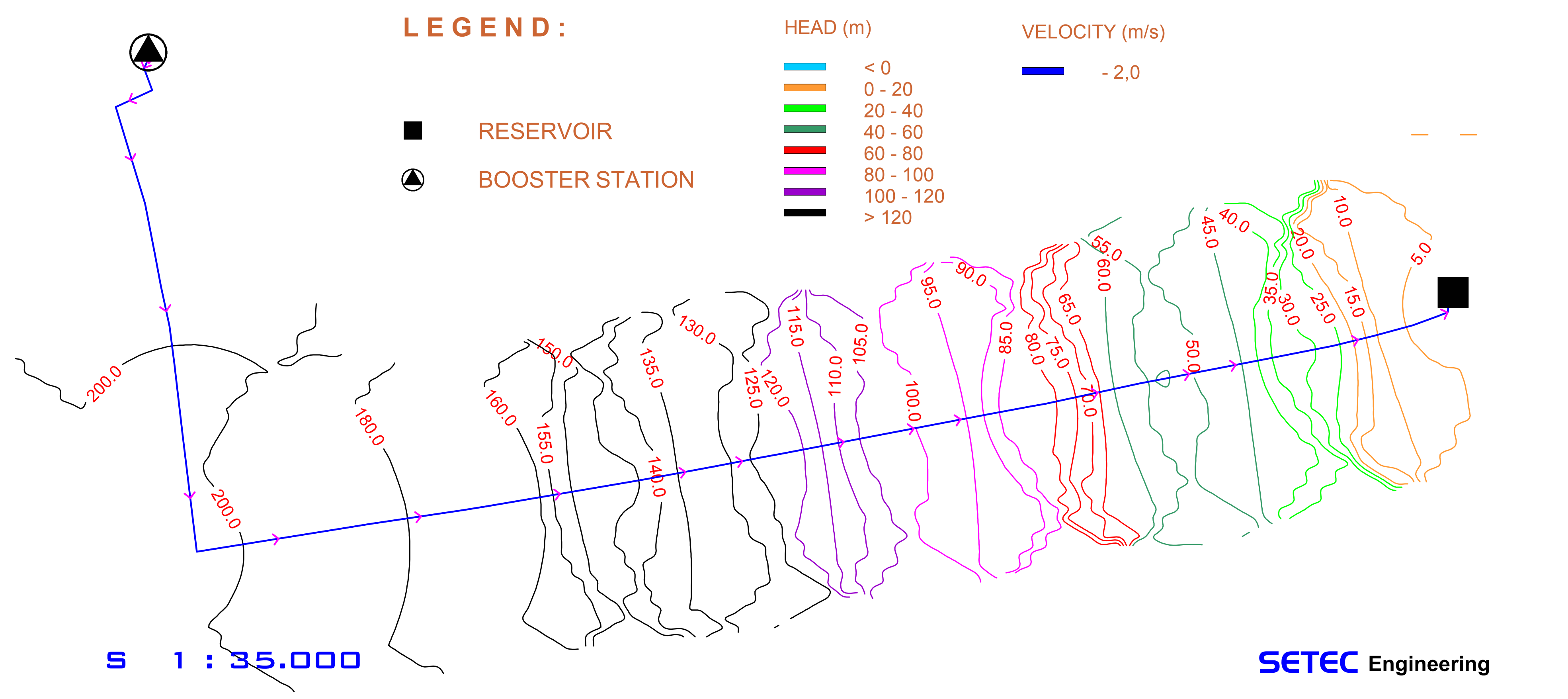
Design 2032 Flow 0,0 m³/h



TM Dawajin-Kasnasan

Design 2032 Flow 3.500 m³/h

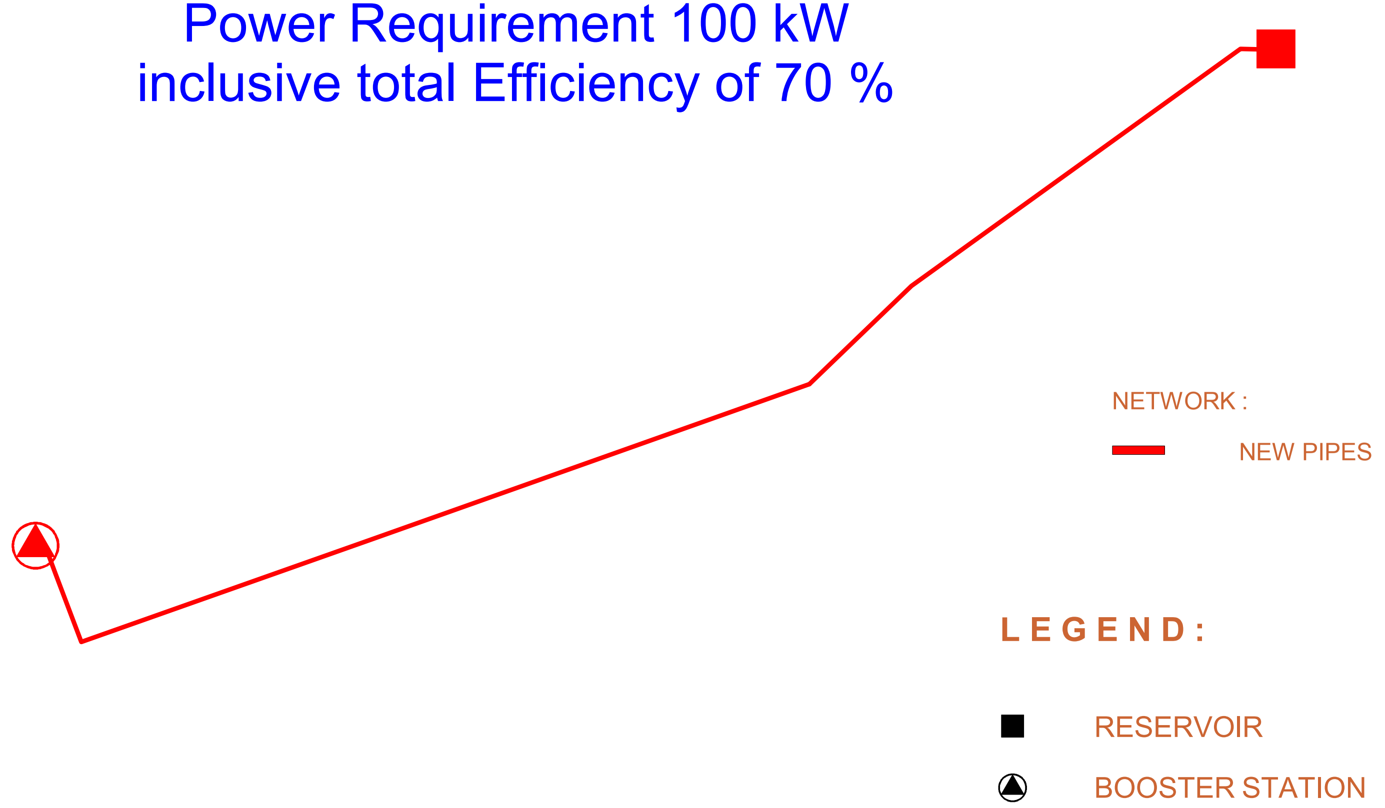
Pressure after Pumps 17,9 bar
DN 800



TM Kasnasan - Kasnasan

Design 2032 Measures

Capacity 650 m^3/h DN 400
Power Requirement 100 kW
inclusive total Efficiency of 70 %



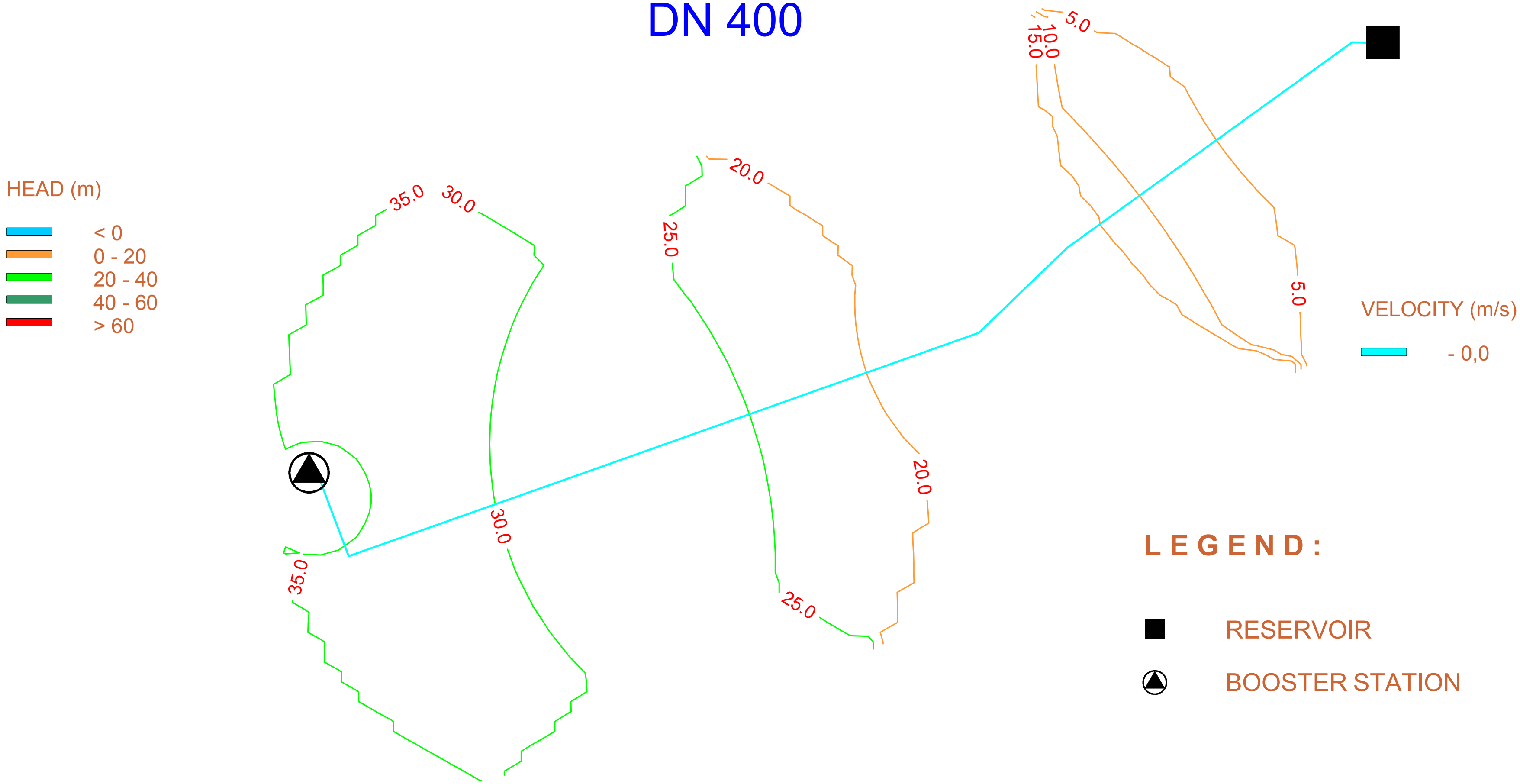
S 1 : 5.000

SETEC Engineering

TM Kasnasan - Kasnasan

Design 2032 Flow 0,0 m³/h

Pressure after Pumps 3,5 bar
DN 400



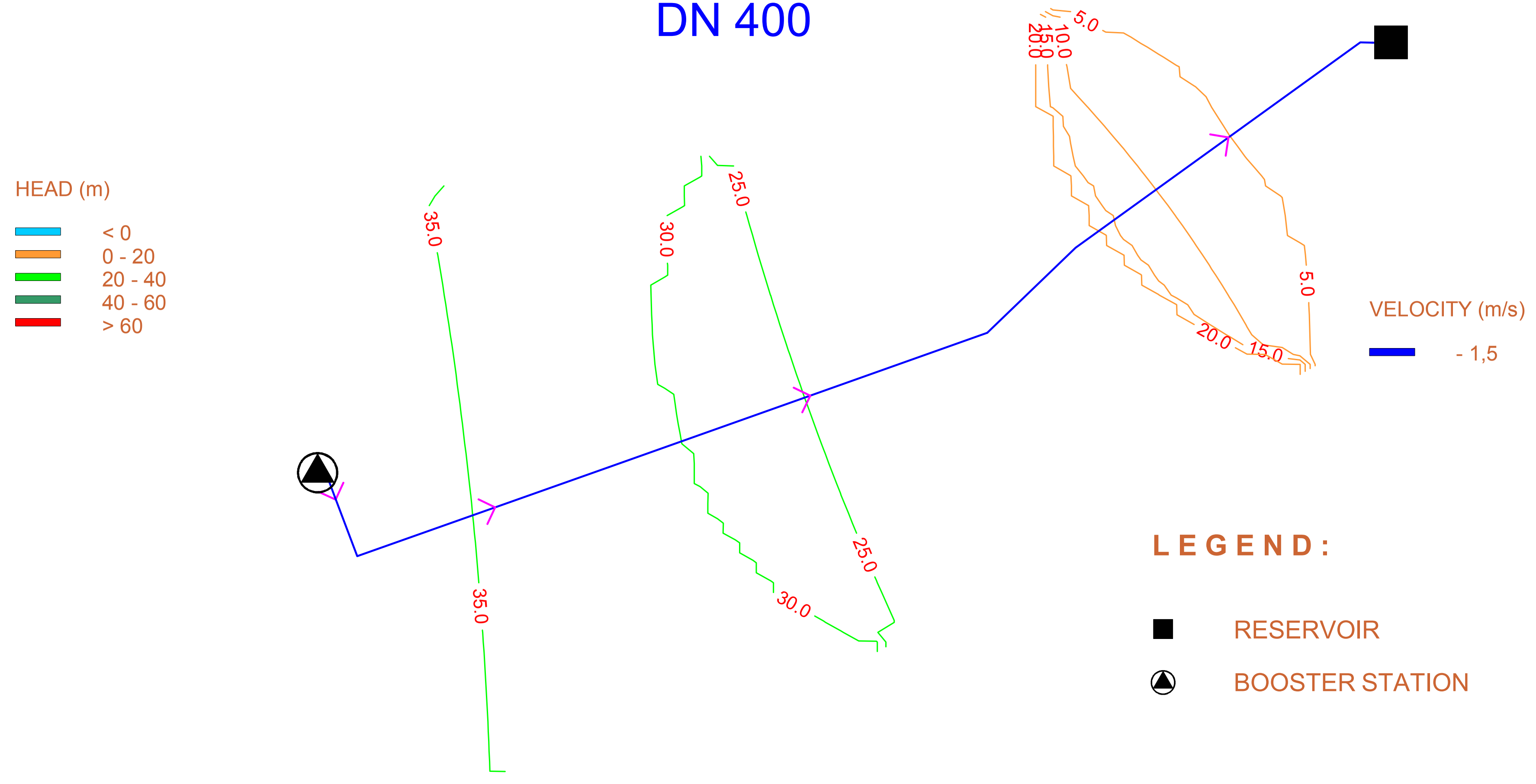
S 1 : 5.000

SETEC Engineering

TM Kasnasan - Kasnasan

Design 2032 Flow 650 m³/h

Pressure after Pumps 3,9 bar
DN 400

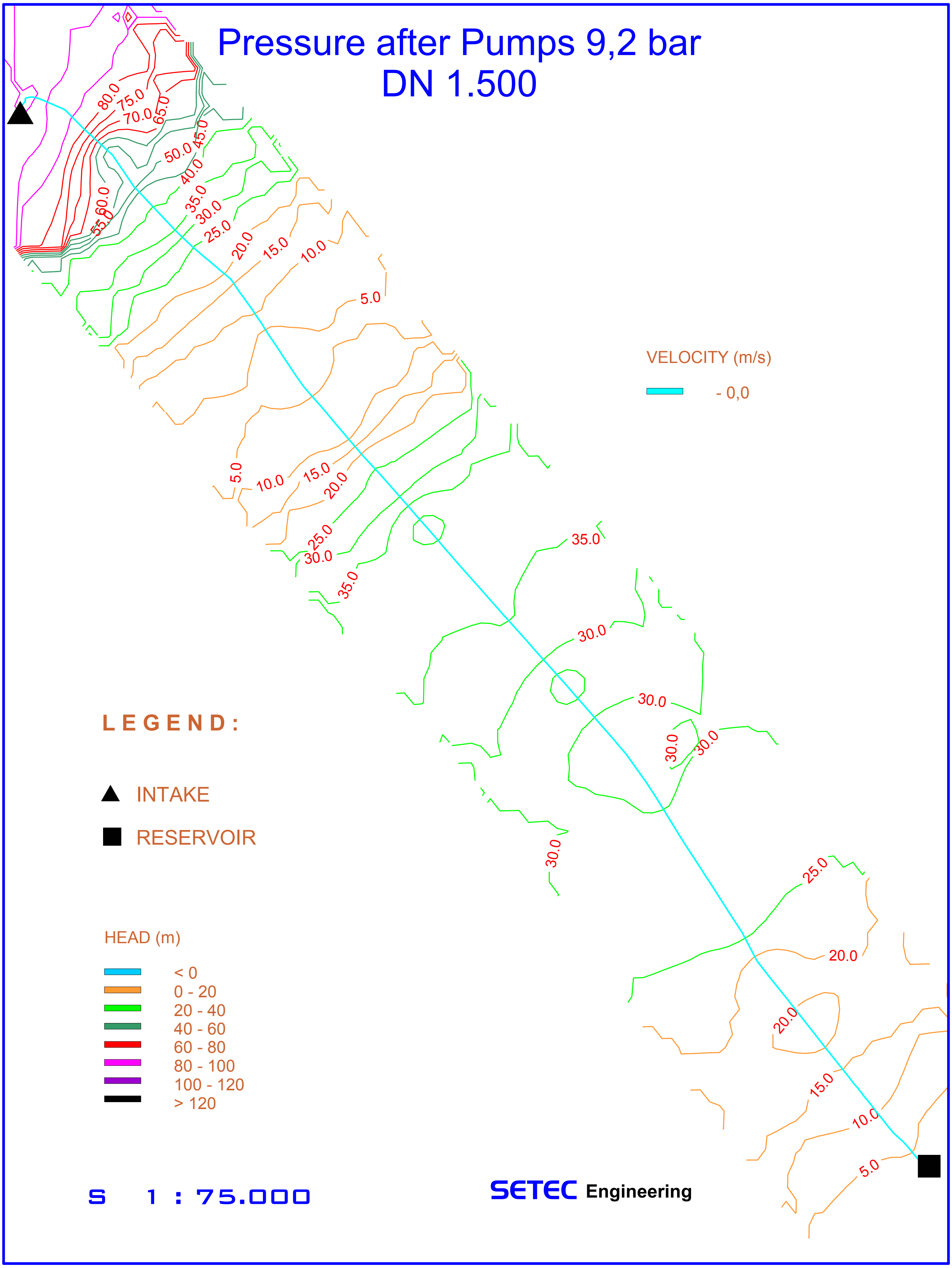


S 1 : 5.000

SETEC Engineering

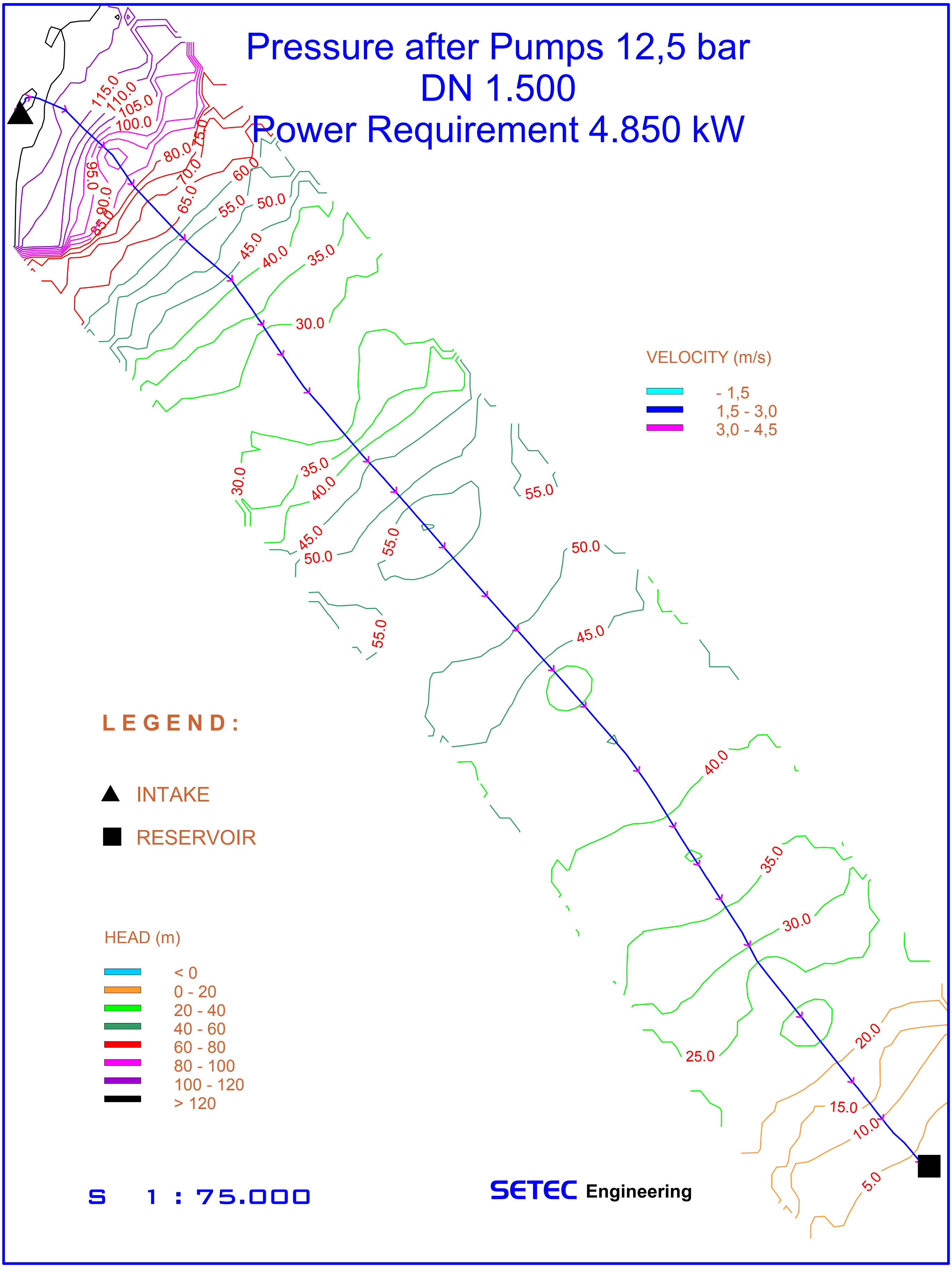
TM Ifraz III Part I

Design 2032 0P Flow 0,0 m³/h



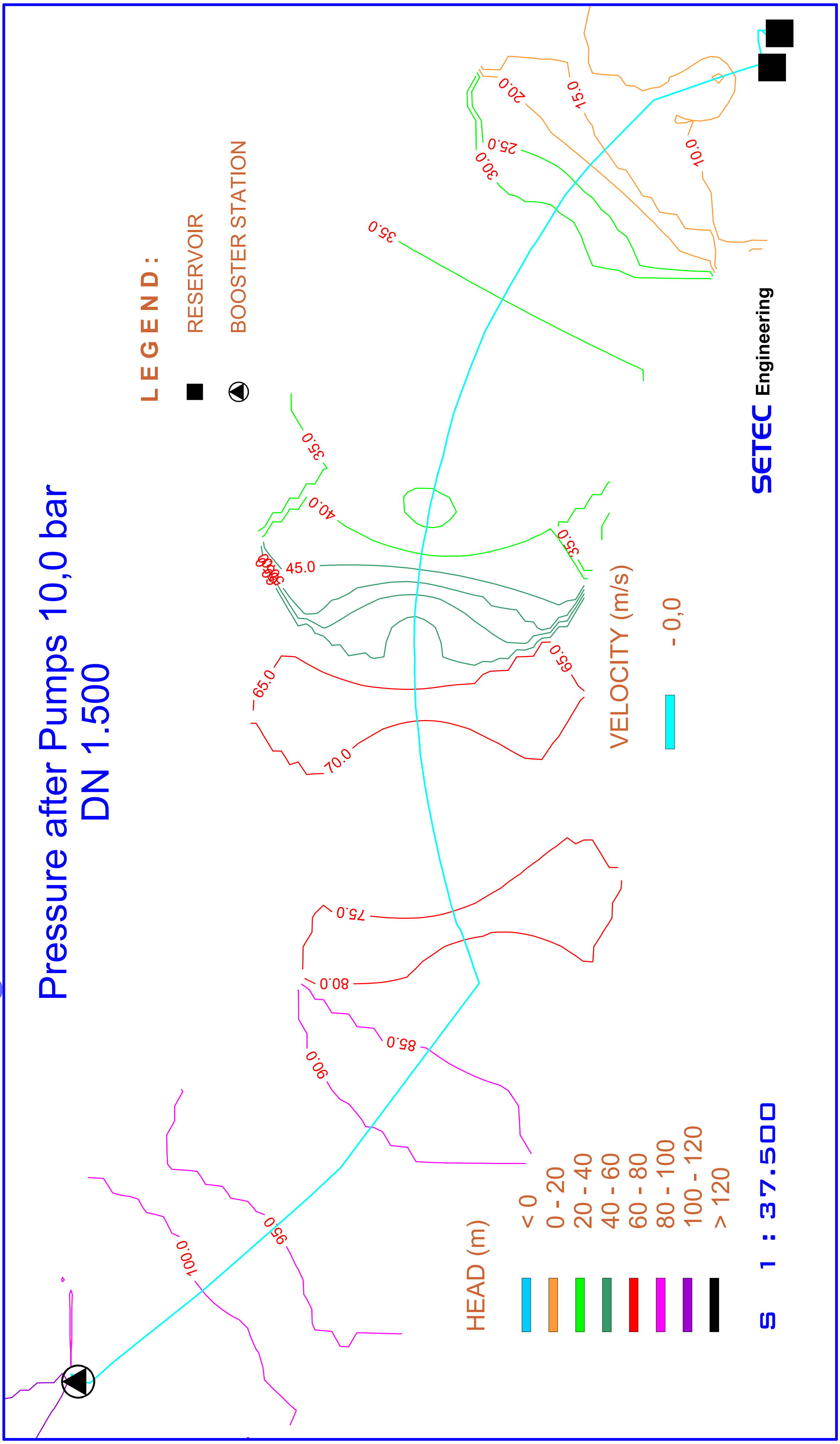
TM Ifraz III Part I

Design 2032 6P Flow 10.200 m³/h



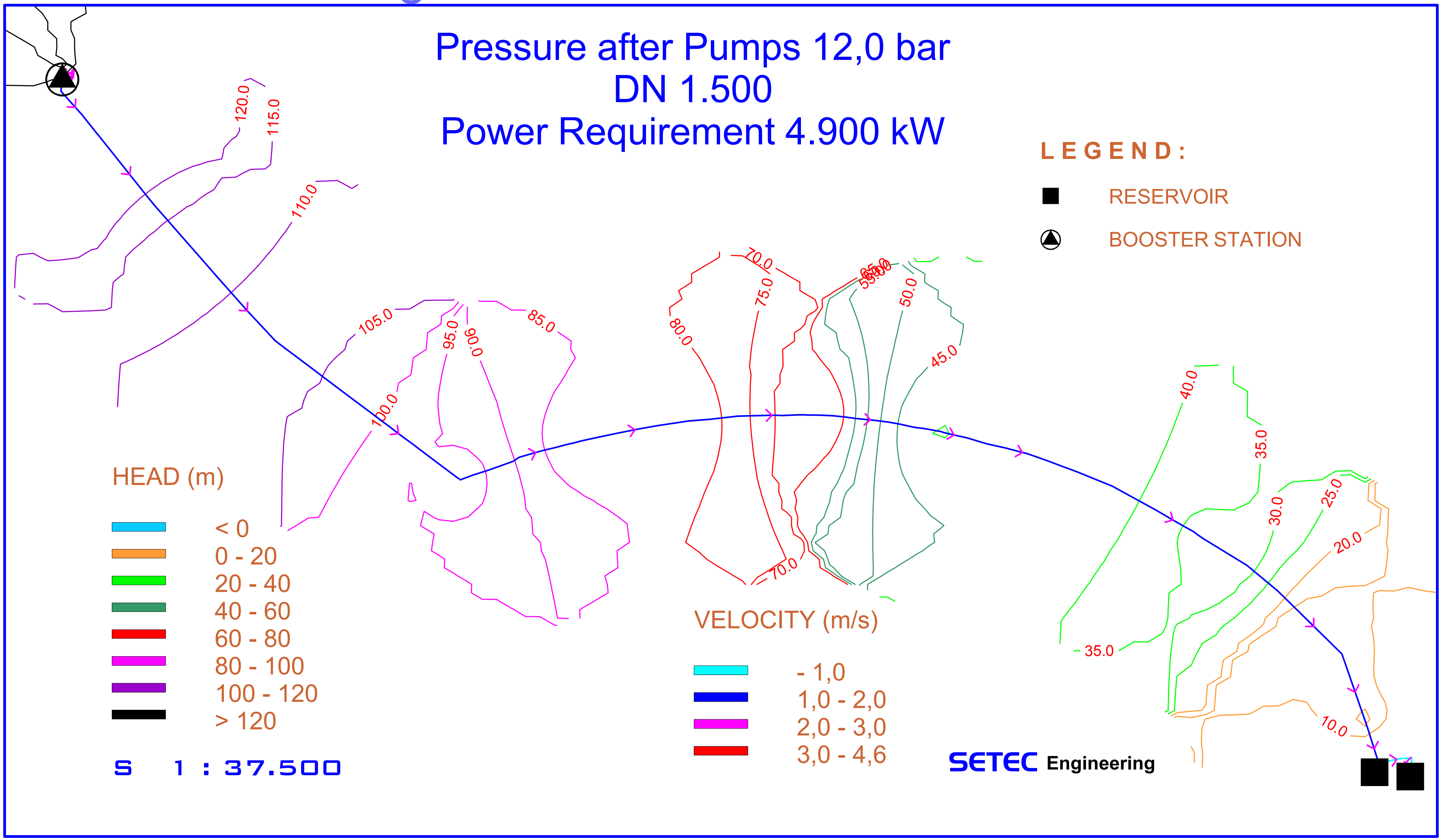
TM Ifraz III Part II

Design 2032 0P Flow 0,0 m^3/h



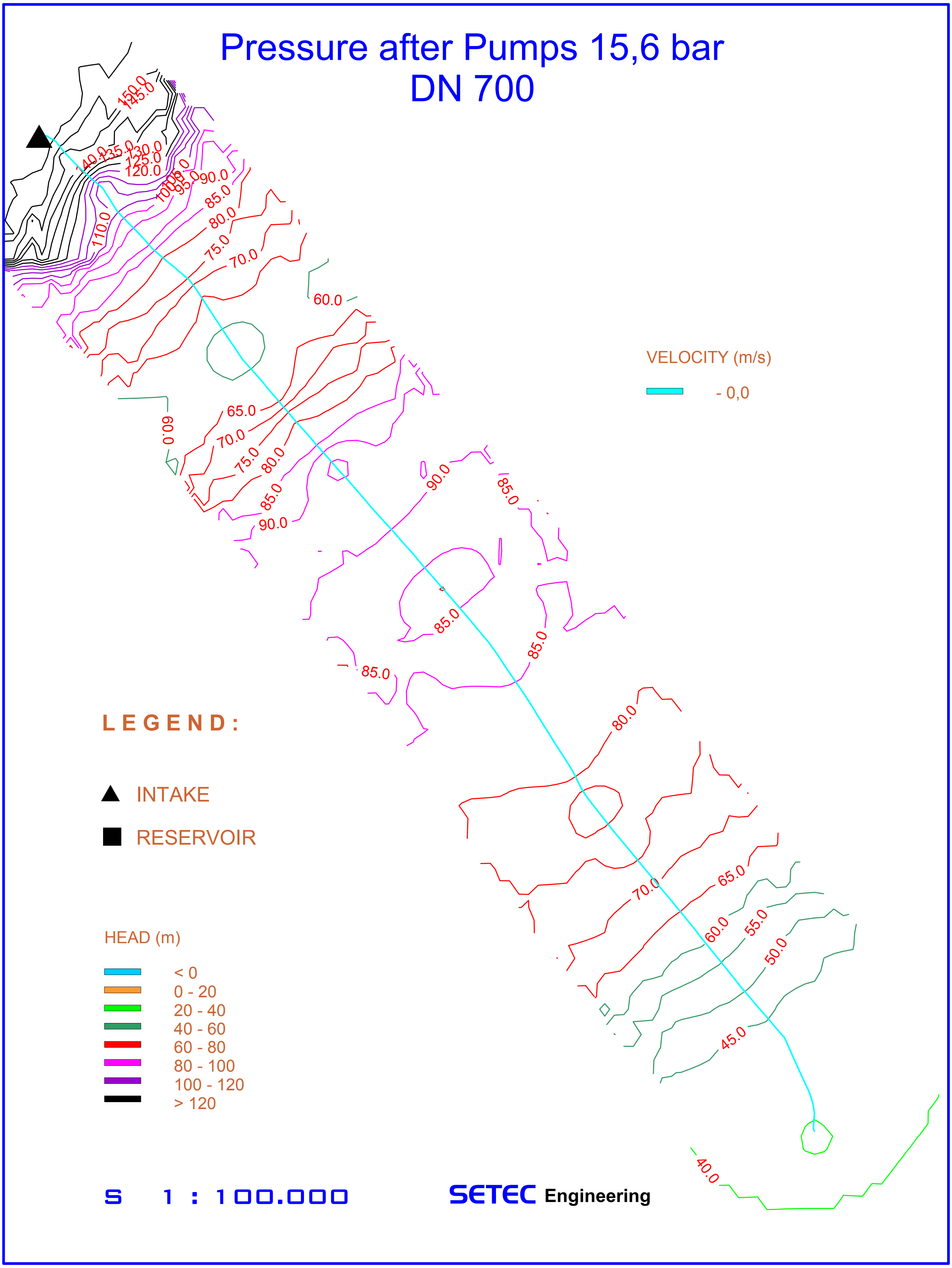
TM Ifraz III Part II

Design 2032 6P Flow 10.500 m^3/h



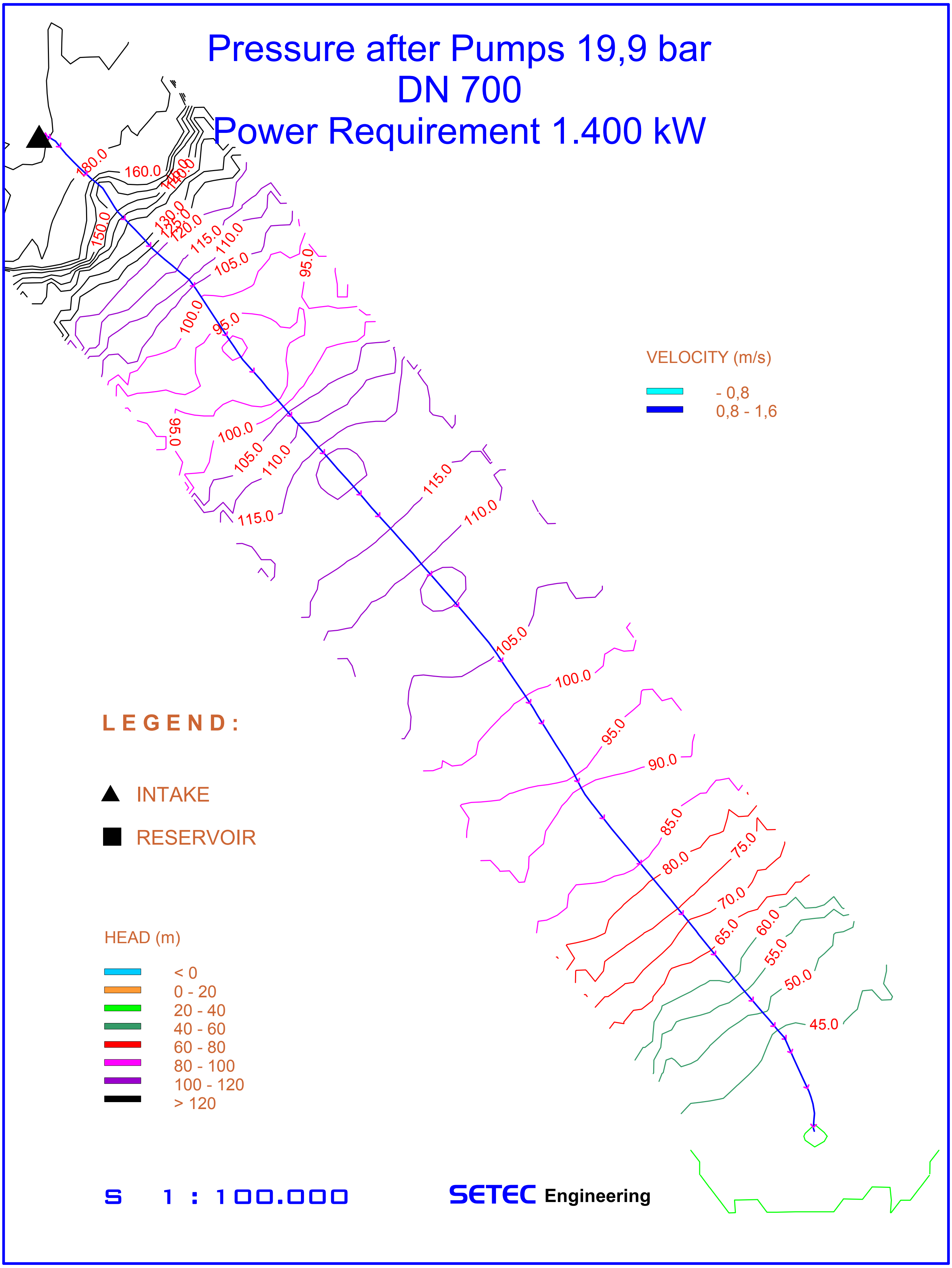
TM Ifraz I

Design 2032 0P Flow 0,0 m³/h



TM Ifraz I

Design 2032 Flow 1.590,0 m³/h



Design Scenario 2032
Time Step Simulation

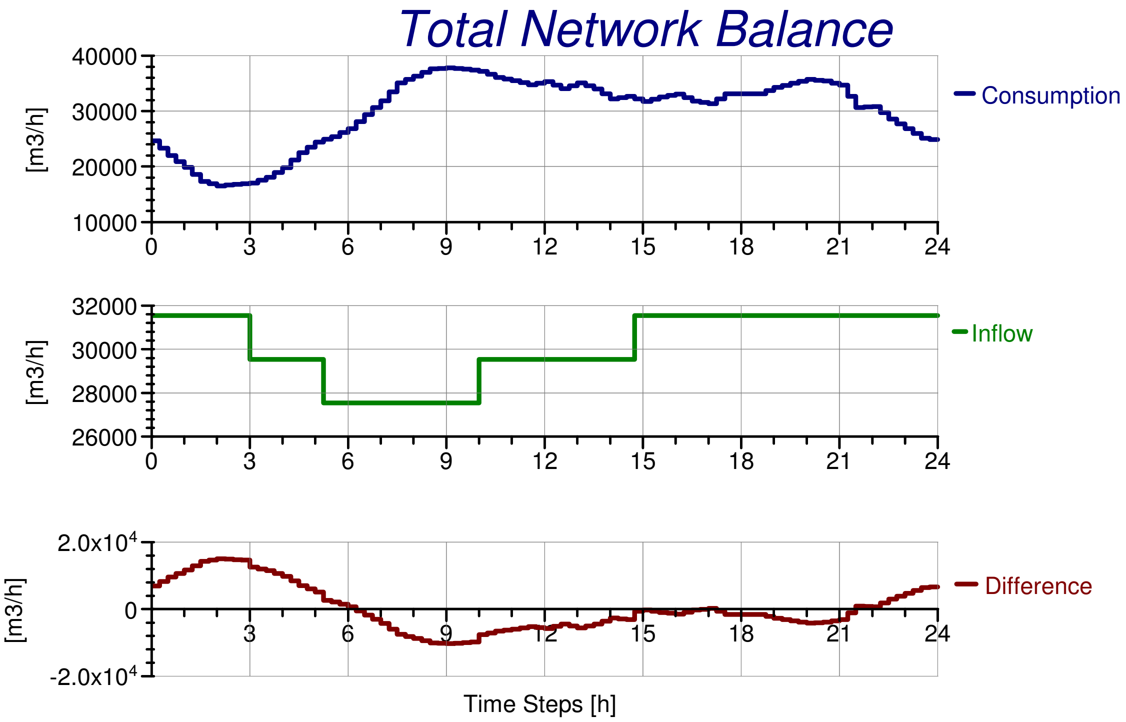
Peak Day Demand 720.000 m³

WTP Ifraz I 38.000 m³/d

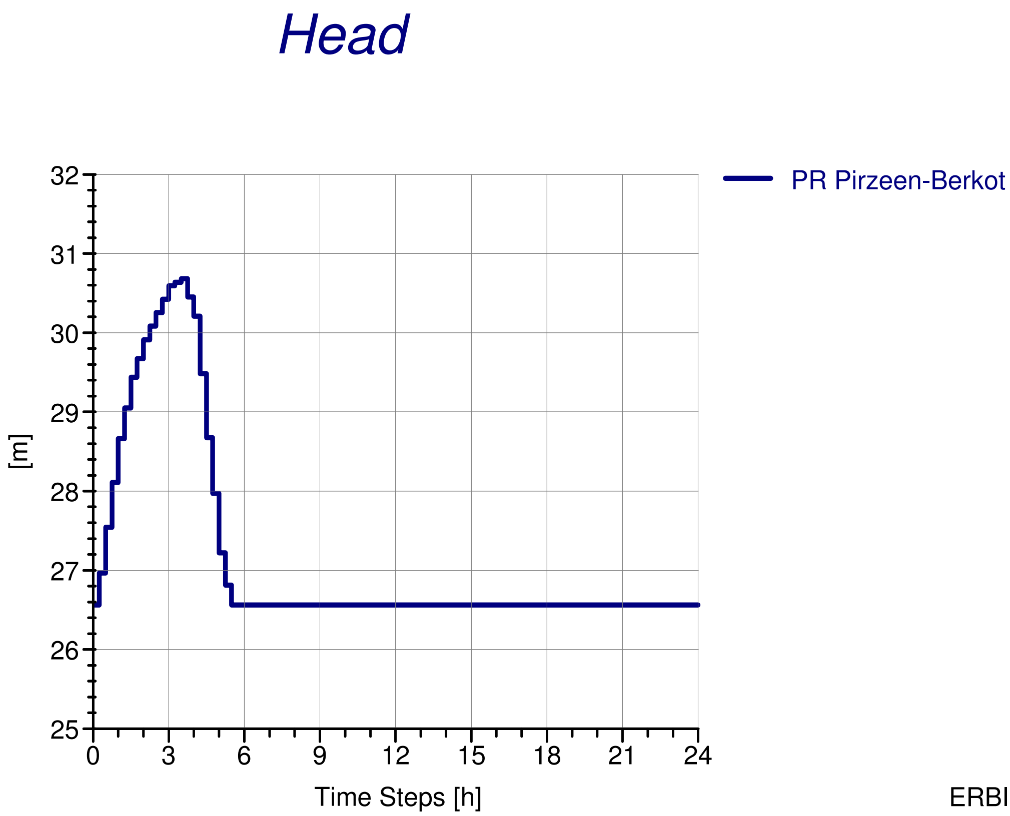
WTP Ifraz II 47.000 m³/d

WTP Ifraz III 240.000 m³/d

WTP Ifraz IV 400.000 m³/d

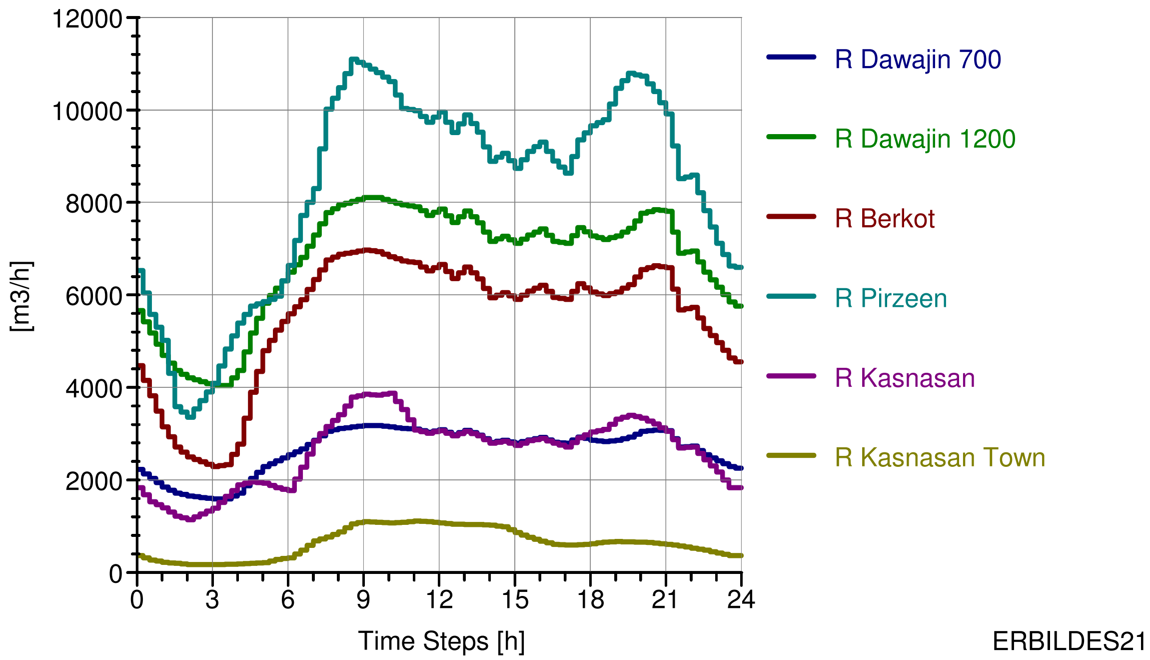


ERBILDES21

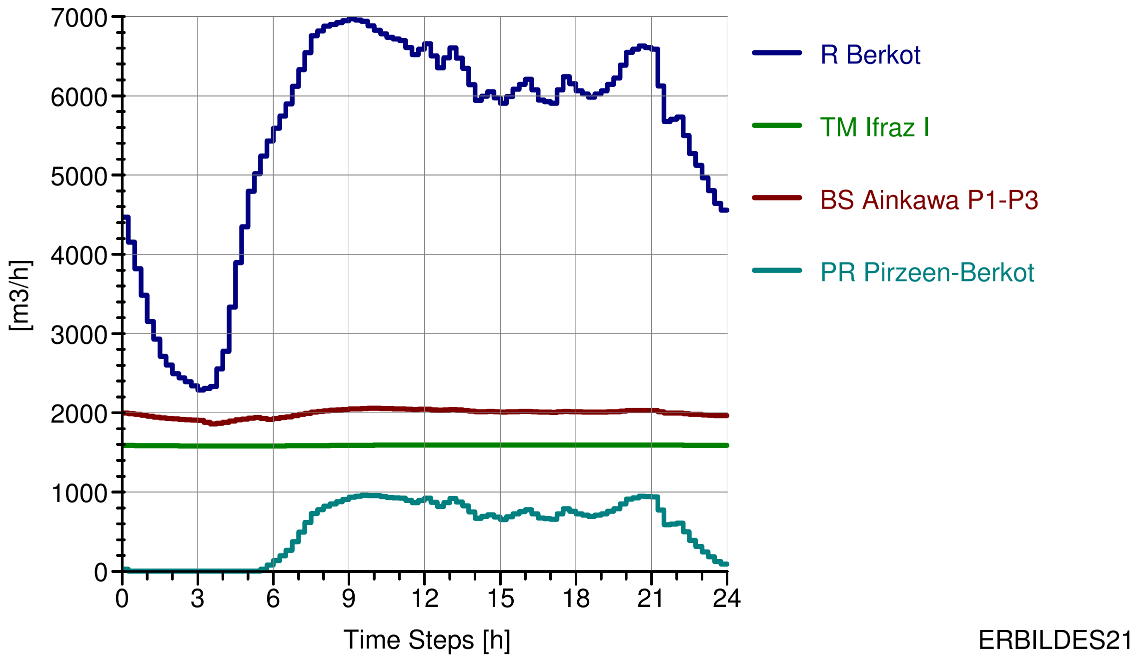


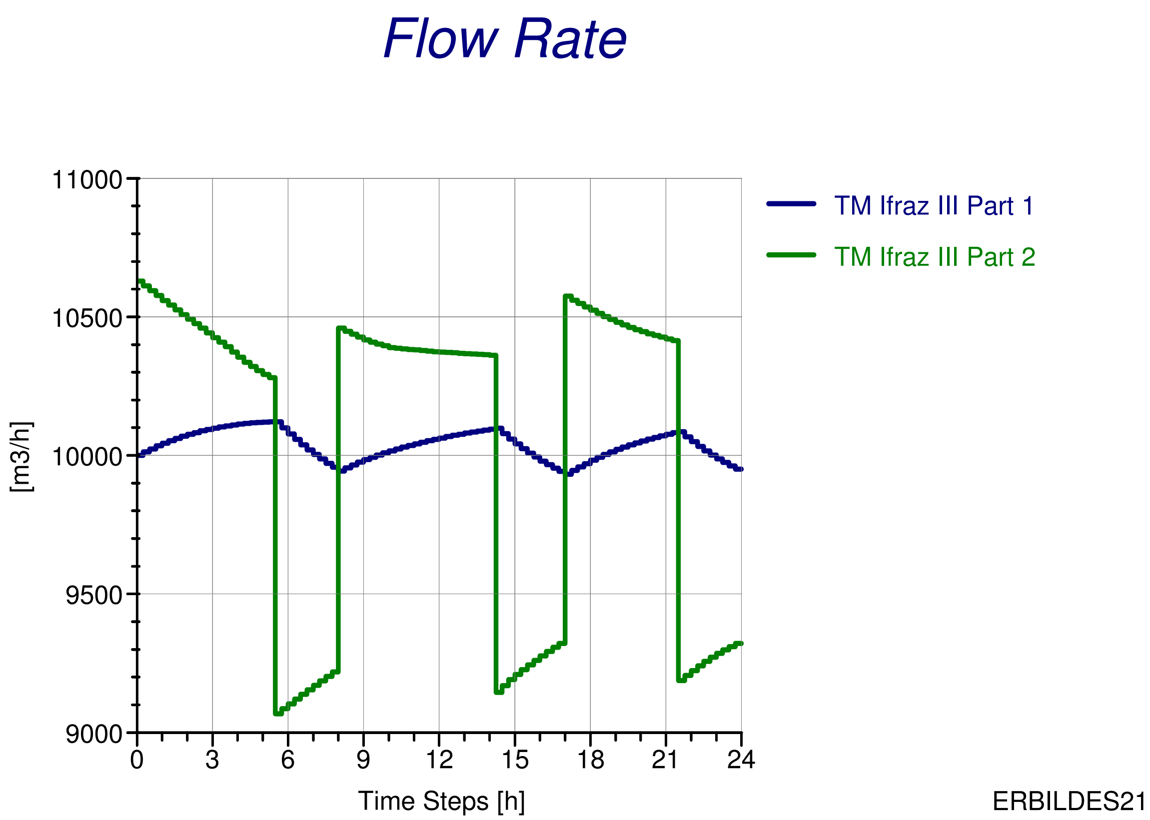
ERBILDES21

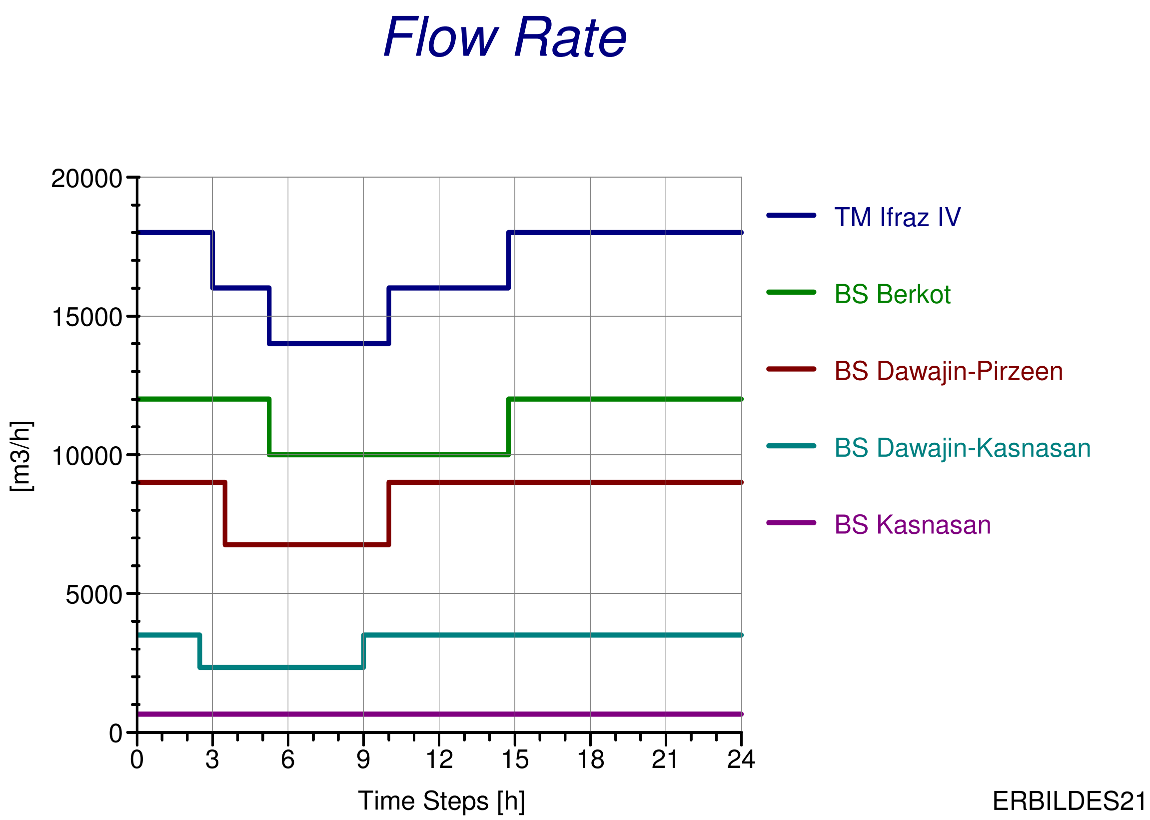
Flow Rate

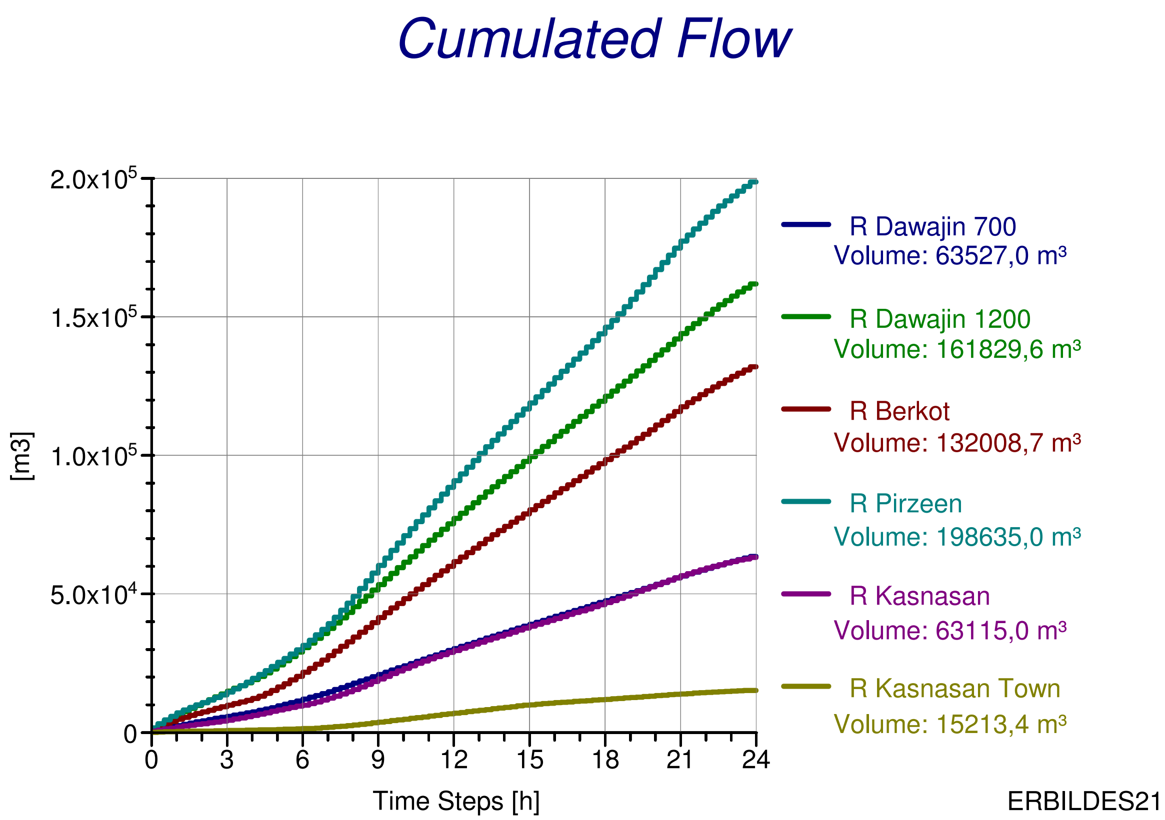


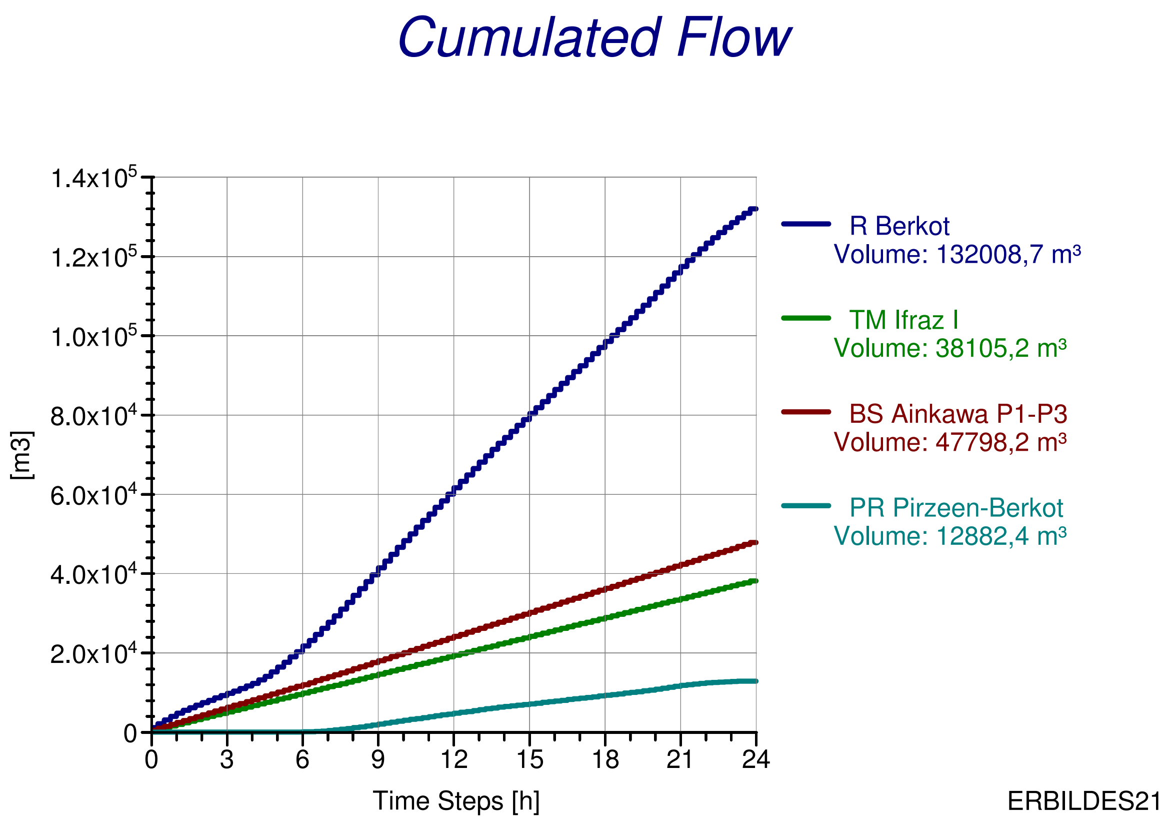
Flow Rate

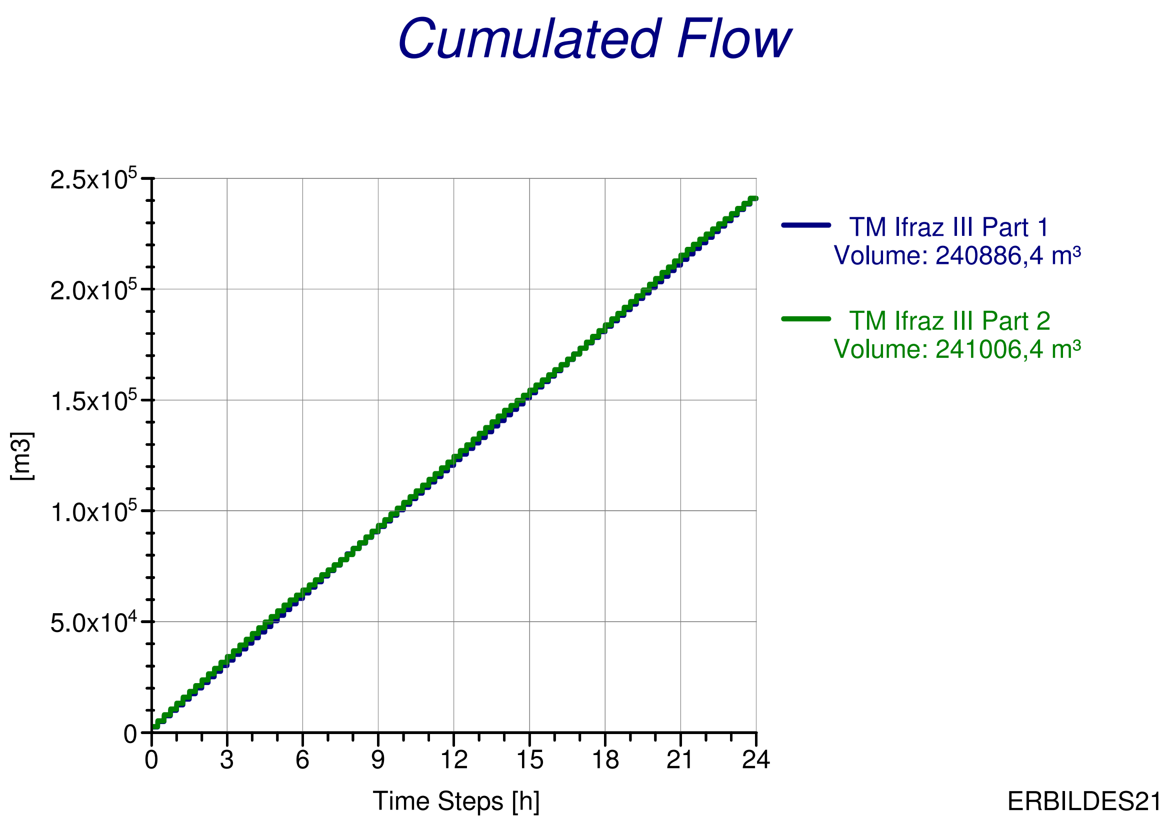


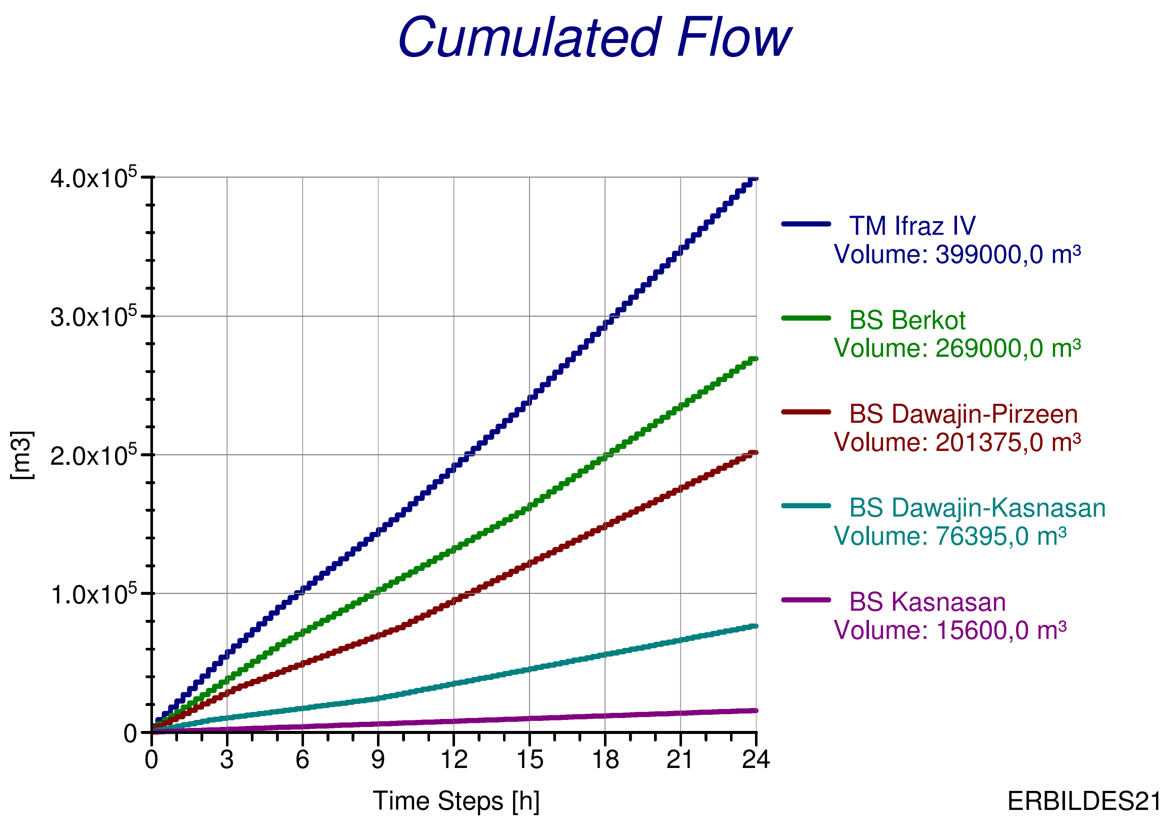

Flow Rate
11000
10500
10000
9500
9000
[m3/h]
0
3
6
9
12
15
18
21
24
Time Steps [h]
TM Ifraz III Part 1
TM Ifraz III Part 2
ERBILDES21


Flow Rate
20000
15000
10000
5000
0
[m3/h]
0
3
6
9
12
15
18
21
24
Time Steps [h]
TM Ifraz IV
BS Berkot
BS Dawajin-Pirzeen
BS Dawajin-Kasnasan
BS Kasnasan
ERBILDES21

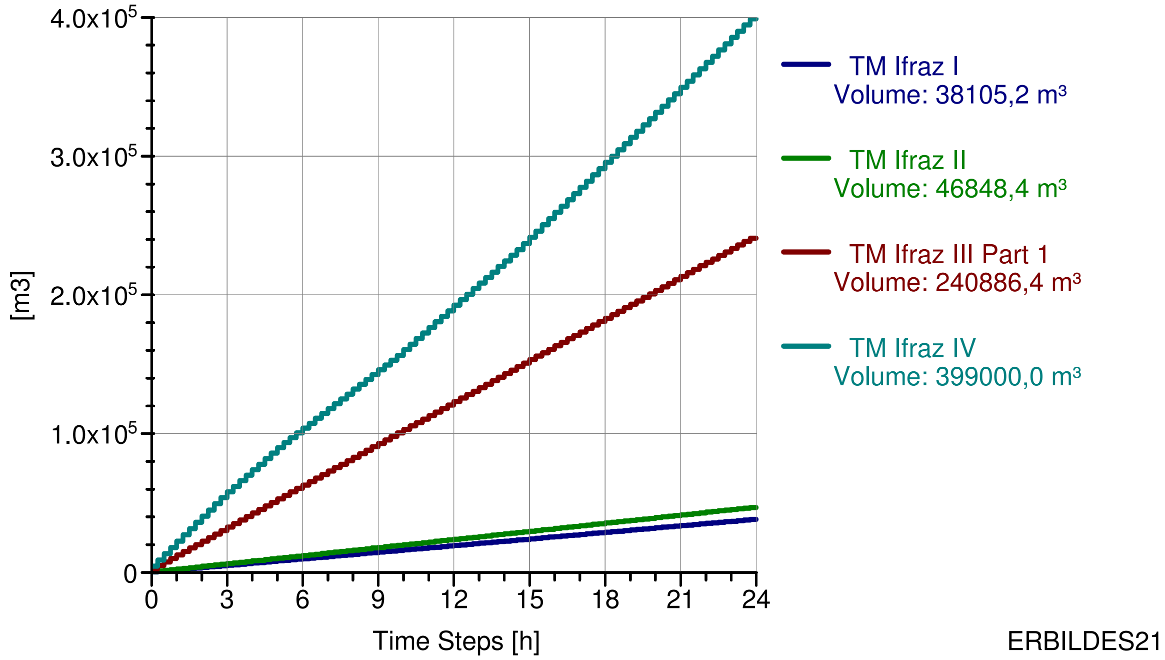

Cumulated Flow
2.0x10^5
1.5x10^5
1.0x10^5
5.0x10^4
0
[m3]
0
3
6
9
12
15
18
21
24
Time Steps [h]
R Dawajin 700
Volume: 63527,0 m³
R Dawajin 1200
Volume: 161829,6 m³
R Berkot
Volume: 132008,7 m³
R Pirzeen
Volume: 198635,0 m³
R Kasnasan
Volume: 63115,0 m³
R Kasnasan Town
Volume: 15213,4 m³
ERBILDES21


Cumulated Flow
1.4x10^5
1.2x10^5
1.0x10^5
8.0x10^4
6.0x10^4
4.0x10^4
2.0x10^4
0
[m3]
0
3
6
9
12
15
18
21
24
Time Steps [h]
R Berkot
Volume: 132008,7 m³
TM Ifraz I
Volume: 38105,2 m³
BS Ainkawa P1-P3
Volume: 47798,2 m³
PR Pirzeen-Berkot
Volume: 12882,4 m³
ERBILDES21

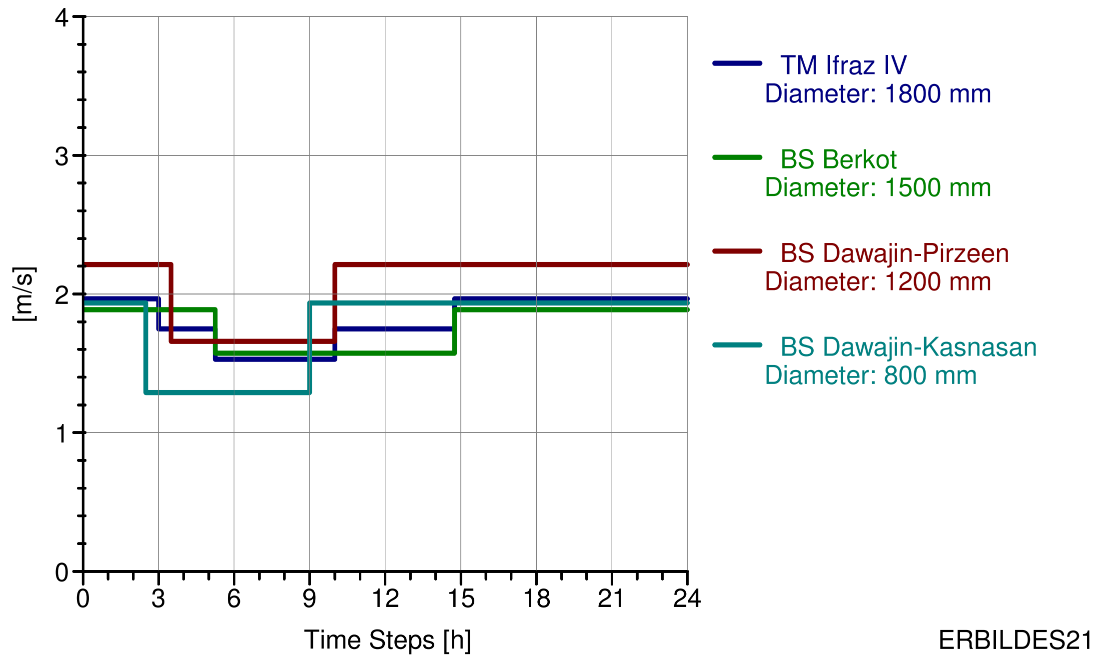

Cumulated Flow
2.5x10^5
2.0x10^5
1.5x10^5
1.0x10^5
5.0x10^4
0
[m3]
0 3 6 9 12 15 18 21 24
Time Steps [h]
TM Ifraz III Part 1
Volume: 240886,4 m³
TM Ifraz III Part 2
Volume: 241006,4 m³
ERBILDES21


Cumulated Flow
4.0x10^5
3.0x10^5
2.0x10^5
1.0x10^5
0
[m3]
0 3 6 9 12 15 18 21 24
Time Steps [h]
TM Ifraz IV
Volume: 399000,0 m³
BS Berkot
Volume: 269000,0 m³
BS Dawajin-Pirzeen
Volume: 201375,0 m³
BS Dawajin-Kasnasan
Volume: 76395,0 m³
BS Kasnasan
Volume: 15600,0 m³
ERBILDES21

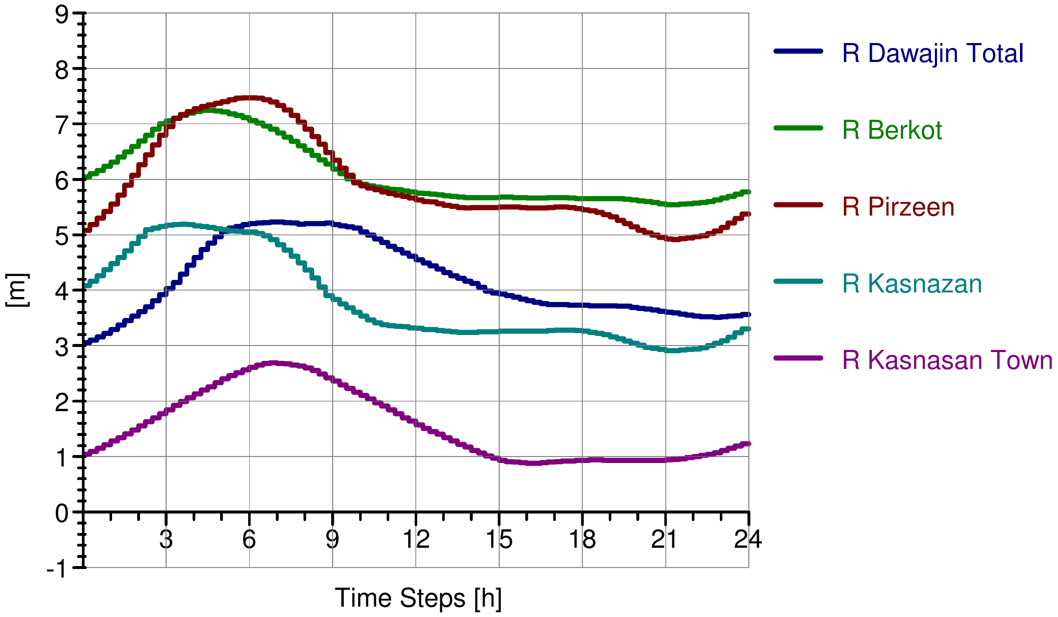
Cumulated Flow



Flow Velocity

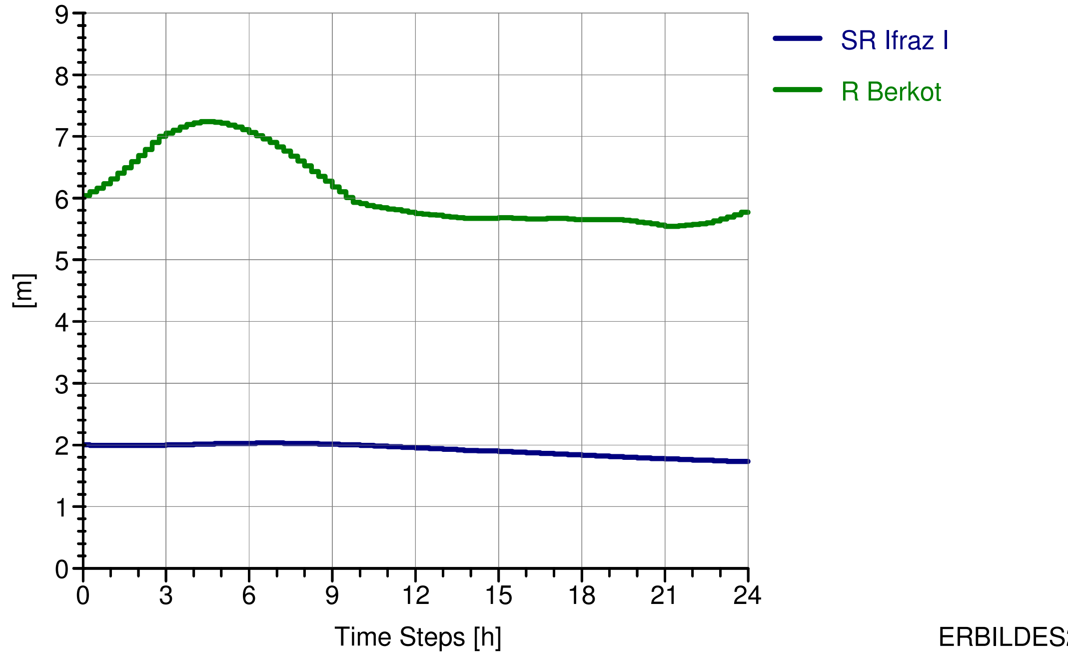


Reservoir Content (m)

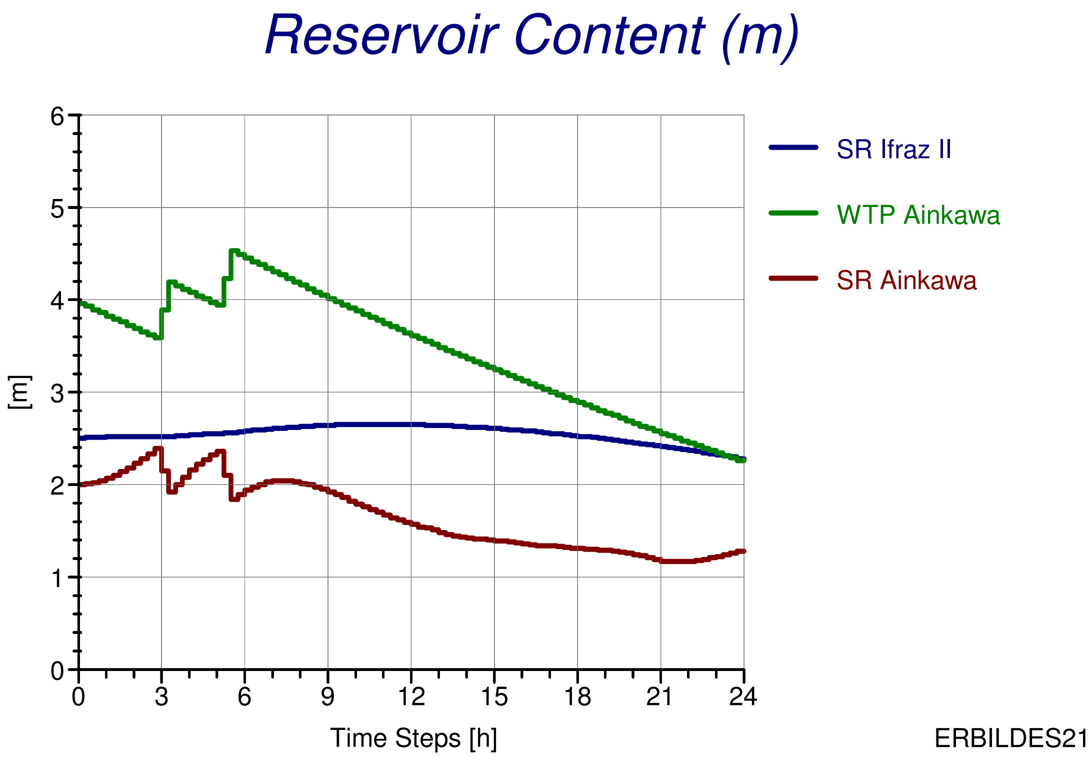


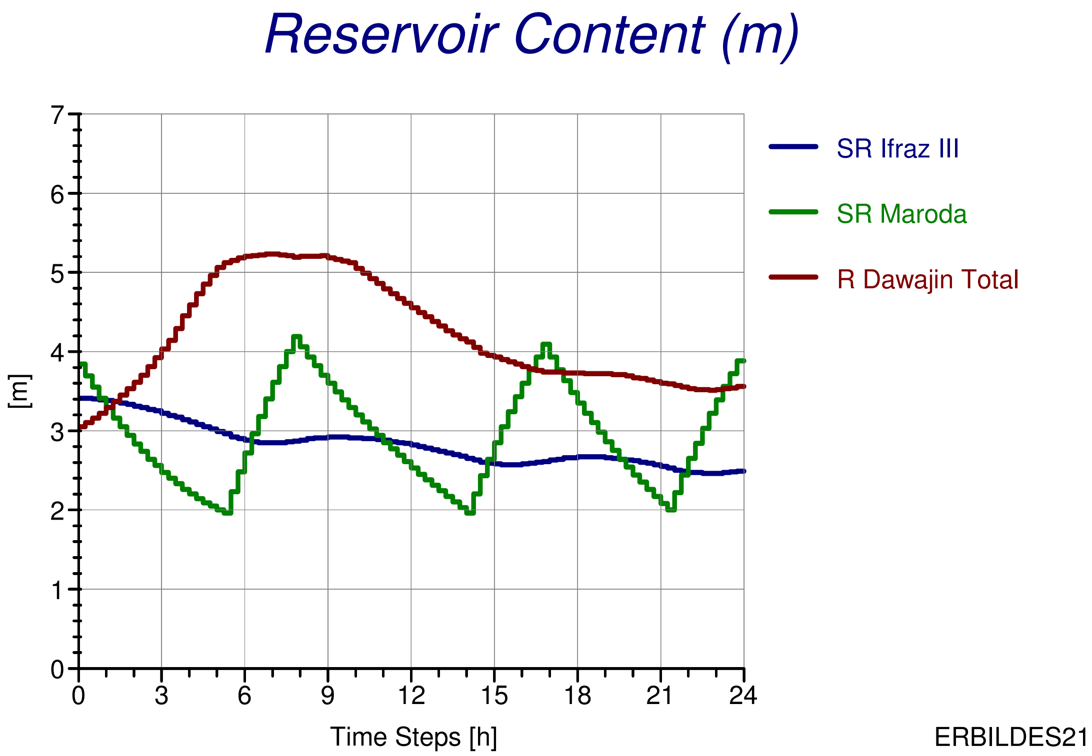
ERBILDES21

Reservoir Content (m)

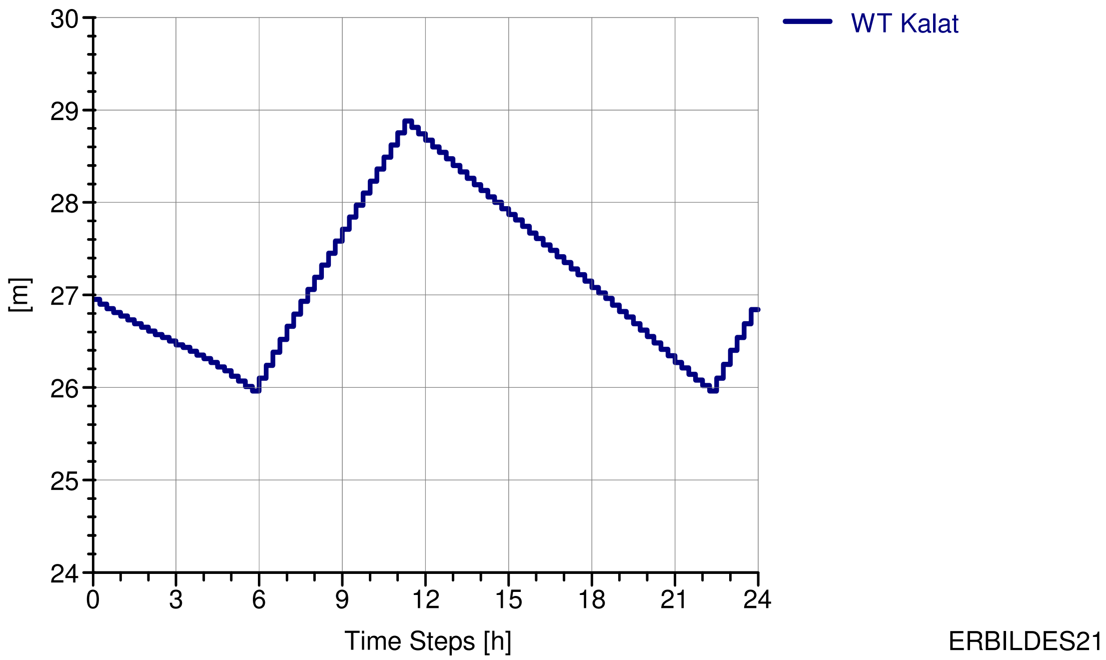


ERBILDES21

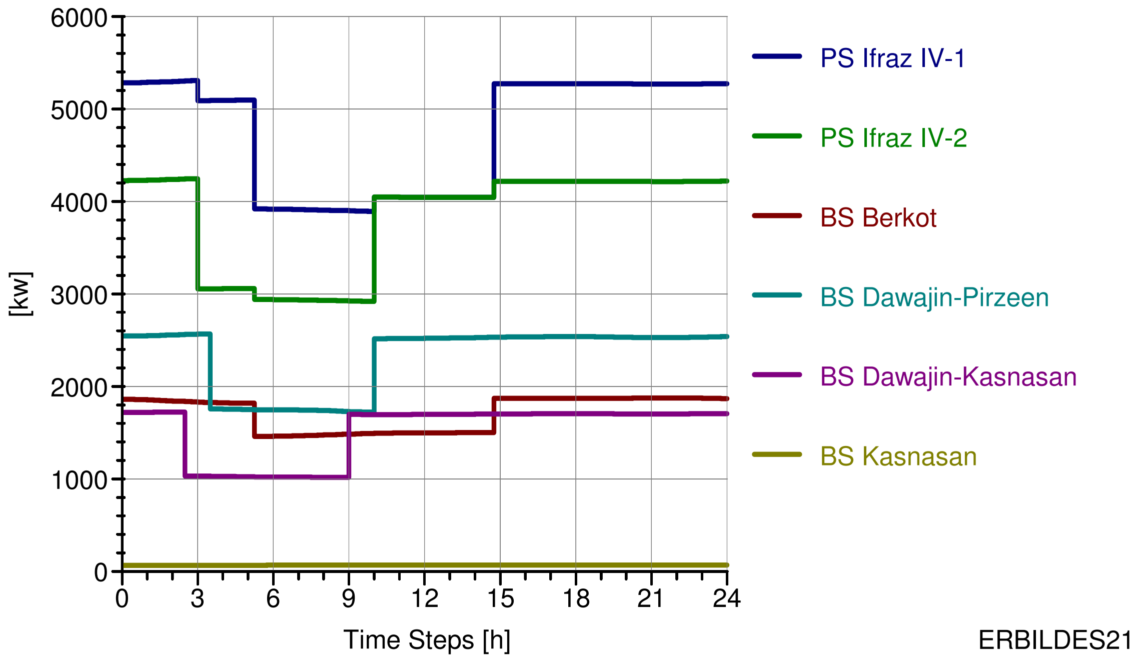

Reservoir Content (m)
[m]
0
1
2
3
4
5
6
0
3
6
9
12
15
18
21
24
Time Steps [h]
SR Ifraz II
WTP Ainkawa
SR Ainkawa
ERBILDES21

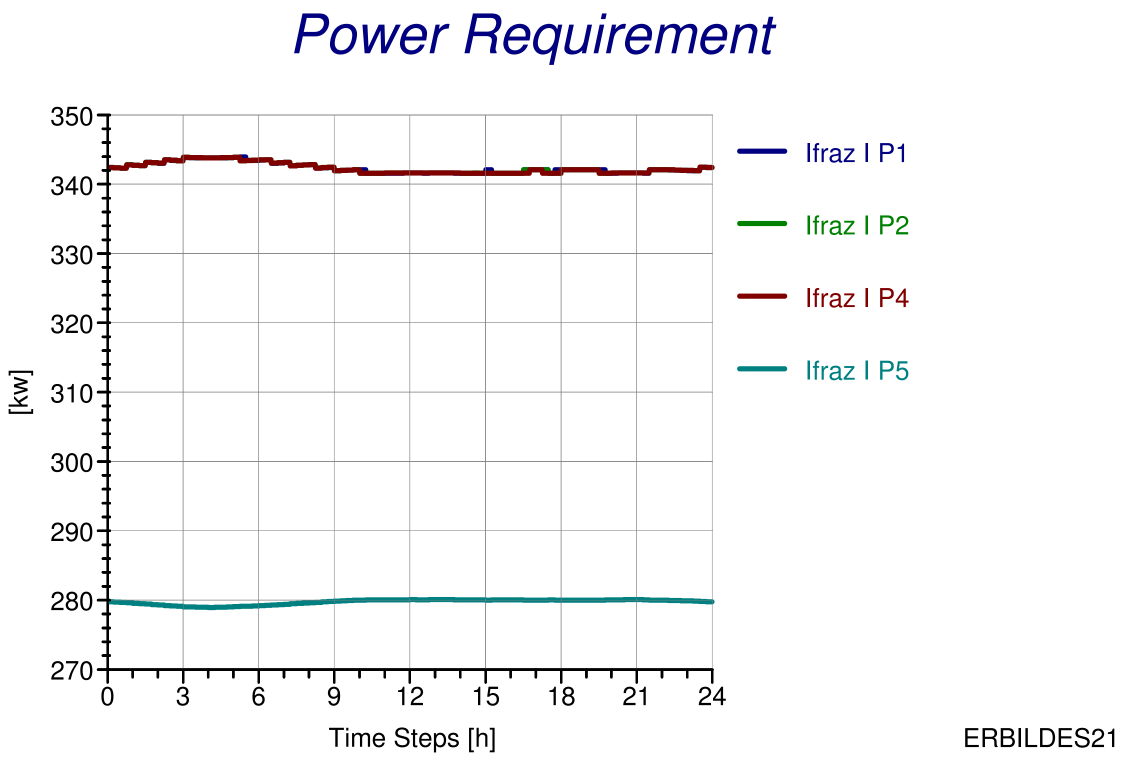

Reservoir Content (m)
[m]
0
1
2
3
4
5
6
7
0
3
6
9
12
15
18
21
24
Time Steps [h]
SR Ifraz III
SR Maroda
R Dawajin Total
ERBILDES21

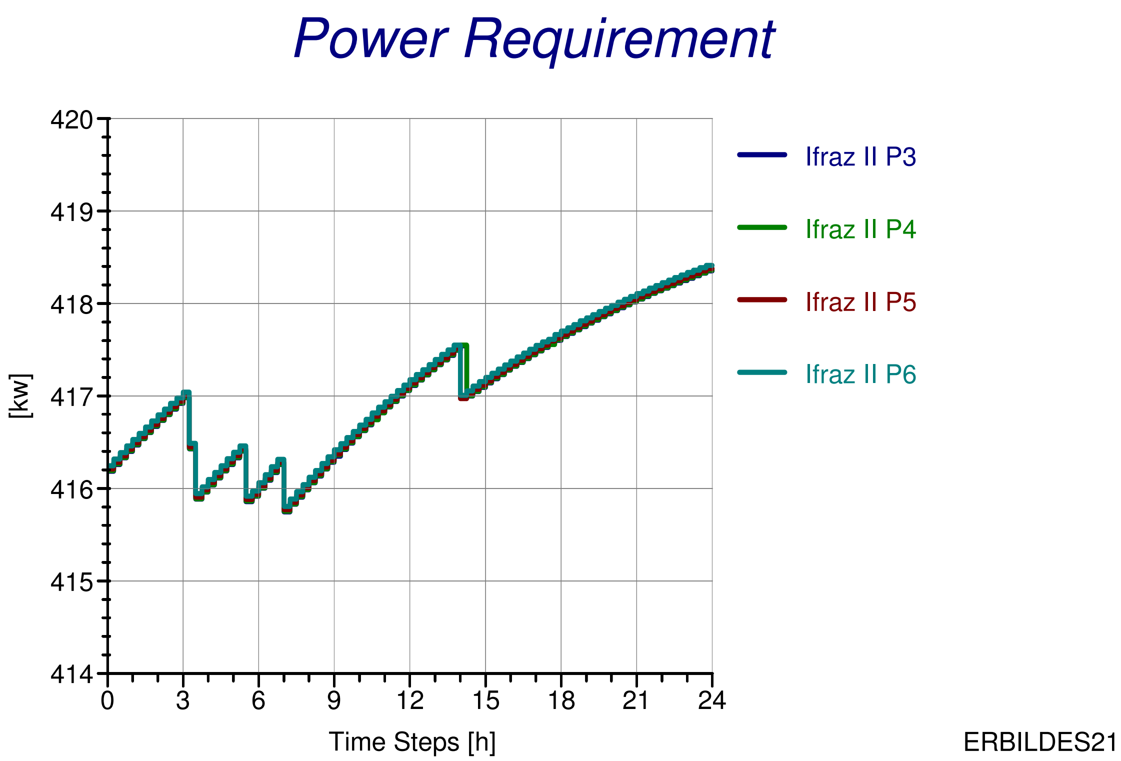
Reservoir Content (m)

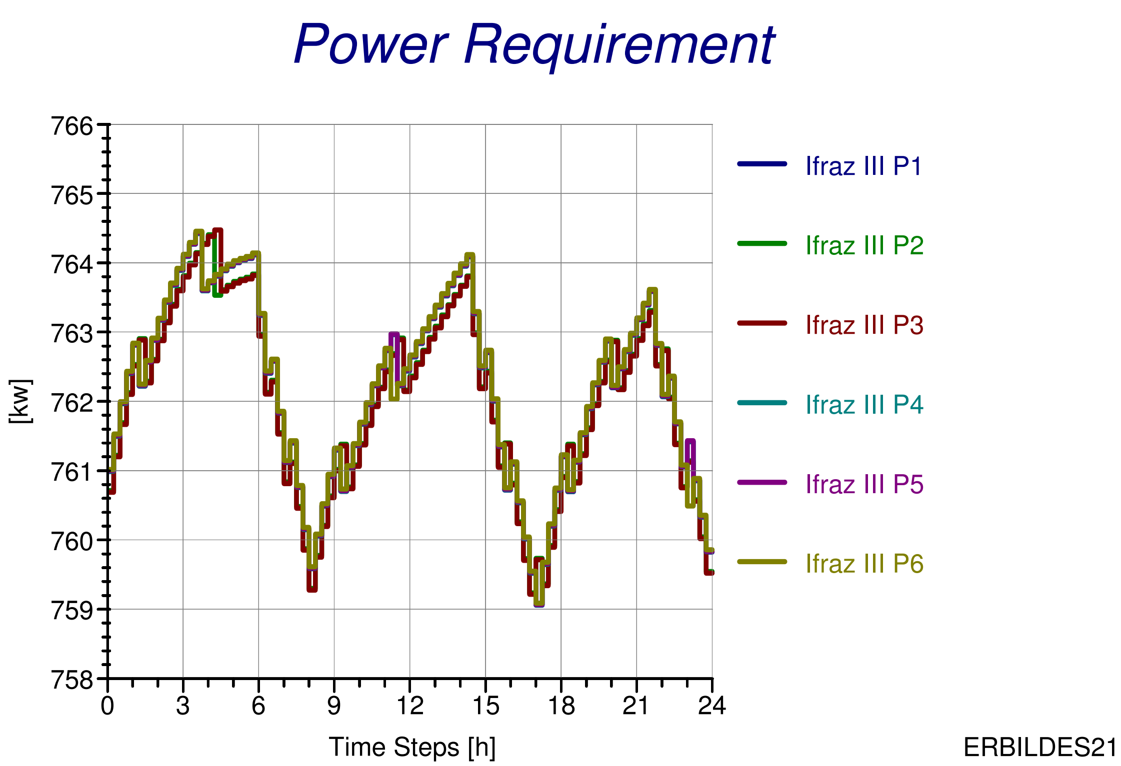


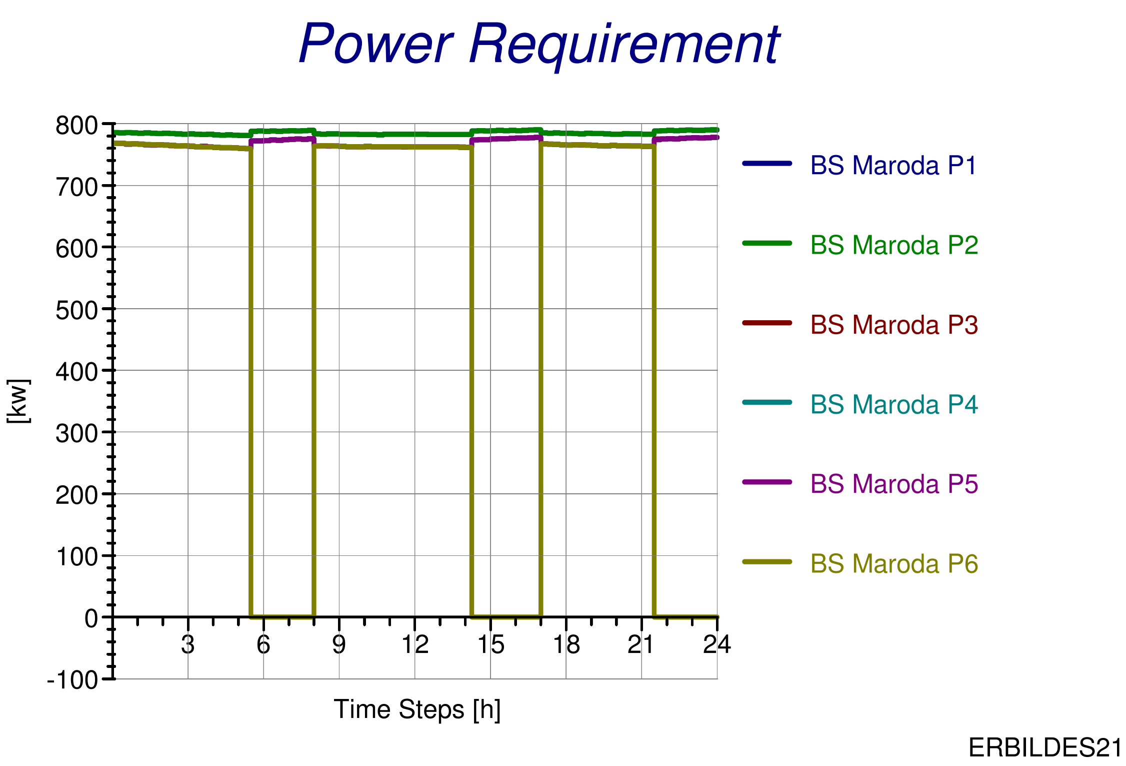
Power Requirement



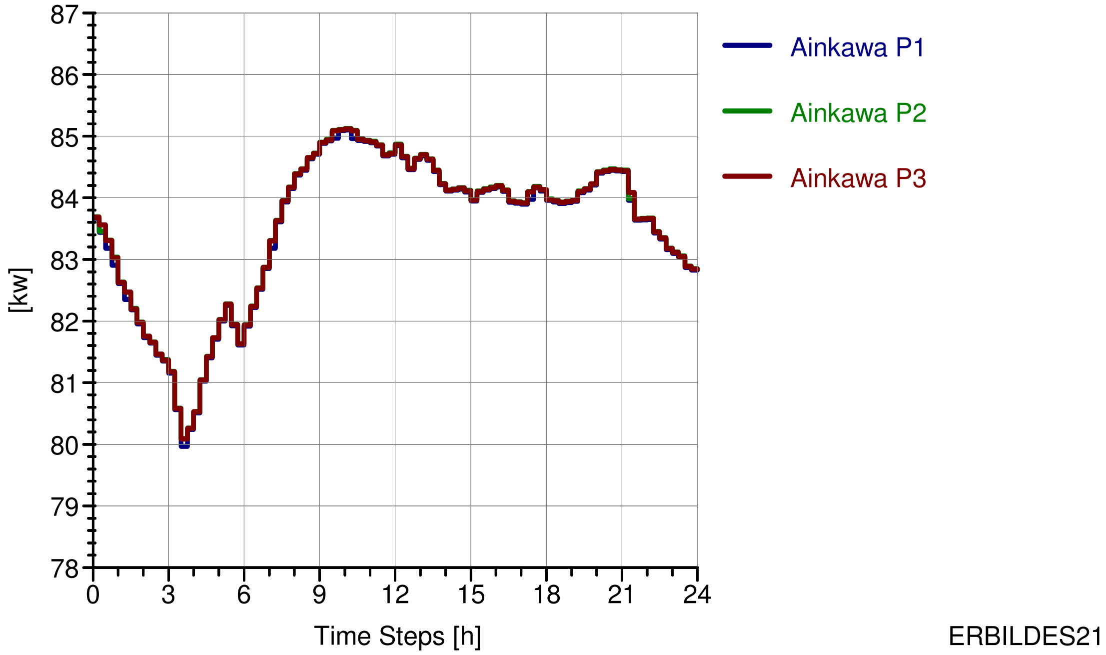

Power Requirement
350
340
330
320
310
300
290
280
270
[kw]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz I P1
Ifraz I P2
Ifraz I P4
Ifraz I P5
ERBILDES21


Power Requirement
420
419
418
417
416
415
414
[kw]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz II P3
Ifraz II P4
Ifraz II P5
Ifraz II P6
ERBILDES21

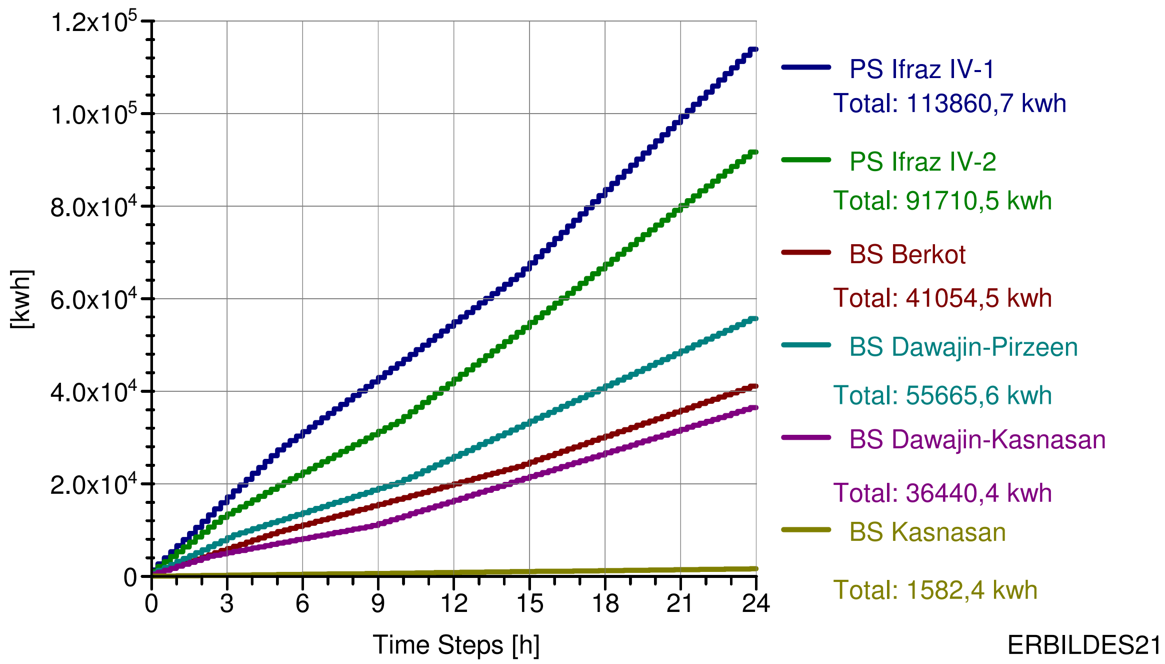

Power Requirement
766
765
764
763
762
761
760
759
758
[kw]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz III P1
Ifraz III P2
Ifraz III P3
Ifraz III P4
Ifraz III P5
Ifraz III P6
ERBILDES21

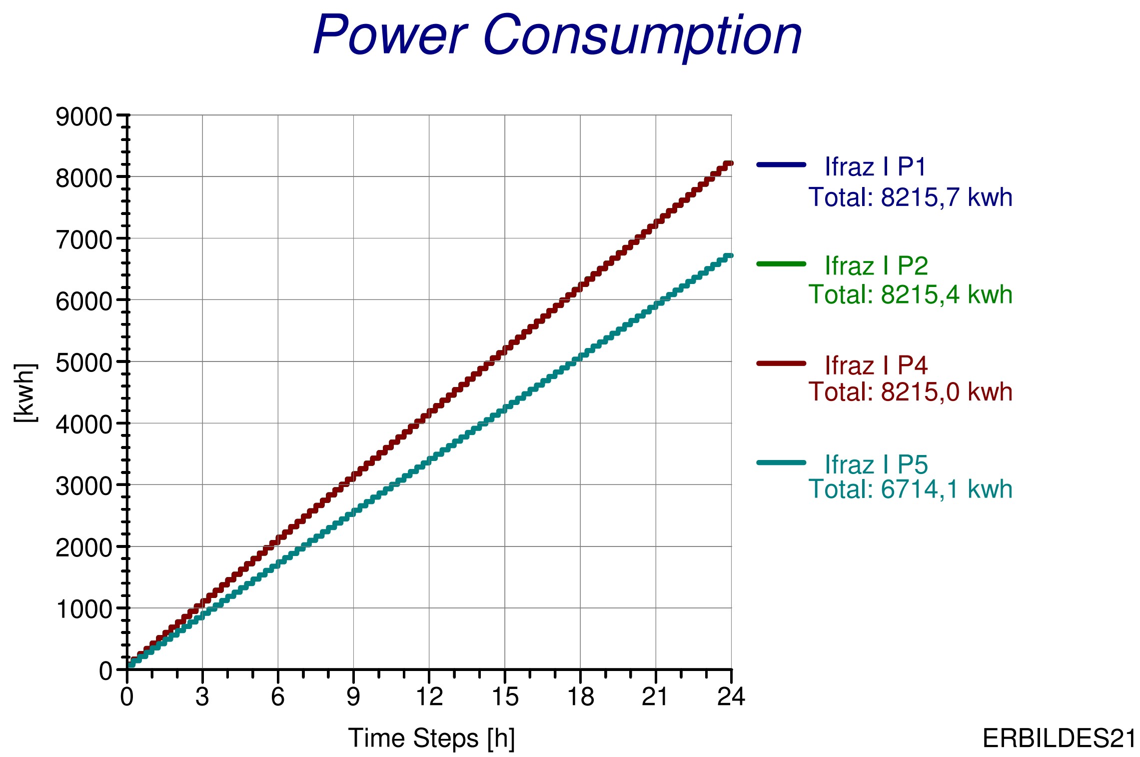

Power Requirement
800
700
600
500
400
300
200
100
0
-100
[kw]
3
6
9
12
15
18
21
24
Time Steps [h]
BS Maroda P1
BS Maroda P2
BS Maroda P3
BS Maroda P4
BS Maroda P5
BS Maroda P6
ERBILDES21

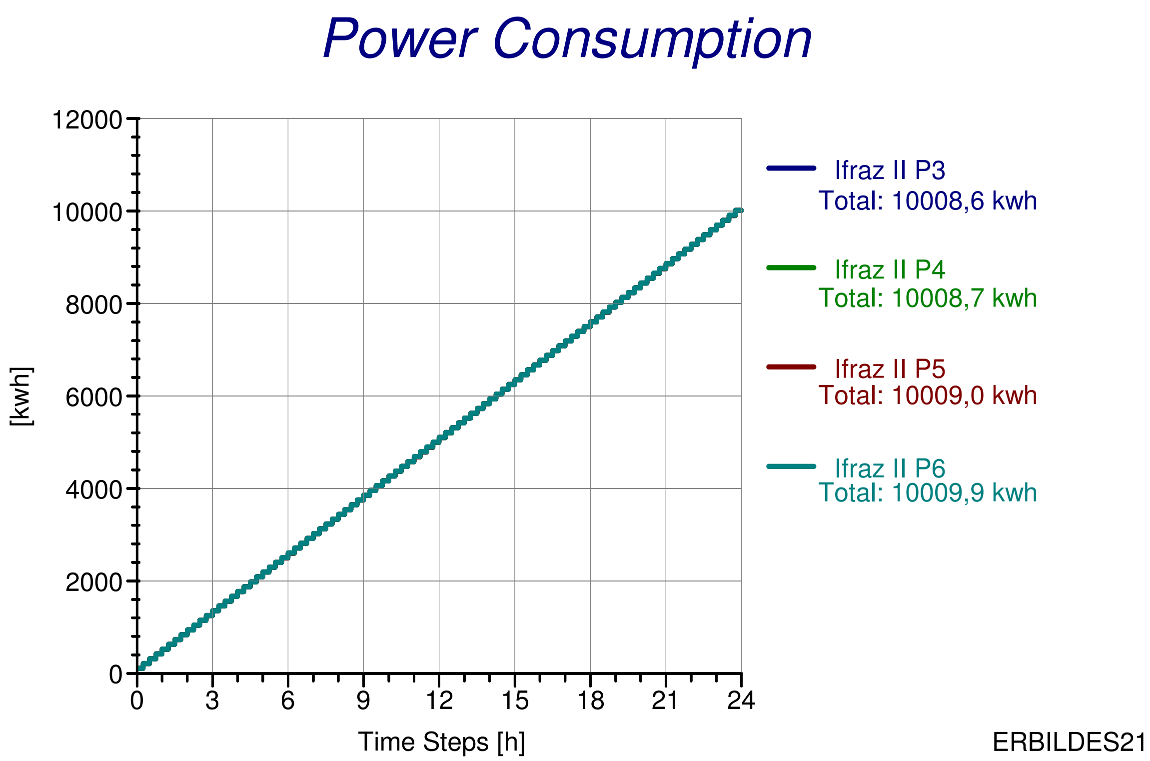
Power Requirement

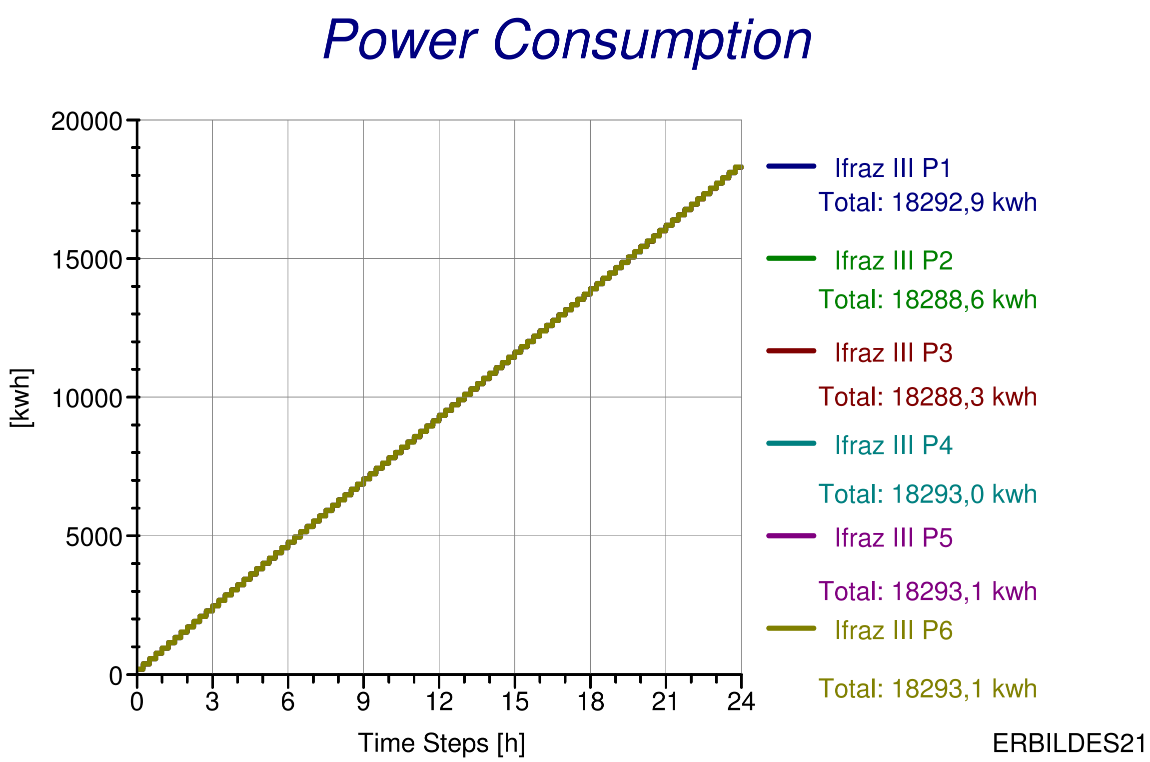


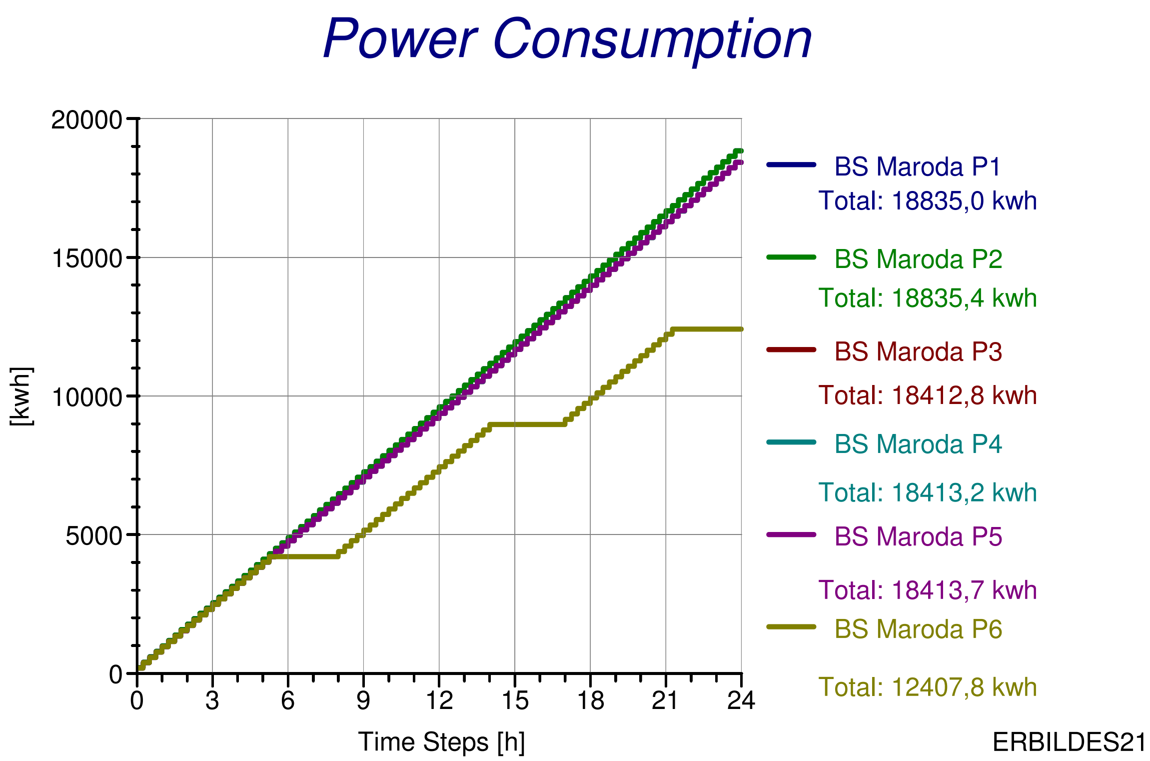
Power Consumption

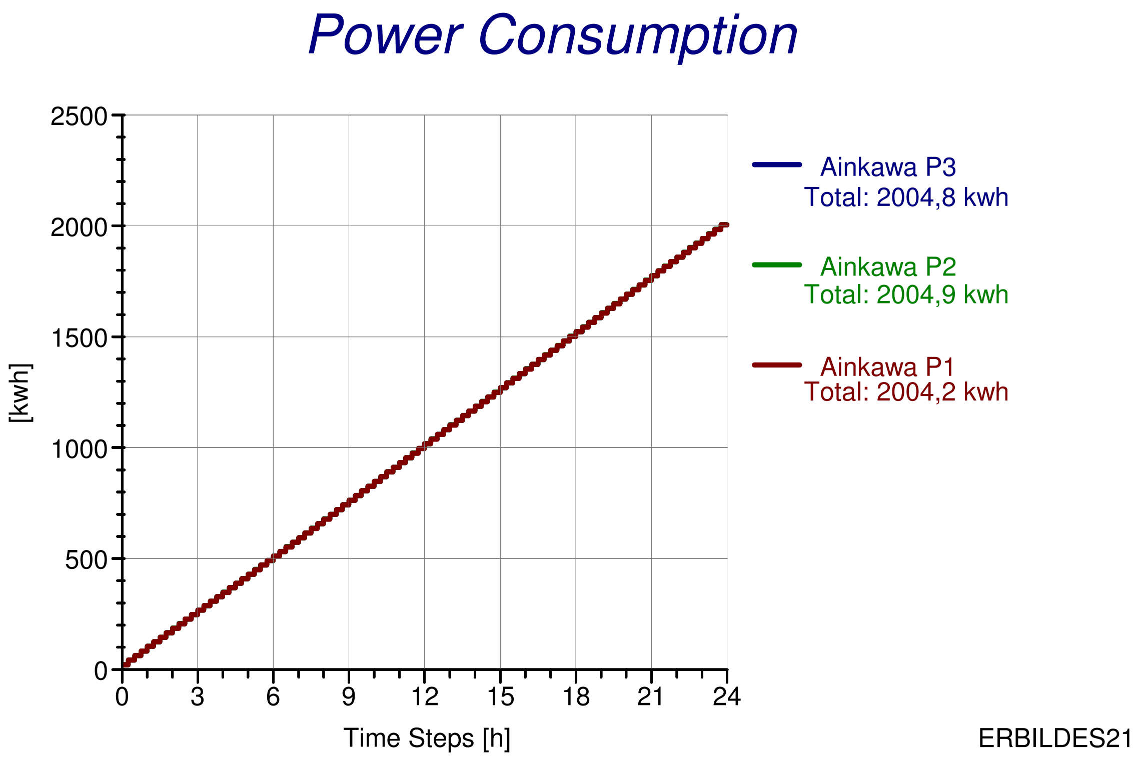


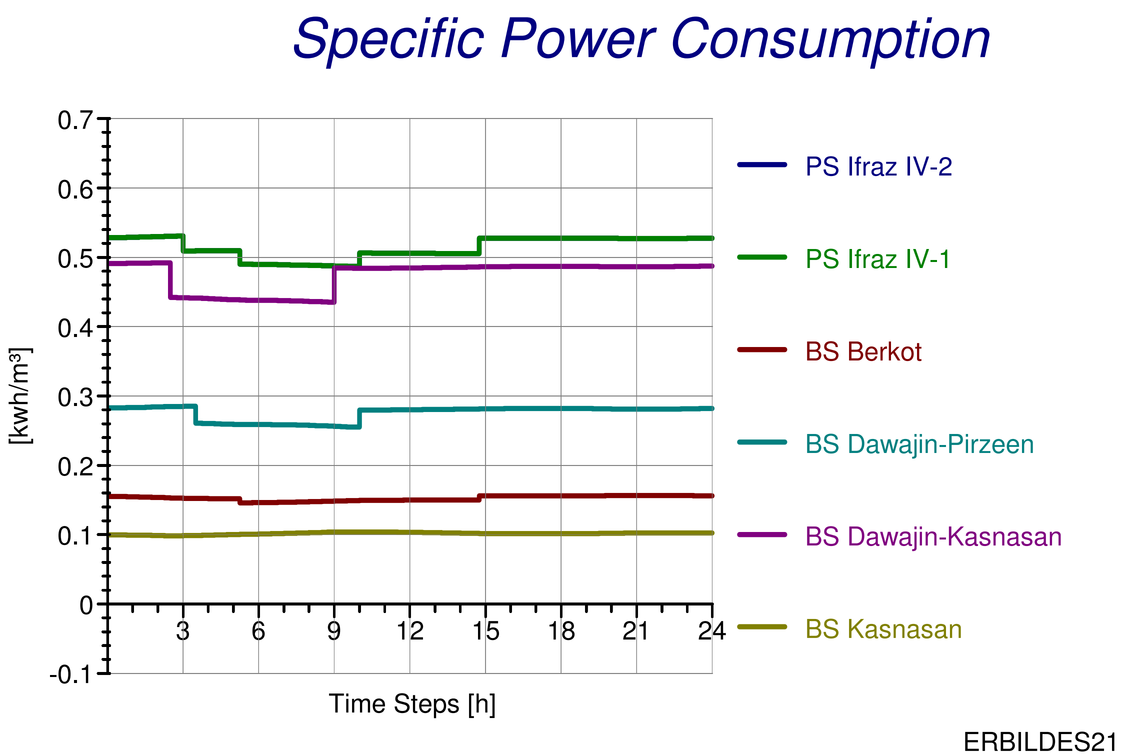

Power Consumption
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
[kwh]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz I P1
Total: 8215,7 kwh
Ifraz I P2
Total: 8215,4 kwh
Ifraz I P4
Total: 8215,0 kwh
Ifraz I P5
Total: 6714,1 kwh
ERBILDES21

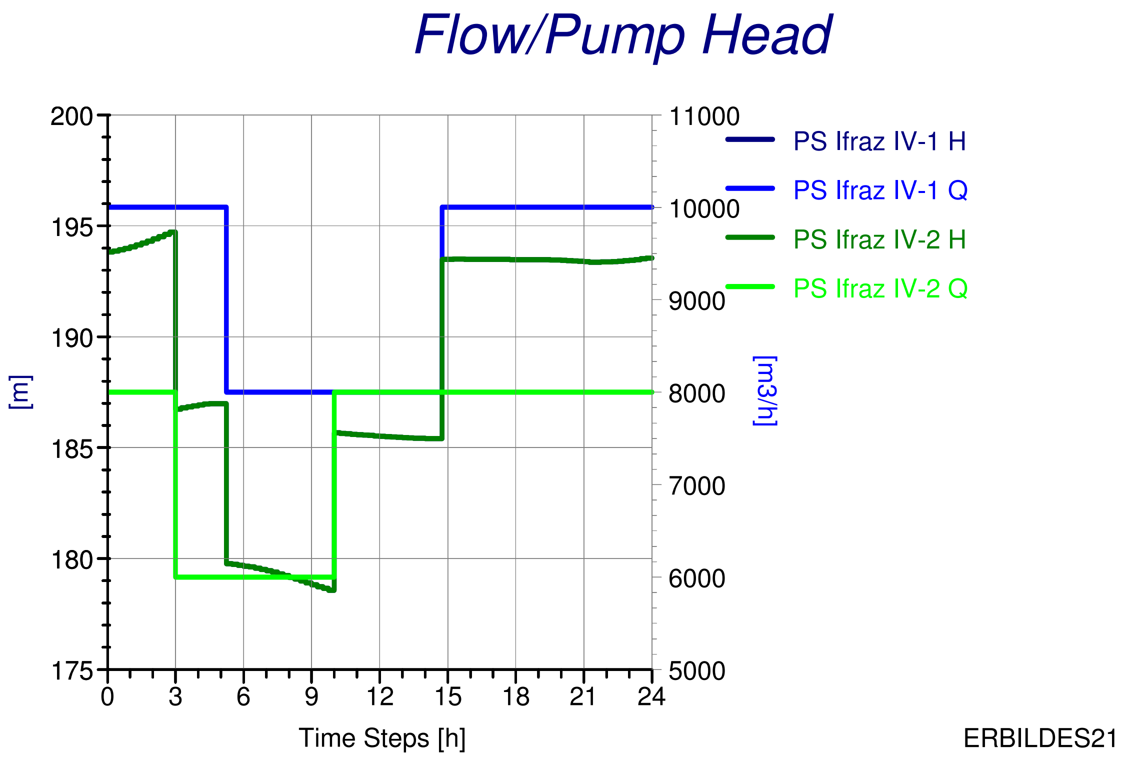

Power Consumption
12000
10000
8000
6000
4000
2000
0
[kwh]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz II P3
Total: 10008,6 kwh
Ifraz II P4
Total: 10008,7 kwh
Ifraz II P5
Total: 10009,0 kwh
Ifraz II P6
Total: 10009,9 kwh
ERBILDES21

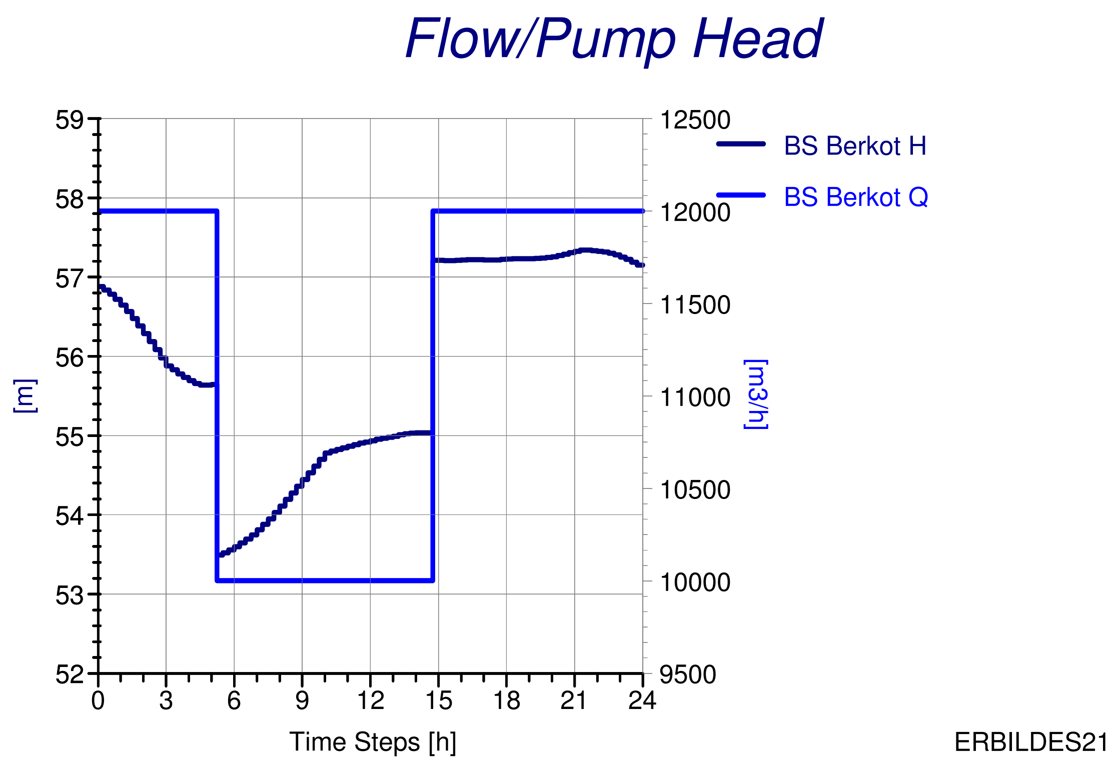

Power Consumption
20000
15000
10000
5000
0
[kwh]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ifraz III P1
Total: 18292,9 kwh
Ifraz III P2
Total: 18288,6 kwh
Ifraz III P3
Total: 18288,3 kwh
Ifraz III P4
Total: 18293,0 kwh
Ifraz III P5
Total: 18293,1 kwh
Ifraz III P6
Total: 18293,1 kwh
ERBILDES21

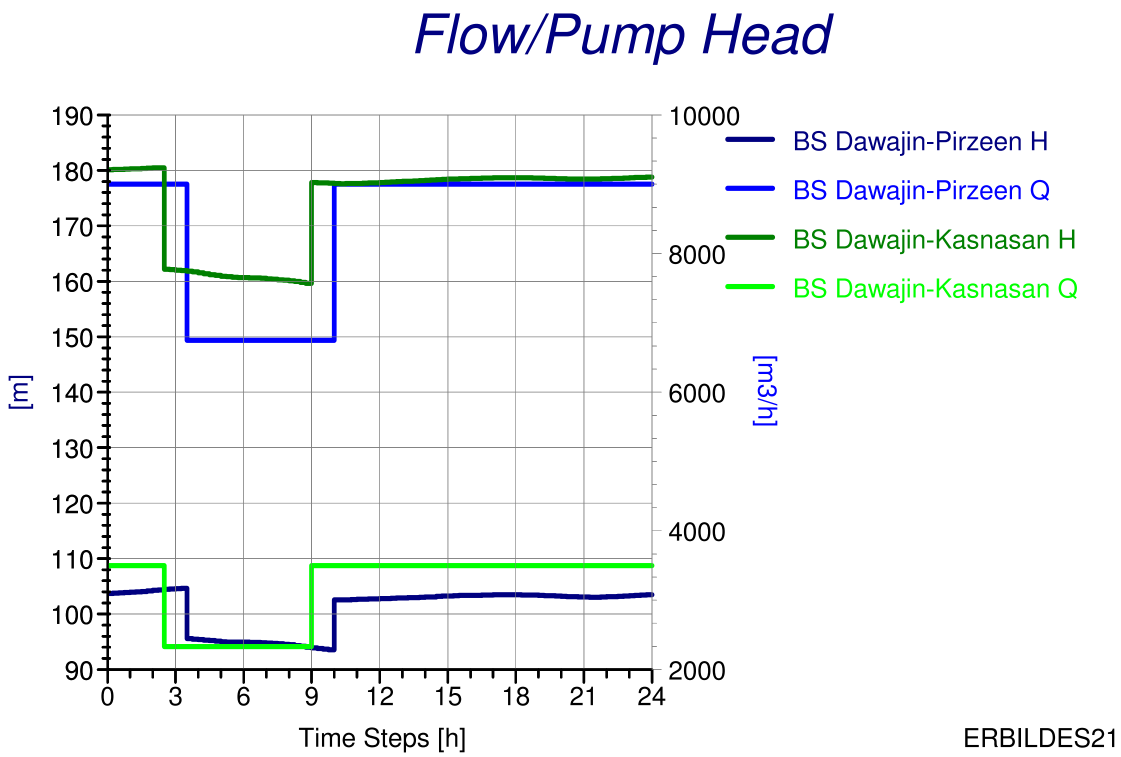

Power Consumption
20000
15000
10000
5000
0
[kwh]
0
3
6
9
12
15
18
21
24
Time Steps [h]
BS Maroda P1
Total: 18835,0 kwh
BS Maroda P2
Total: 18835,4 kwh
BS Maroda P3
Total: 18412,8 kwh
BS Maroda P4
Total: 18413,2 kwh
BS Maroda P5
Total: 18413,7 kwh
BS Maroda P6
Total: 12407,8 kwh
ERBILDES21

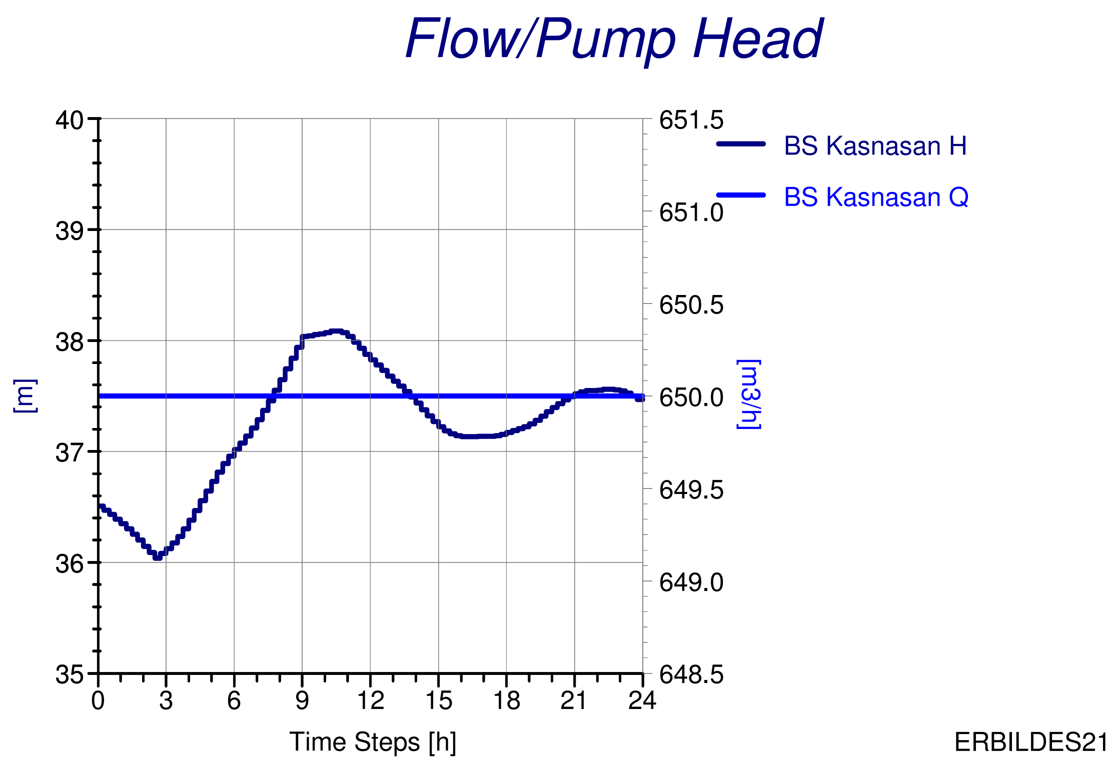

Power Consumption
2500
2000
1500
1000
500
0
[kwh]
0
3
6
9
12
15
18
21
24
Time Steps [h]
Ainkawa P3
Total: 2004,8 kwh
Ainkawa P2
Total: 2004,9 kwh
Ainkawa P1
Total: 2004,2 kwh
ERBILDES21


Specific Power Consumption
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
[kwh/m³]
3
6
9
12
15
18
21
24
Time Steps [h]
PS Ifraz IV-2
PS Ifraz IV-1
BS Berkot
BS Dawajin-Pirzeen
BS Dawajin-Kasnasan
BS Kasnasan
ERBILDES21


Flow/Pump Head
[m]
[m3/h]
Time Steps [h]
PS Ifraz IV-1 H
PS Ifraz IV-1 Q
PS Ifraz IV-2 H
PS Ifraz IV-2 Q
ERBILDES21


Flow/Pump Head
[m]
[m3/h]
Time Steps [h]
BS Berkot H
BS Berkot Q
ERBILDES21


Flow/Pump Head
190
180
170
160
150
140
130
120
110
100
90
[m]
10000
8000
6000
4000
2000
[m3/h]
0
3
6
9
12
15
18
21
24
Time Steps [h]
BS Dawajin-Pirzeen H
BS Dawajin-Pirzeen Q
BS Dawajin-Kasnasan H
BS Dawajin-Kasnasan Q
ERBILDES21


Flow/Pump Head
40
39
38
37
36
35
[m]
651.5
651.0
650.5
650.0
649.5
649.0
648.5
[m3/h]
0
3
6
9
12
15
18
21
24
Time Steps [h]
BS Kasnasan H
BS Kasnasan Q
ERBILDES21

APPENDIX 2

Flow and Pressure Records

KURDISTAN REGIONAL GOVERNMENT - IRAQ

MINISTRY OF MUNICIPALITIES AND TOURISM

Kurdistan Region Infrastructure

Water Sector Master Plan

HYDRAULIC CALCULATION

ERBIL

APPENDIX 2

FLOW- AND PRESSURE RECORDS

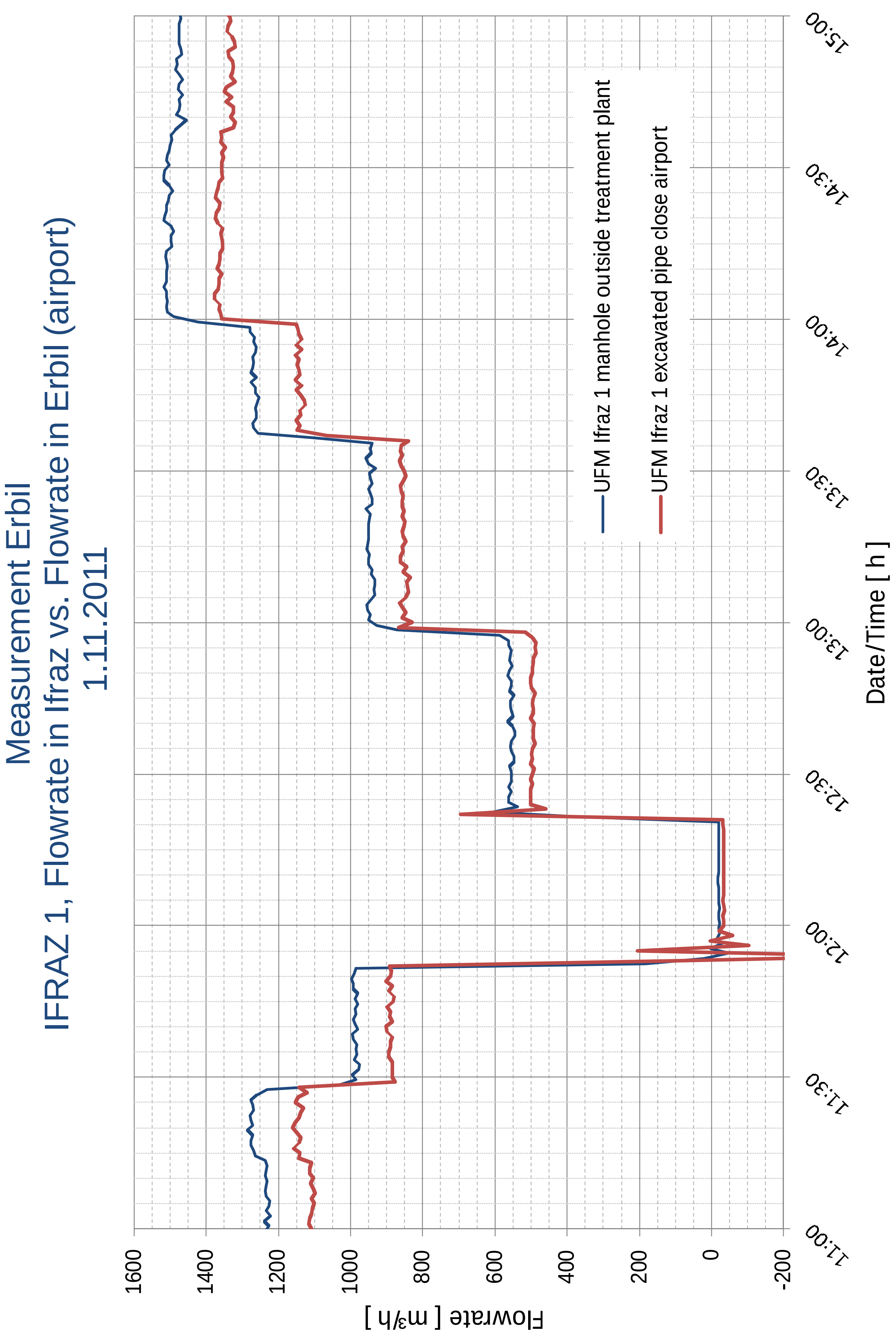
JUNE 2012

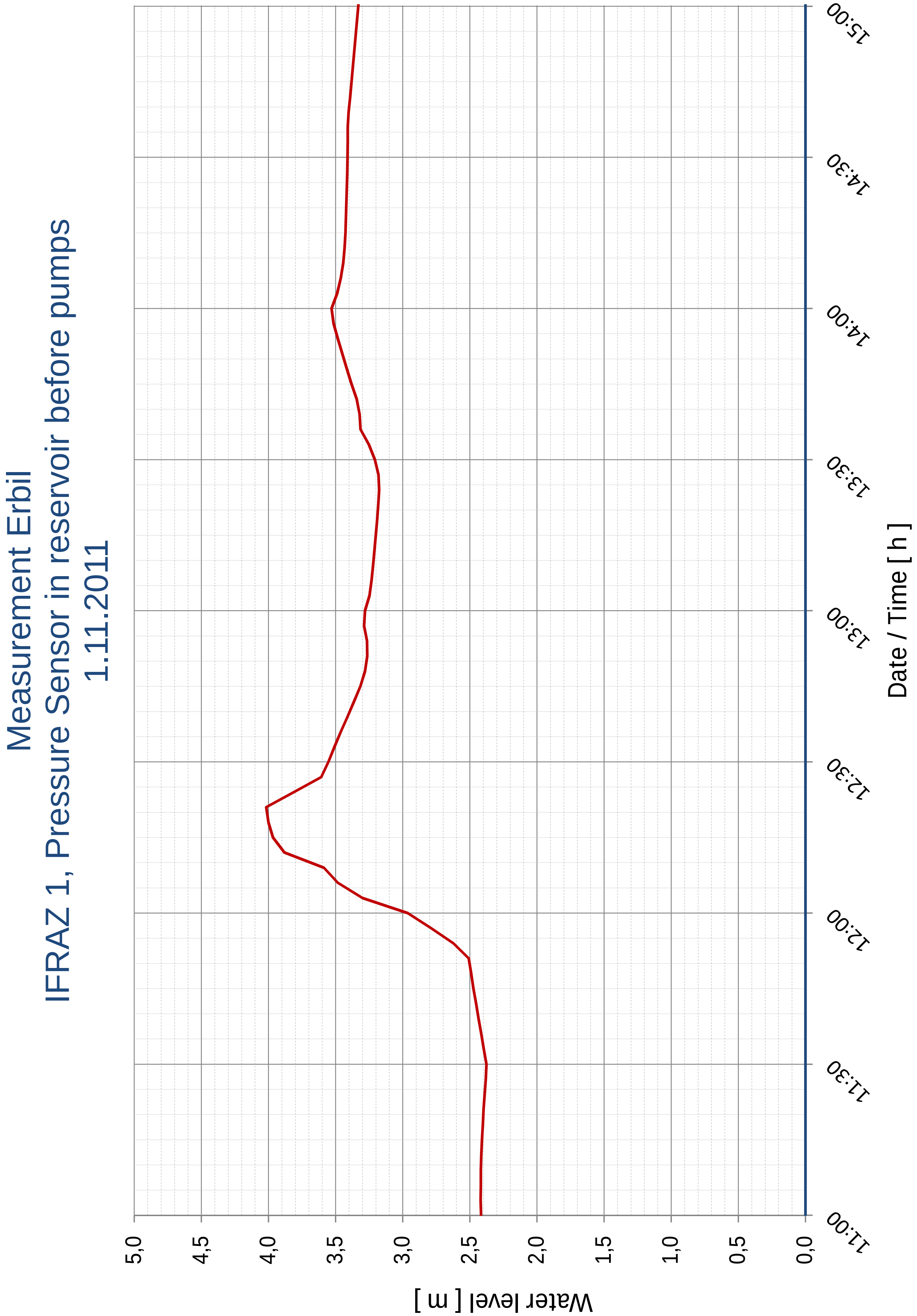
SETEC Engineering

Flow- and Pressure Records

Flowmeter and Pressure Sensor Records

Ifraz I

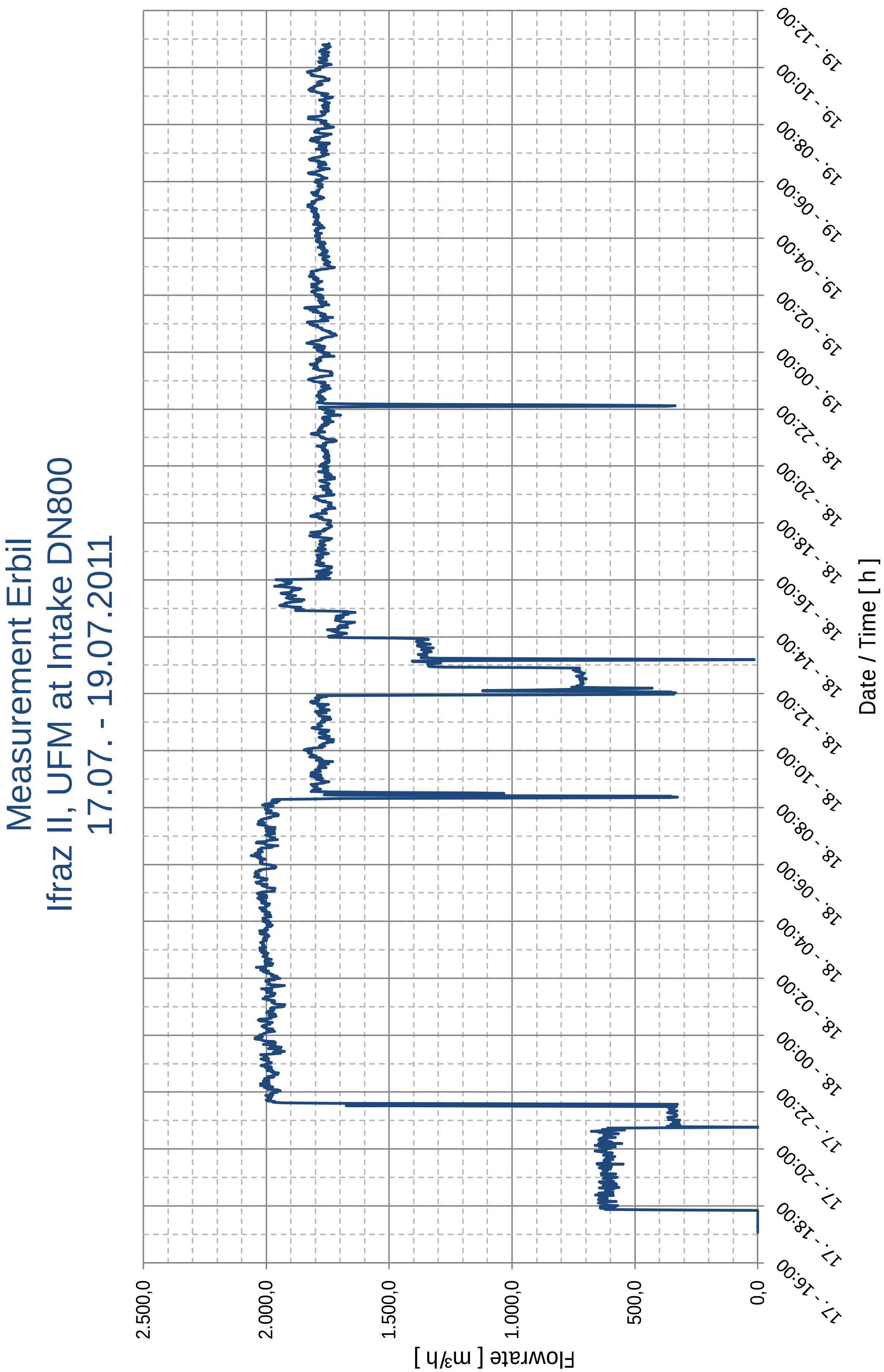

Measurement Erbil
IFRAZ 1, Flowrate in Ifraz vs. Flowrate in Erbil (airport)
1.11.2011
Flowrate [m³/h]
1600
1400
1200
1000
800
600
400
200
0
-200
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
Date/Time [h]
UFM Ifraz 1 manhole outside treatment plant
UFM Ifraz 1 excavated pipe close airport

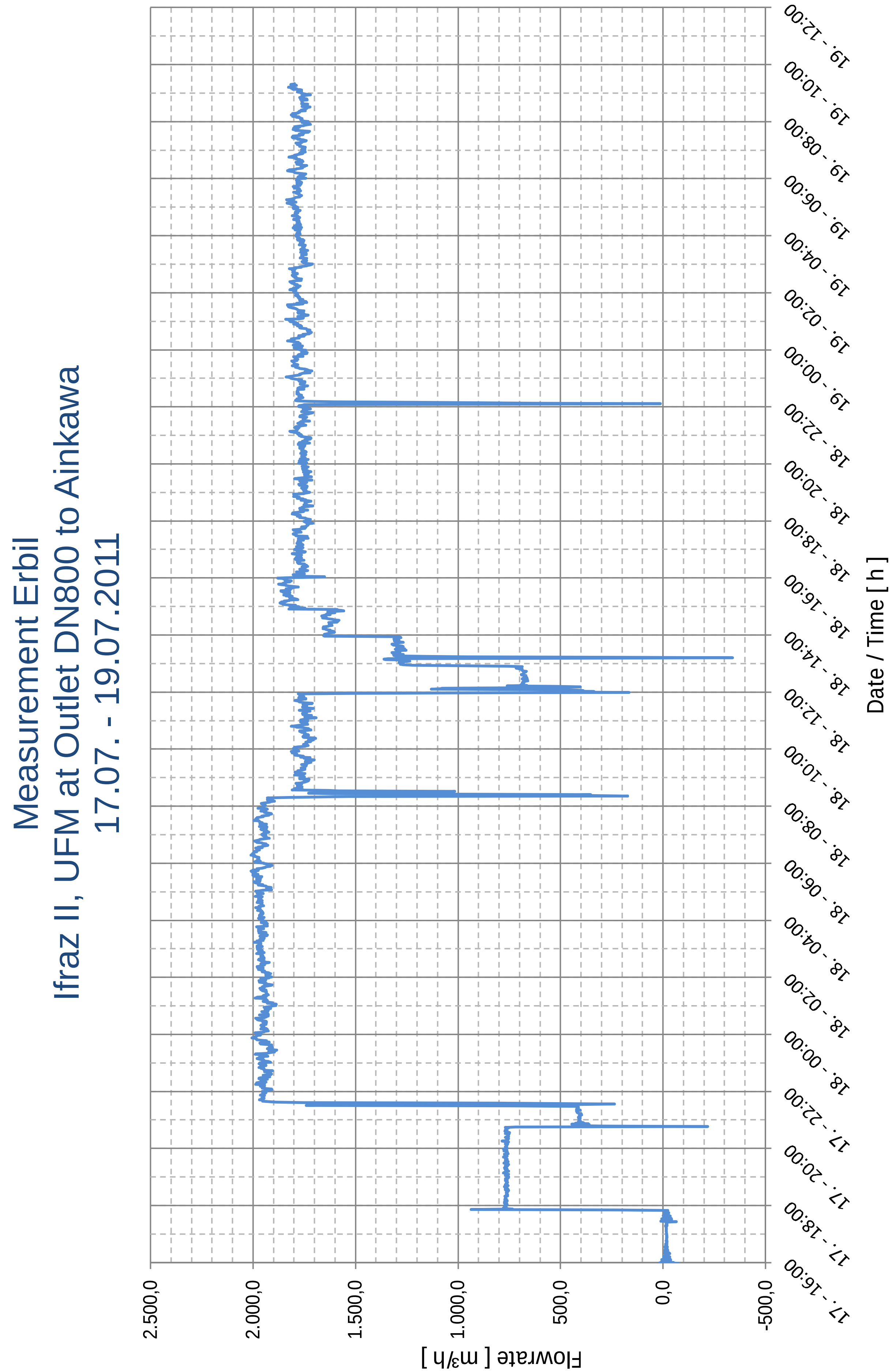

Measurement Erbil
IFRAZ 1, Pressure Sensor in reservoir before pumps
1.11.2011
Water level [m]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
Date / Time [h]
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00

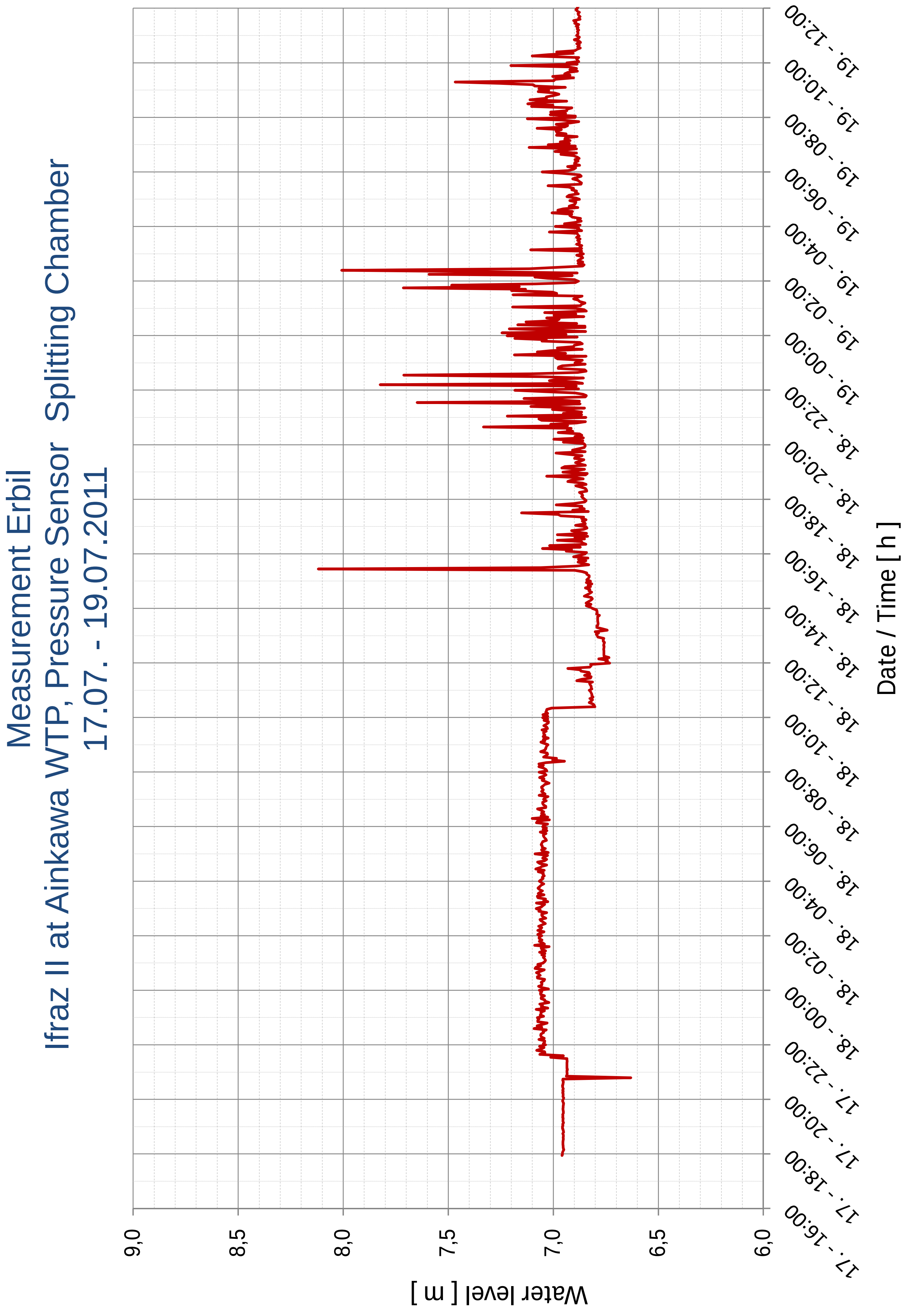
Flow- and Pressure Records

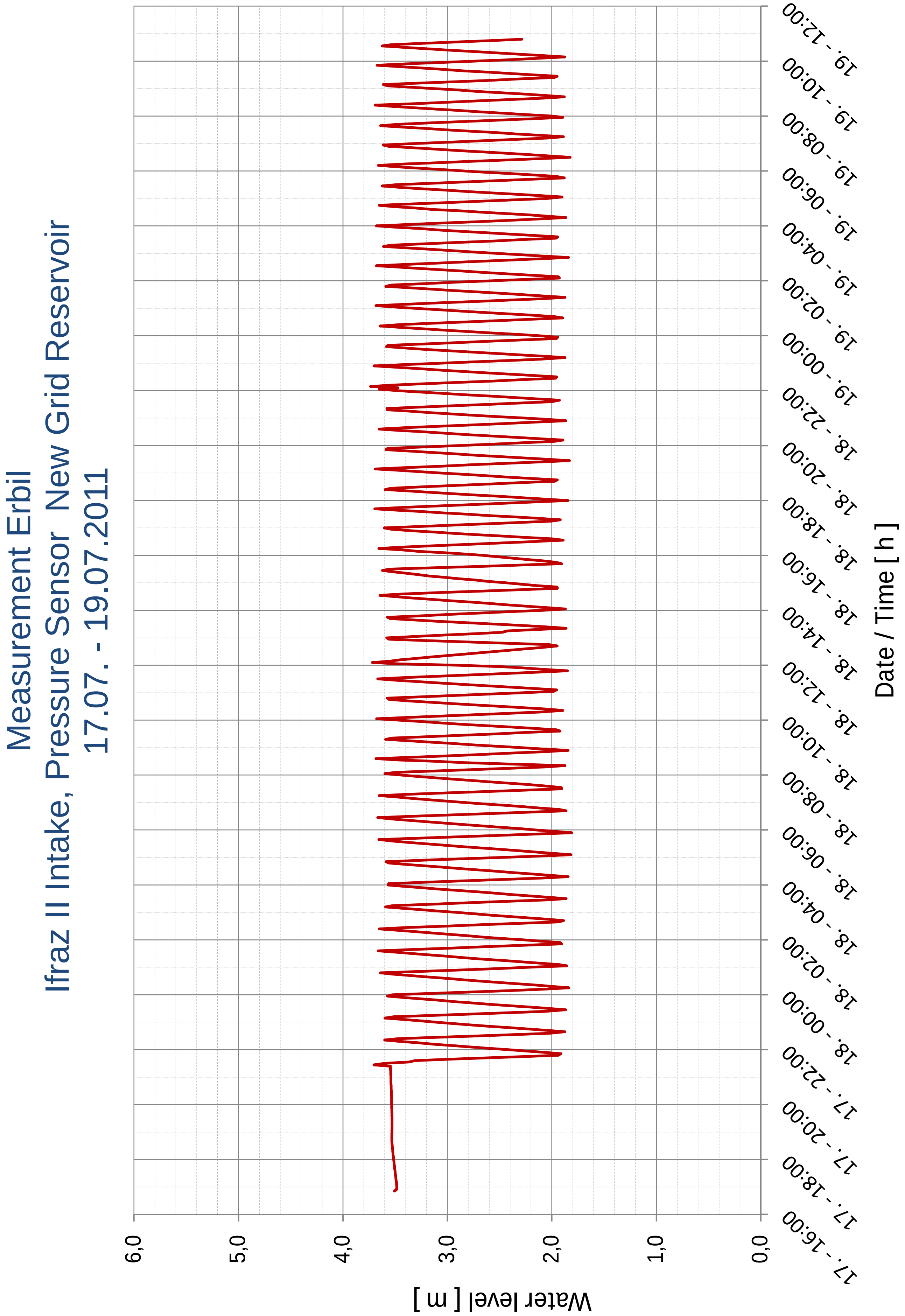
Flowmeter and Pressure Sensor Records

Ifraz II


Measurement Erbil
Ifraz II, UFM at Intake DN800
17.07. - 19.07.2011
Flowrate [m³/h]
Date / Time [h]
2.500,0
2.000,0
1.500,0
1.000,0
500,0
0,0
17. - 16:00
17. - 18:00
17. - 20:00
17. - 22:00
18. - 00:00
18. - 02:00
18. - 04:00
18. - 06:00
18. - 08:00
18. - 10:00
18. - 12:00
18. - 14:00
18. - 16:00
18. - 18:00
18. - 20:00
18. - 22:00
19. - 00:00
19. - 02:00
19. - 04:00
19. - 06:00
19. - 08:00
19. - 10:00
19. - 12:00


Measurement Erbil
Ifraz II, UFM at Outlet DN800 to Ainkawa
17.07. - 19.07.2011
Flowrate [m³/h]
Date / Time [h]
2.500,0
2.000,0
1.500,0
1.000,0
500,0
0,0
-500,0
17. - 16:00
17. - 18:00
17. - 20:00
17. - 22:00
18. - 00:00
18. - 02:00
18. - 04:00
18. - 06:00
18. - 08:00
18. - 10:00
18. - 12:00
18. - 14:00
18. - 16:00
18. - 18:00
18. - 20:00
18. - 22:00
19. - 00:00
19. - 02:00
19. - 04:00
19. - 06:00
19. - 08:00
19. - 10:00
19. - 12:00

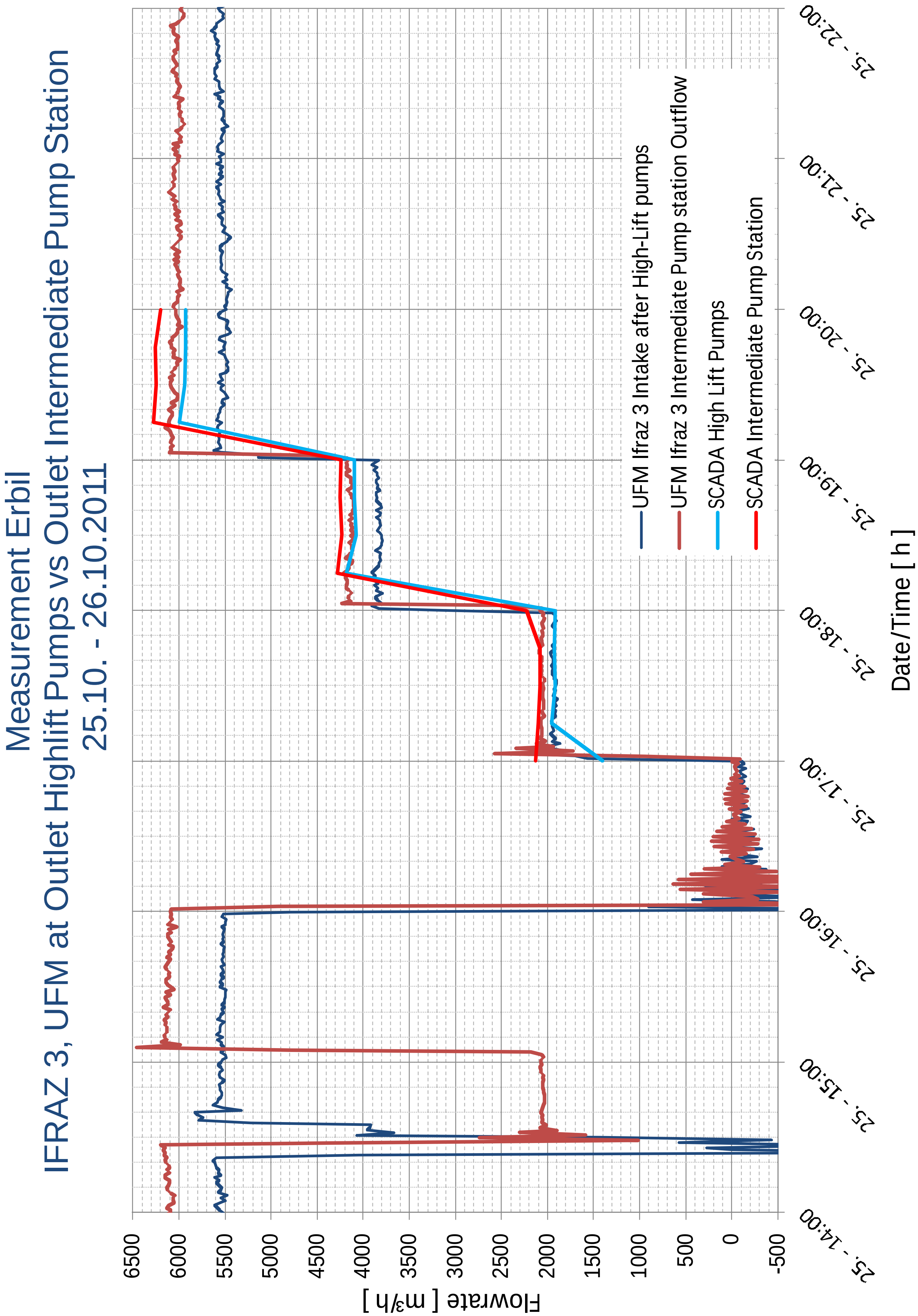

Measurement Erbil
Ifraz II at Ainkawa WTP, Pressure Sensor Splitting Chamber
17.07. - 19.07.2011
Water level [m]
9,0
8,5
8,0
7,5
7,0
6,5
6,0
Date / Time [h]
17. - 16:00
17. - 18:00
17. - 20:00
17. - 22:00
18. - 00:00
18. - 02:00
18. - 04:00
18. - 06:00
18. - 08:00
18. - 10:00
18. - 12:00
18. - 14:00
18. - 16:00
18. - 18:00
18. - 20:00
18. - 22:00
19. - 00:00
19. - 02:00
19. - 04:00
19. - 06:00
19. - 08:00
19. - 10:00
19. - 12:00

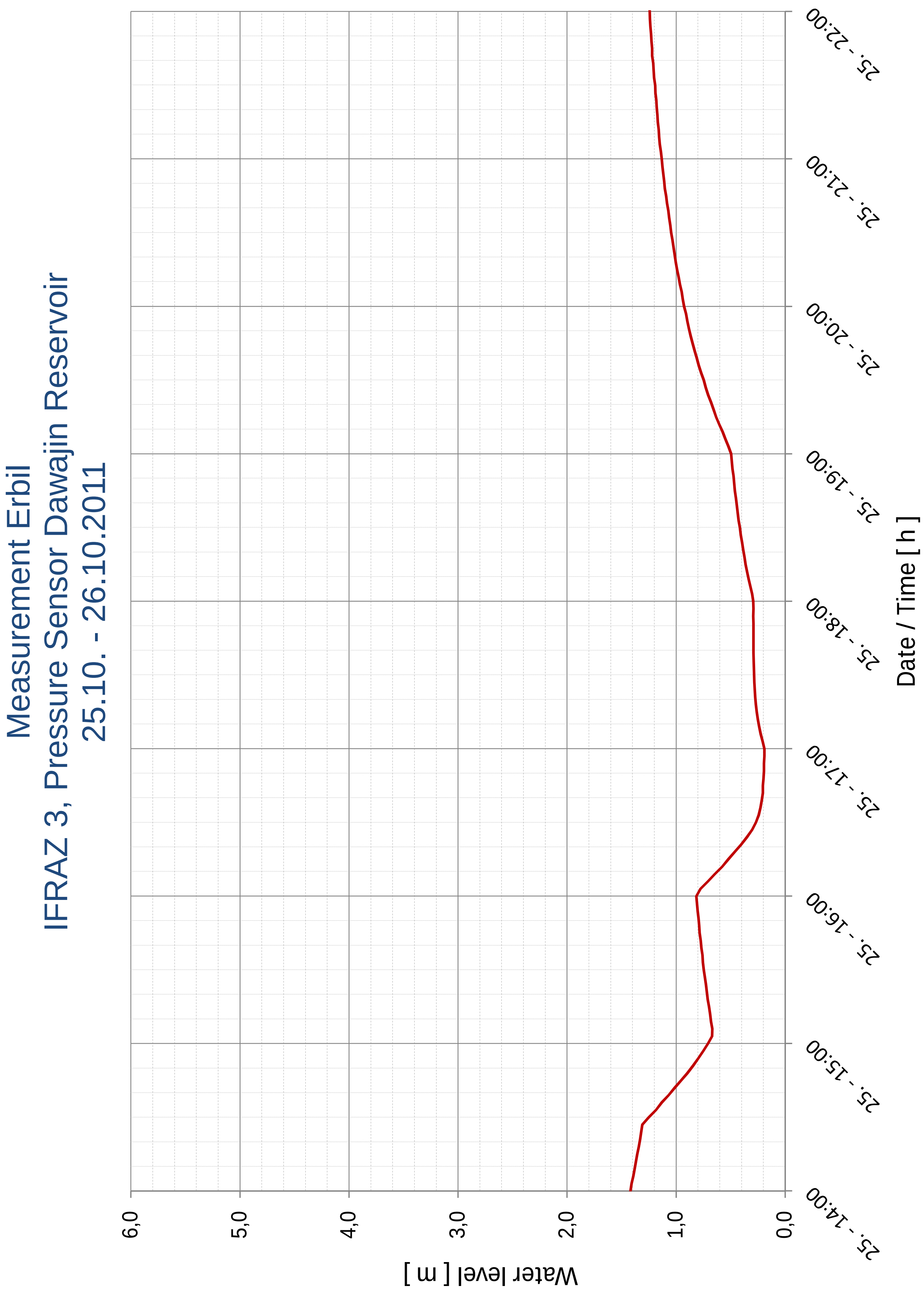

Measurement Erbil
Ifraz II Intake, Pressure Sensor New Grid Reservoir
17.07. - 19.07.2011
Water level [m]
0,0
1,0
2,0
3,0
4,0
5,0
6,0
Date / Time [h]
17. - 16:00
17. - 18:00
17. - 20:00
17. - 22:00
18. - 00:00
18. - 02:00
18. - 04:00
18. - 06:00
18. - 08:00
18. - 10:00
18. - 12:00
18. - 14:00
18. - 16:00
18. - 18:00
18. - 20:00
18. - 22:00
19. - 00:00
19. - 02:00
19. - 04:00
19. - 06:00
19. - 08:00
19. - 10:00
19. - 12:00

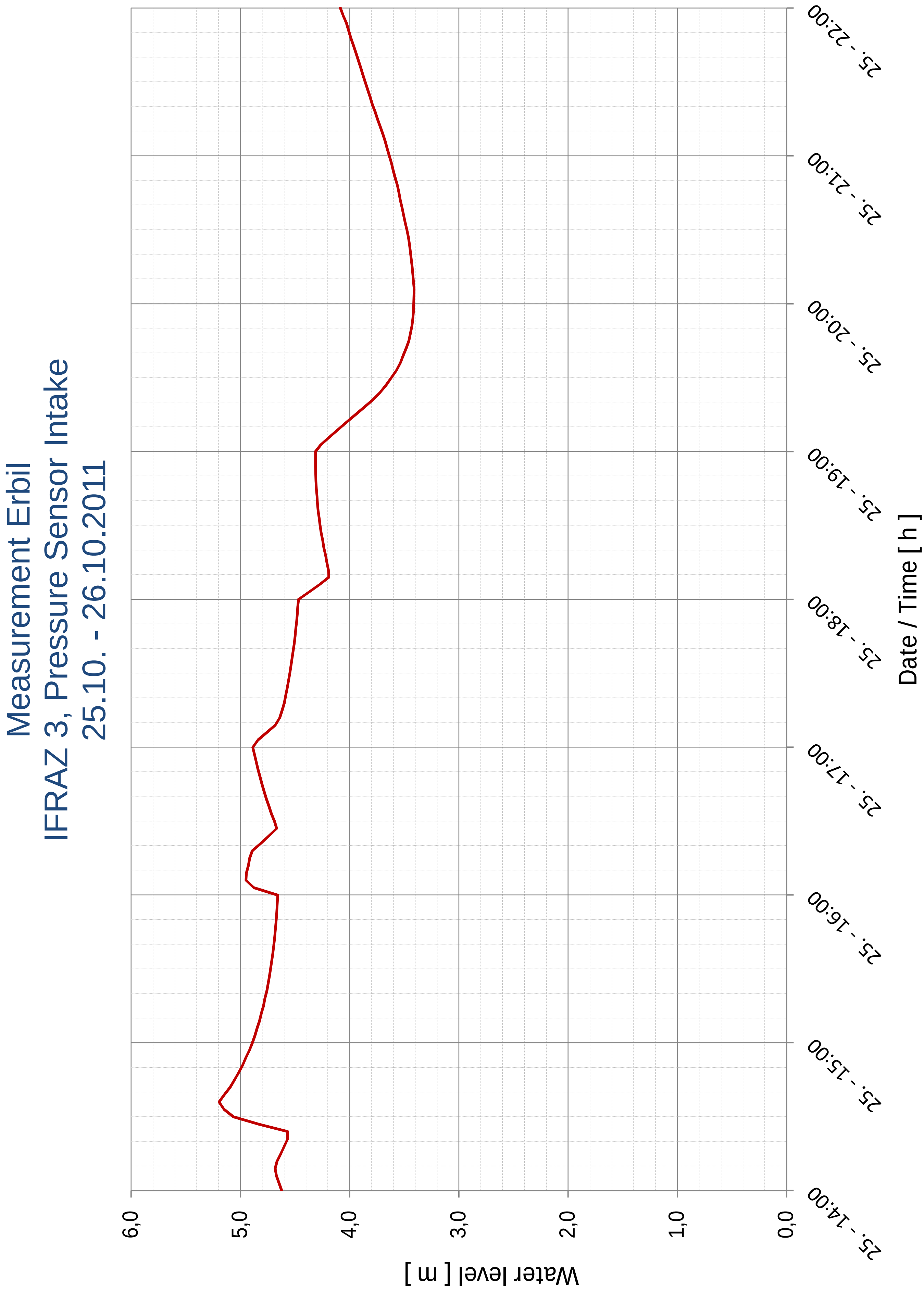
Flow- and Pressure Records

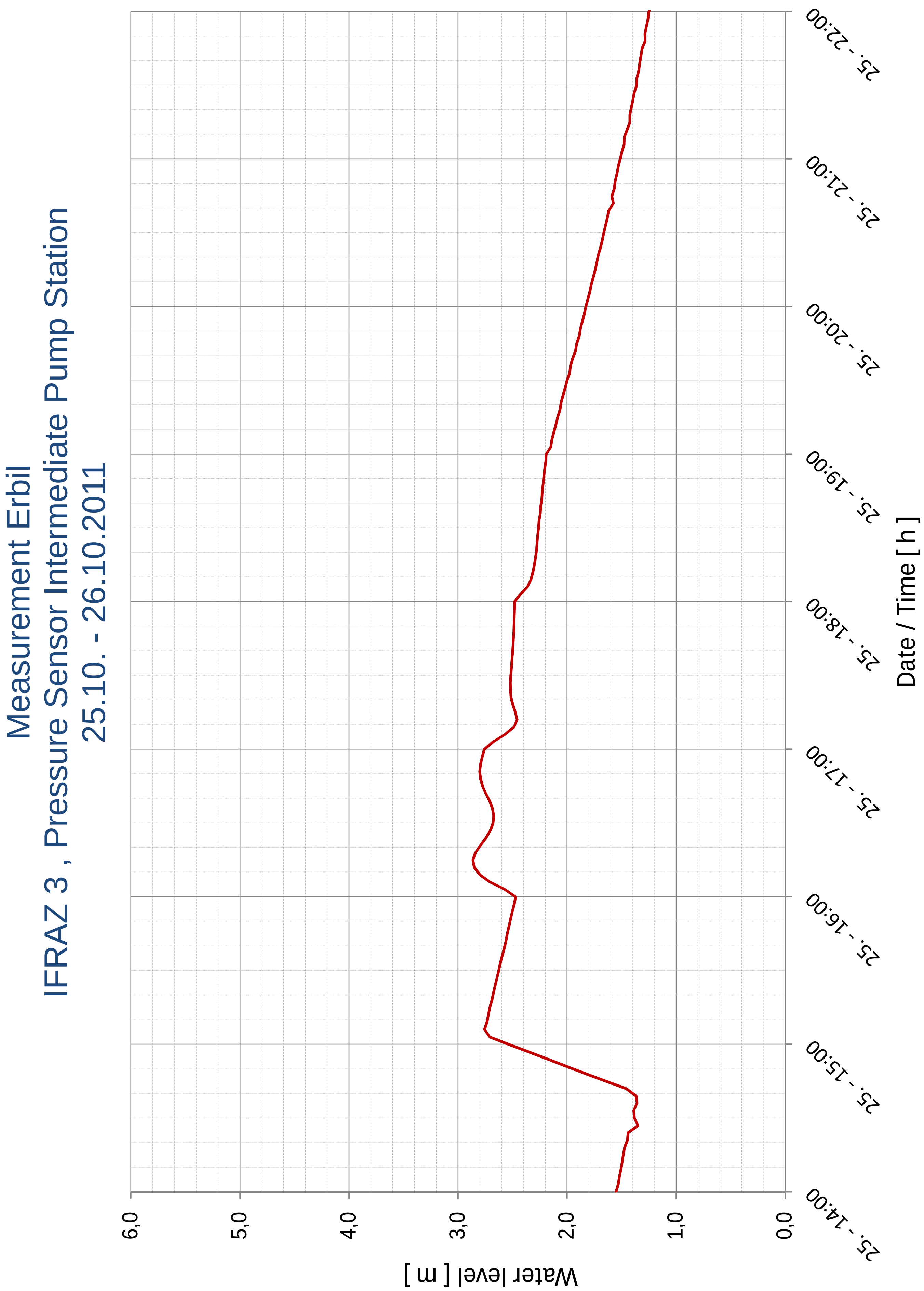
Flowmeter and Pressure Sensor Records

Ifraz III


Measurement Erbil
IFRAZ 3, UFM at Outlet Highlift Pumps vs Outlet Intermediate Pump Station
25.10. - 26.10.2011
Flowrate [m³/h]
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
25. - 14:00
25. - 15:00
25. - 16:00
25. - 17:00
25. - 18:00
25. - 19:00
25. - 20:00
25. - 21:00
25. - 22:00
Date/Time [h]
UFM Ifraz 3 Intake after High-Lift pumps
UFM Ifraz 3 Intermediate Pump station Outflow
SCADA High Lift Pumps
SCADA Intermediate Pump Station


Measurement Erbil
IFRAZ 3, Pressure Sensor Dawajin Reservoir
25.10. - 26.10.2011
Water level [m]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
25. - 14:00
25. - 15:00
25. - 16:00
25. - 17:00
25. - 18:00
25. - 19:00
25. - 20:00
25. - 21:00
25. - 22:00
Date / Time [h]

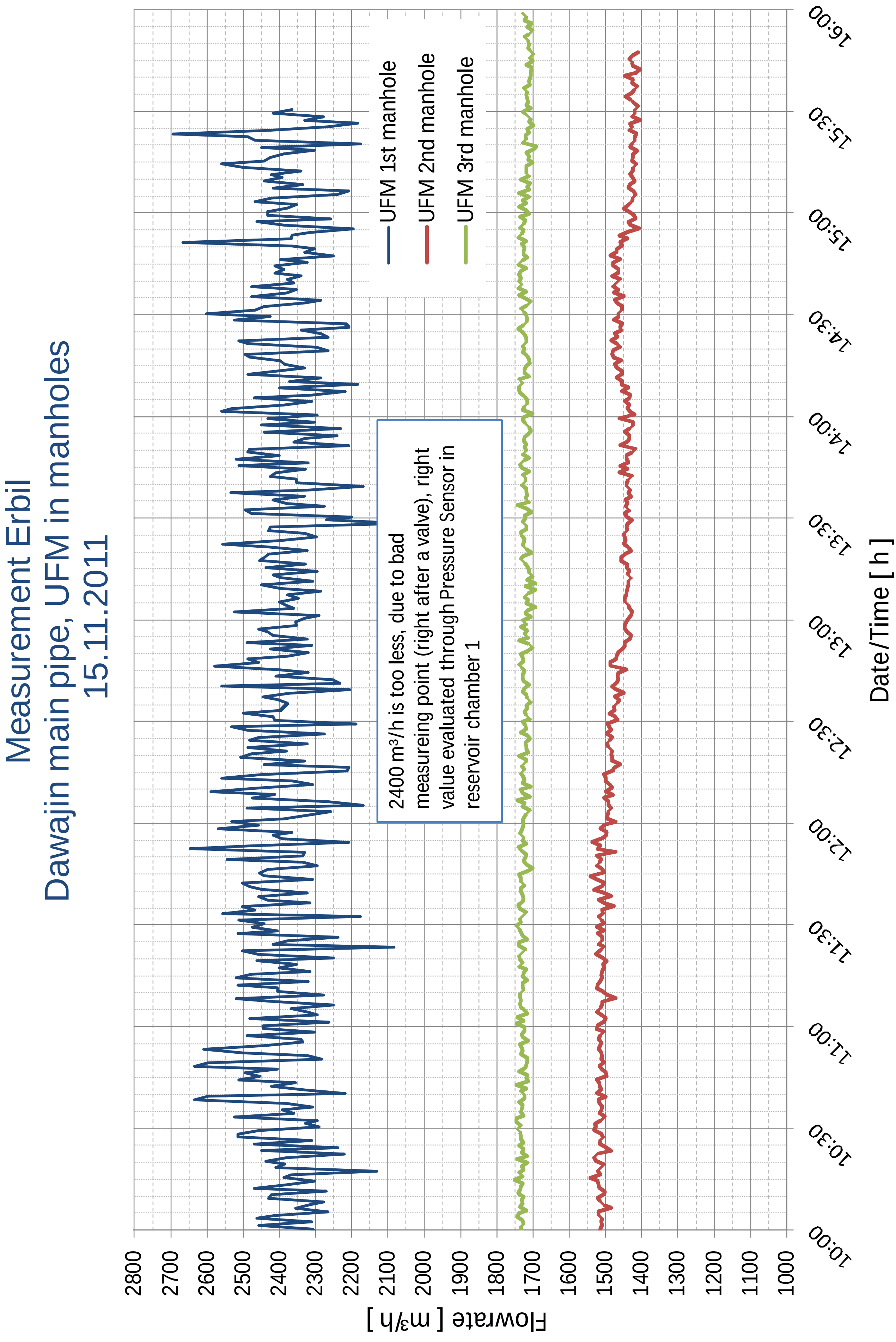

Measurement Erbil
IFRAZ 3, Pressure Sensor Intake
25.10. - 26.10.2011
Water level [m]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
Date / Time [h]
25. - 14:00
25. - 15:00
25. - 16:00
25. - 17:00
25. - 18:00
25. - 19:00
25. - 20:00
25. - 21:00
25. - 22:00

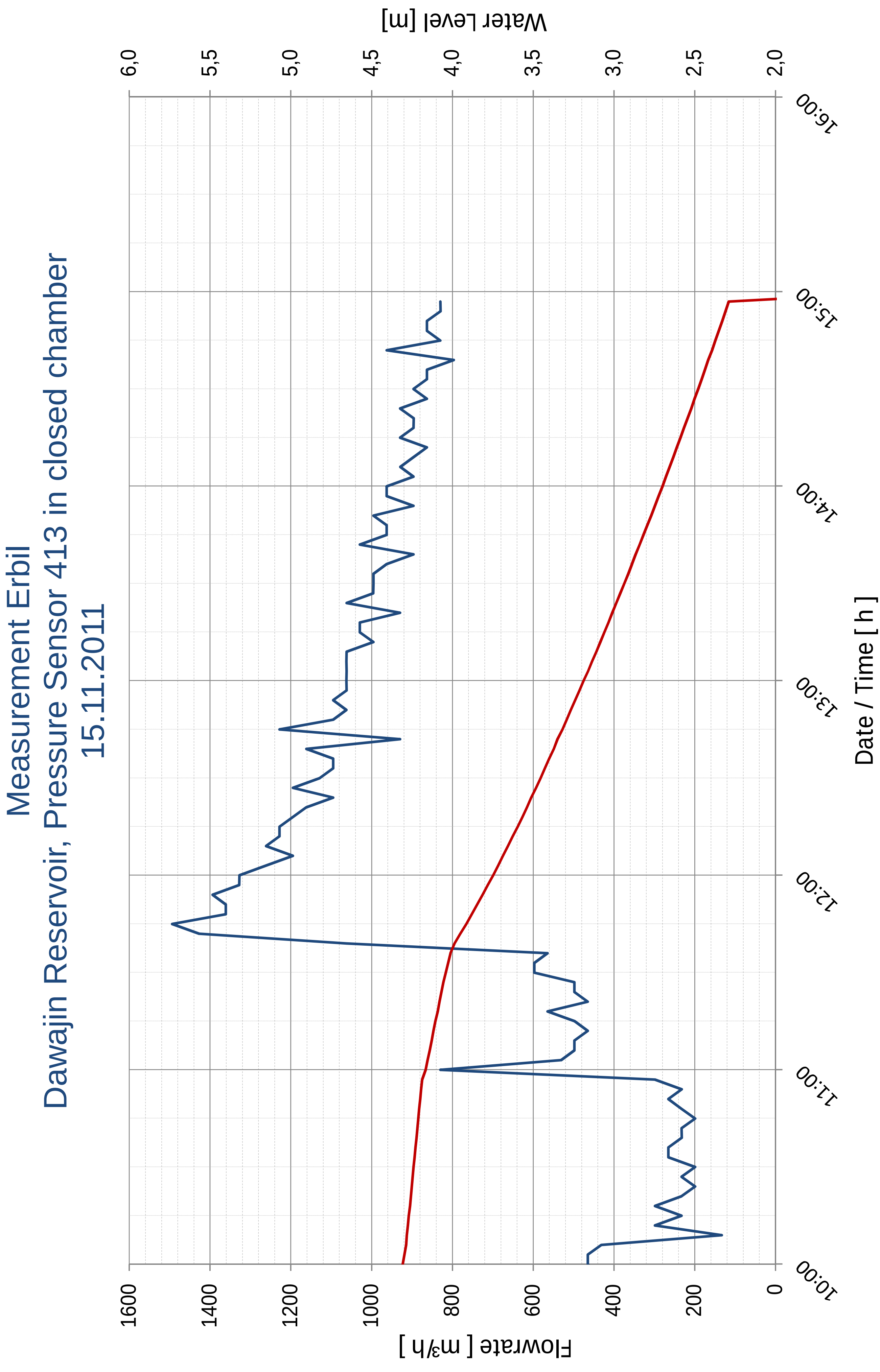

Measurement Erbil
IFRAZ 3 , Pressure Sensor Intermediate Pump Station
25.10. - 26.10.2011
Water level [m]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
25. - 14:00
25. - 15:00
25. - 16:00
25. - 17:00
25. - 18:00
25. - 19:00
25. - 20:00
25. - 21:00
25. - 22:00
Date / Time [h]

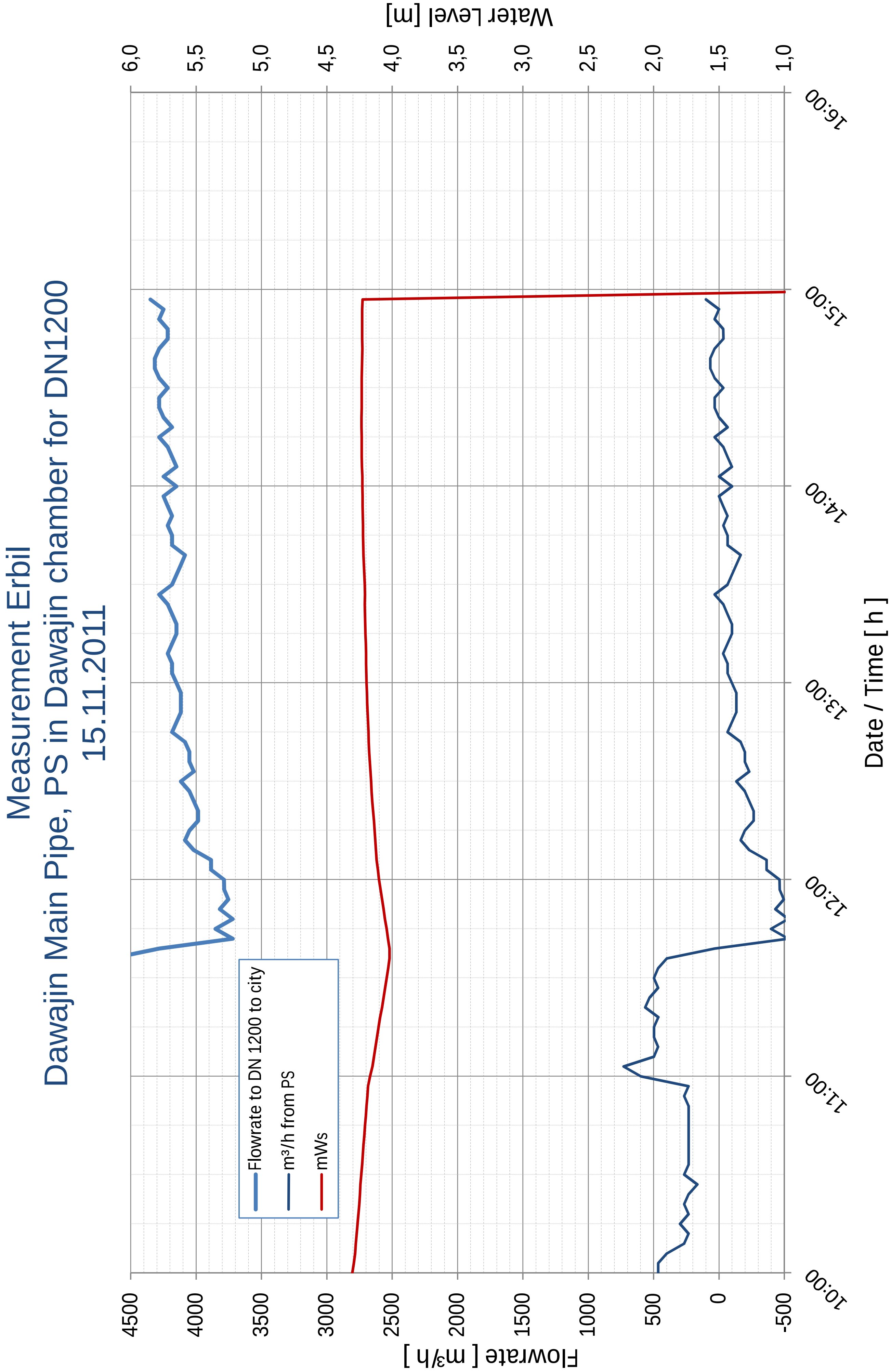
Flow- and Pressure Records

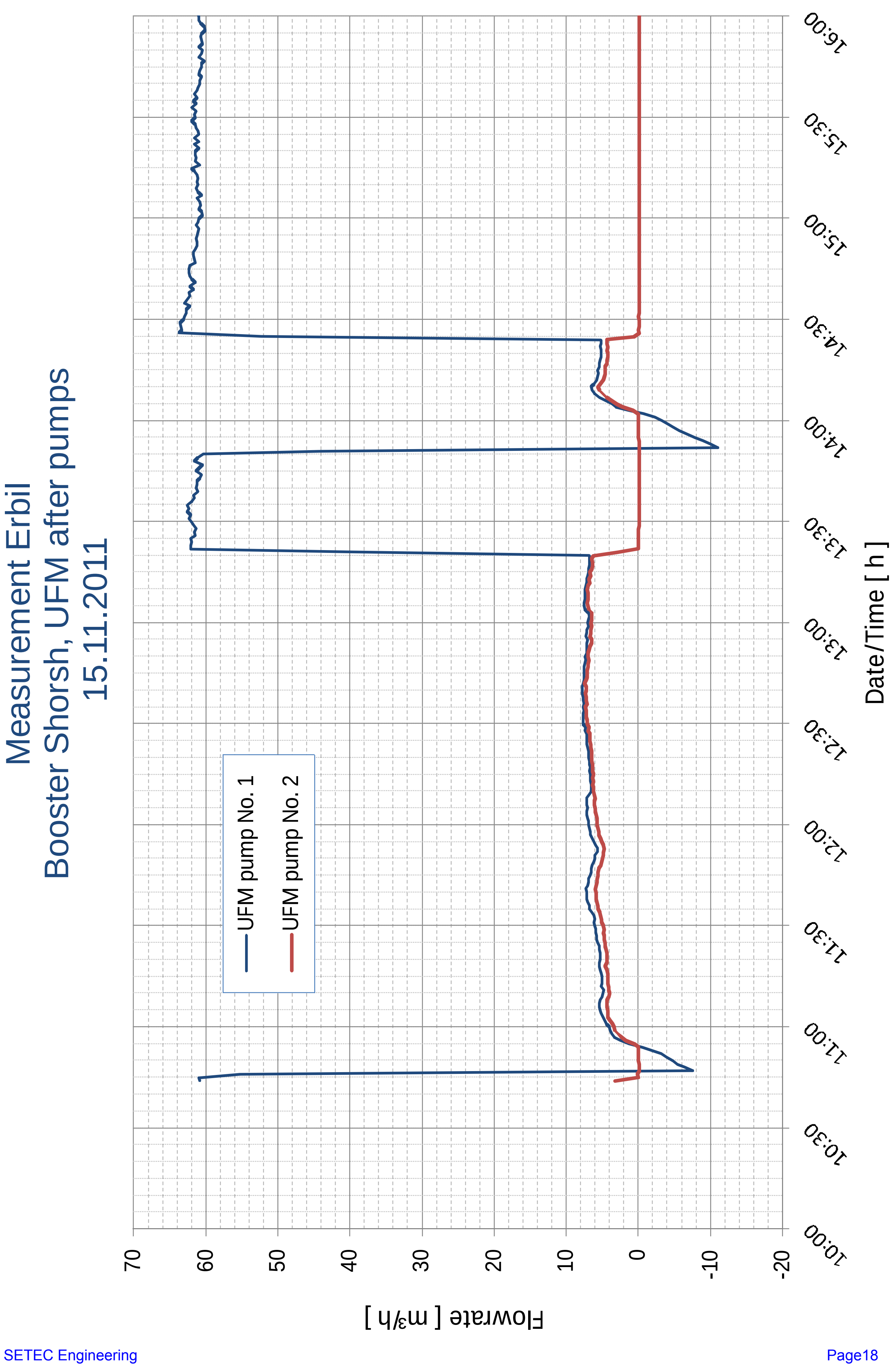
Flowmeter and Pressure Sensor Records

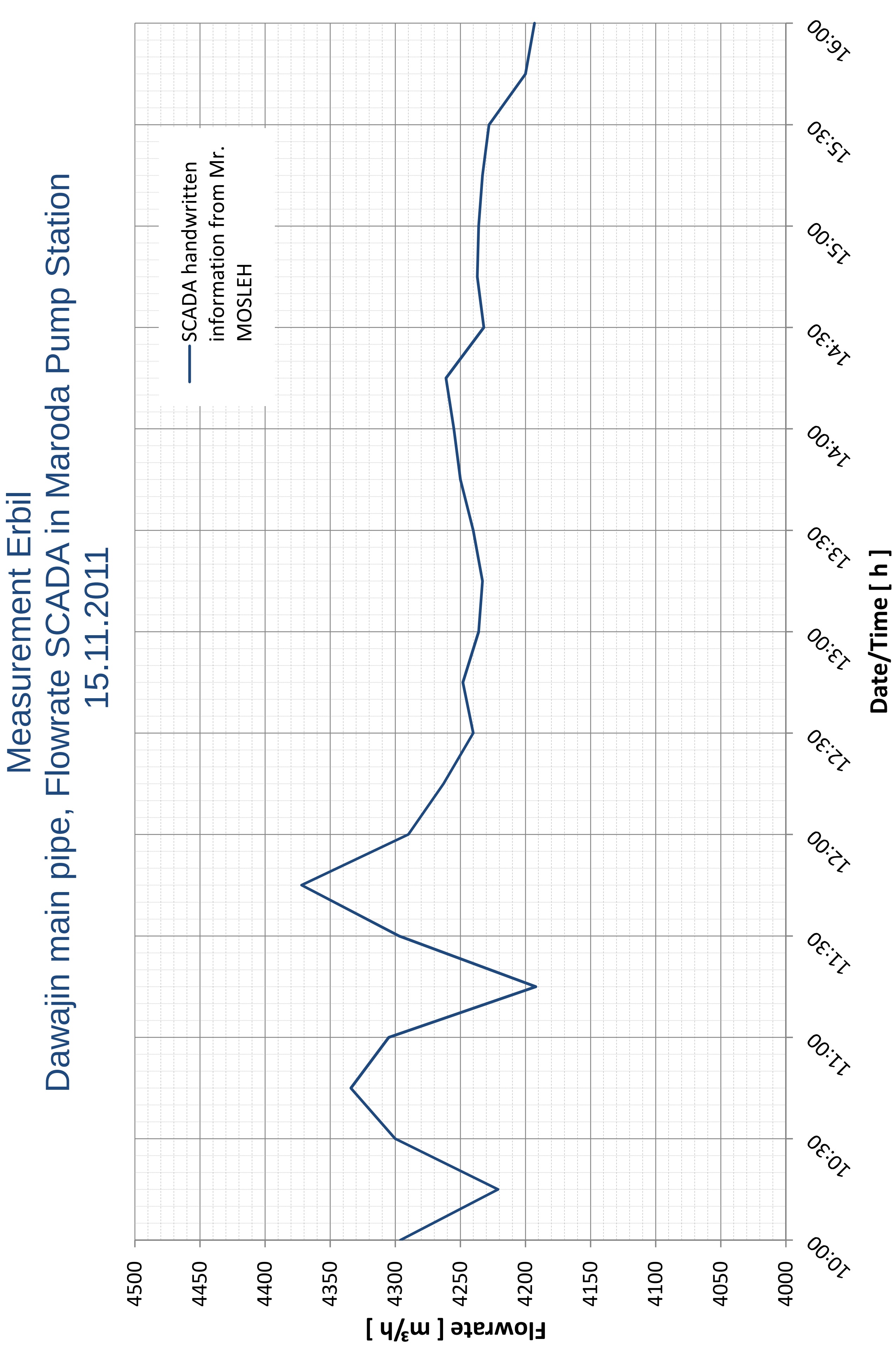
Dawajin Main Pipe


Measurement Erbil
Dawajin main pipe, UFM in manholes
15.11.2011
UFM 1st manhole
UFM 2nd manhole
UFM 3rd manhole
2400 m³/h is too less, due to bad measureing point (right after a valve), right value evaluated through Pressure Sensor in reservoir chamber 1
Flowrate [m³/h]
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
Date/Time [h]
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00


Measurement Erbil
Dawajin Reservoir, Pressure Sensor 413 in closed chamber
15.11.2011
Water Level [m]
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1600
1400
1200
1000
800
600
400
200
0
Flowrate [m³/h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Date / Time [h]


Measurement Erbil
Dawajin Main Pipe, PS in Dawajin chamber for DN1200
15.11.2011
Flowrate to DN 1200 to city
m³/h from PS
mWs
Flowrate [m³/h]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Water Level [m]
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
Date / Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00

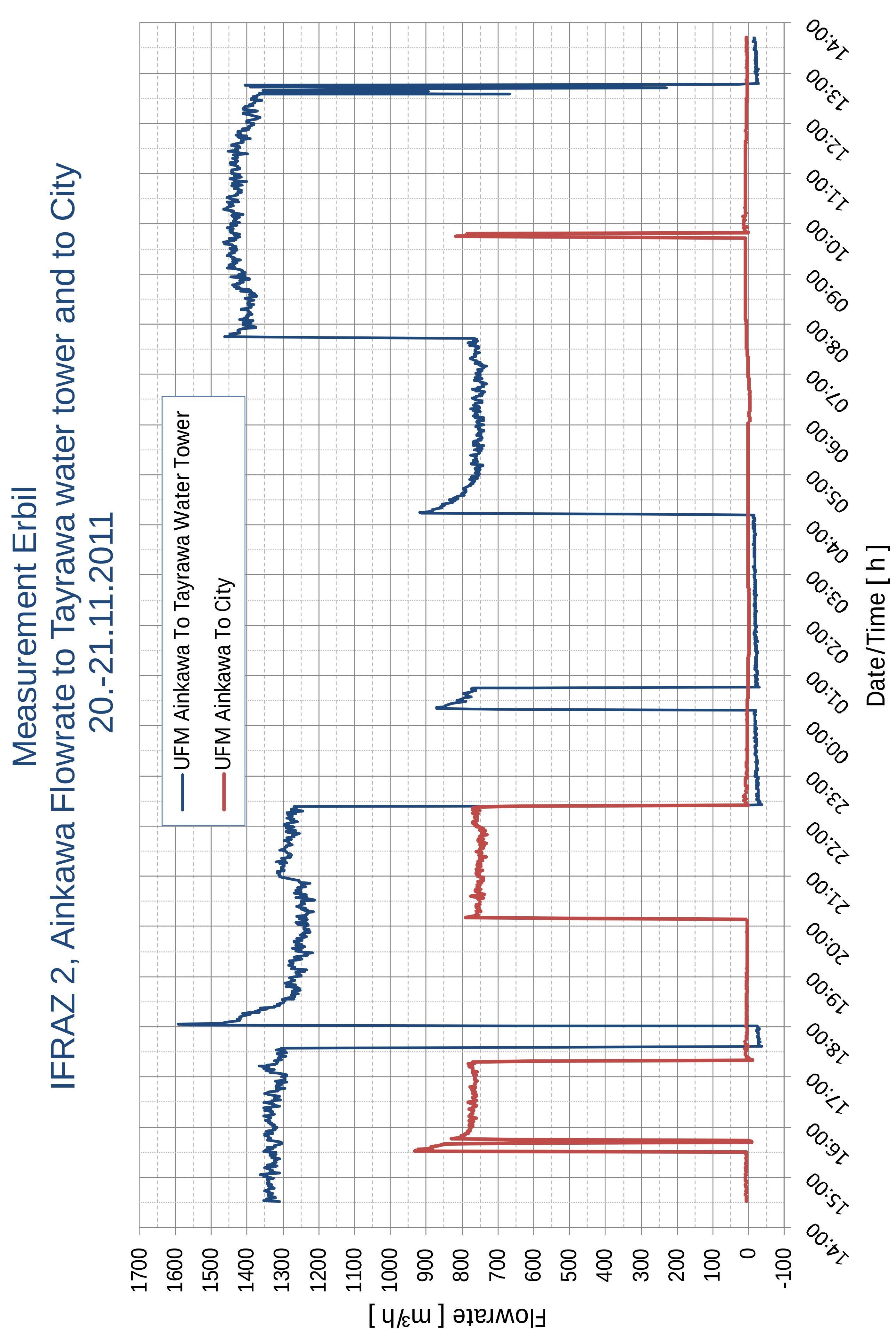

Measurement Erbil
Booster Shorsh, UFM after pumps
15.11.2011
UFM pump No. 1
UFM pump No. 2
Flowrate [m³/h]
Date/Time [h]
70
60
50
40
30
20
10
0
-10
-20
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00

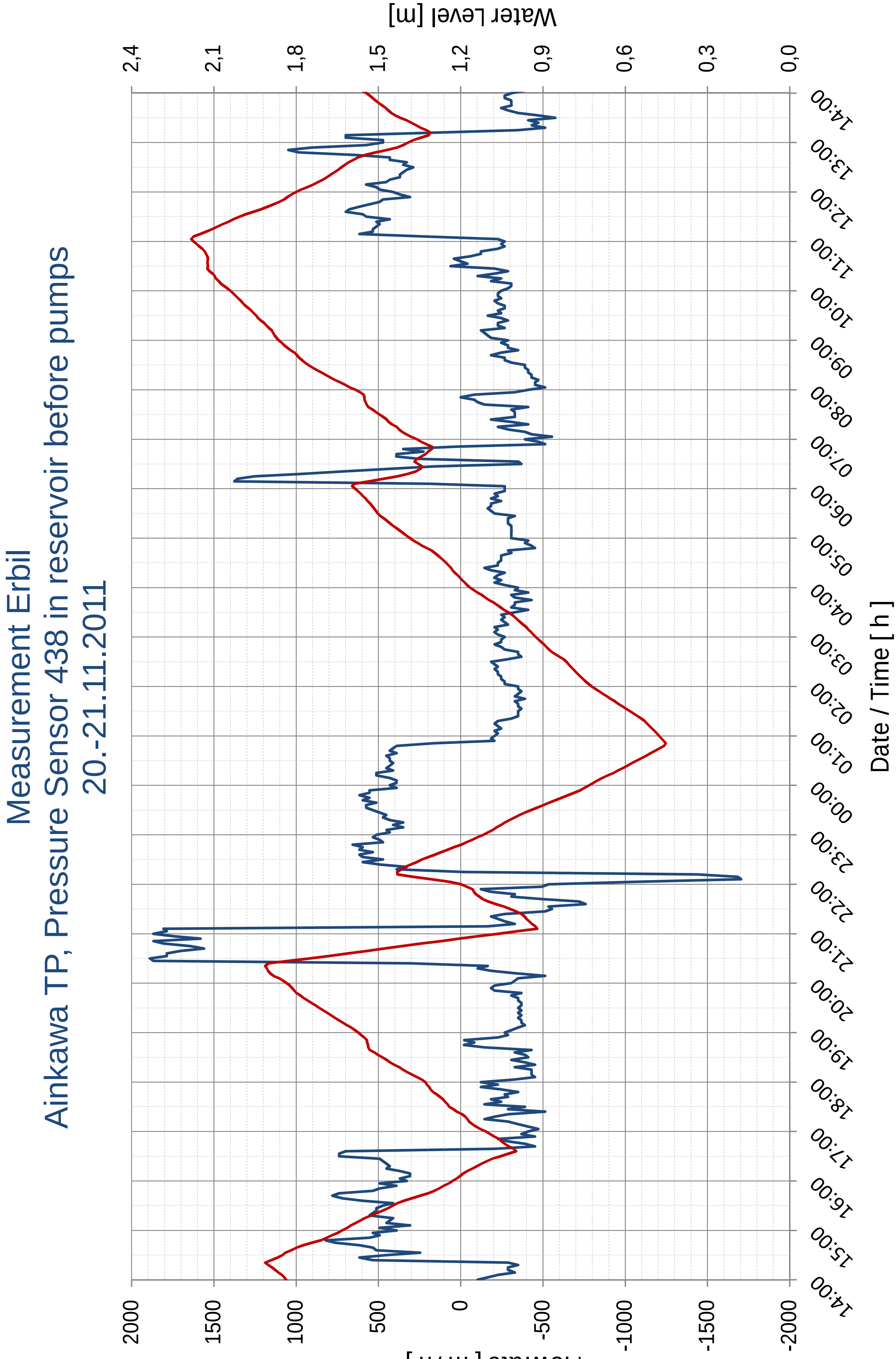

Measurement Erbil
Dawajin main pipe, Flowrate SCADA in Maroda Pump Station
15.11.2011
SCADA handwritten information from Mr. MOSLEH
Flowrate [m³/h]
Date/Time [h]
4500
4450
4400
4350
4300
4250
4200
4150
4100
4050
4000
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00

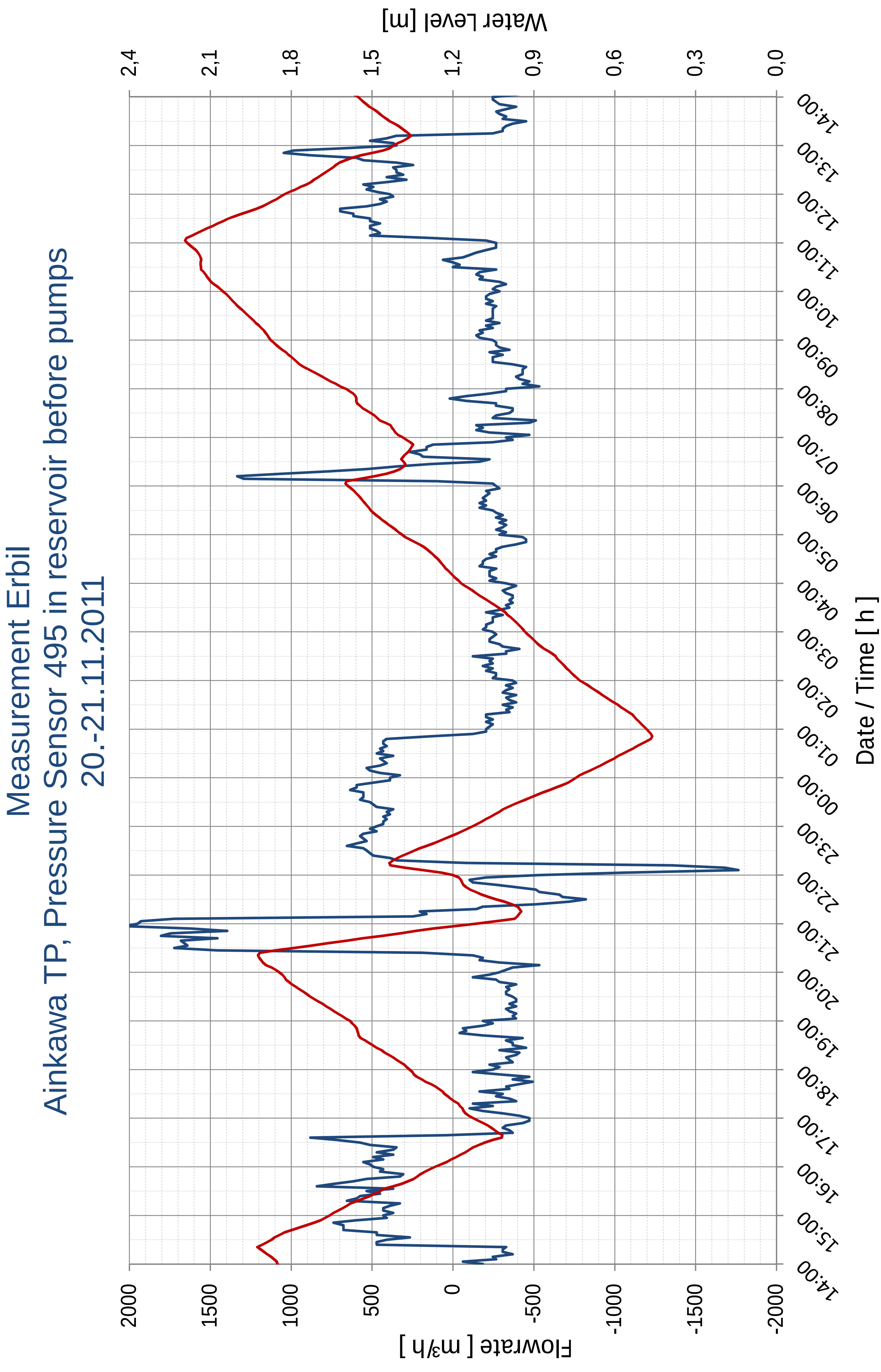
Flow- and Pressure Records

Flowmeter and Pressure Sensor Records

Ainkawa TP to Tayrawa Water Tower and to City


Measurement Erbil
IFRAZ 2, Ainkawa Flowrate to Tayrawa water tower and to City
20.-21.11.2011
UFM Ainkawa To Tayrawa Water Tower
UFM Ainkawa To City
Flowrate [m³/h]
Date/Time [h]
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

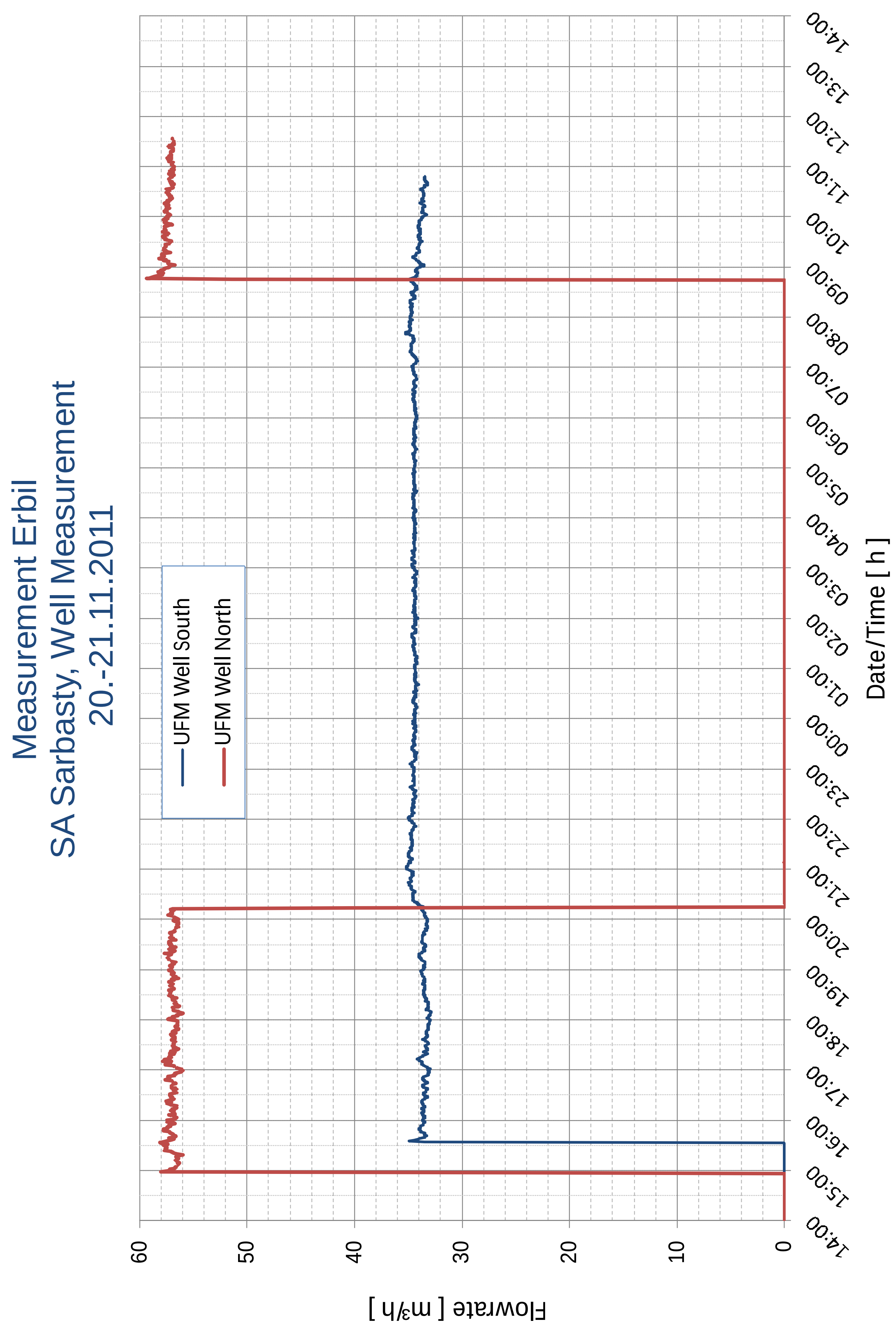

Measurement Erbil
Ainkawa TP, Pressure Sensor 438 in reservoir before pumps
20.-21.11.2011
Water Level [m]
2,4
2,1
1,8
1,5
1,2
0,9
0,6
0,3
0,0
Flowrate [m³/h]
2000
1500
1000
500
0
-500
-1000
-1500
-2000
Date / Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00


Measurement Erbil
Ainkawa TP, Pressure Sensor 495 in reservoir before pumps
20.-21.11.2011
Water Level [m]
2,4
2,1
1,8
1,5
1,2
0,9
0,6
0,3
0,0
Flowrate [m³/h]
2000
1500
1000
500
0
-500
-1000
-1500
-2000
Date / Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

Flow- and Pressure Records

Flowmeter and Pressure Sensor Records

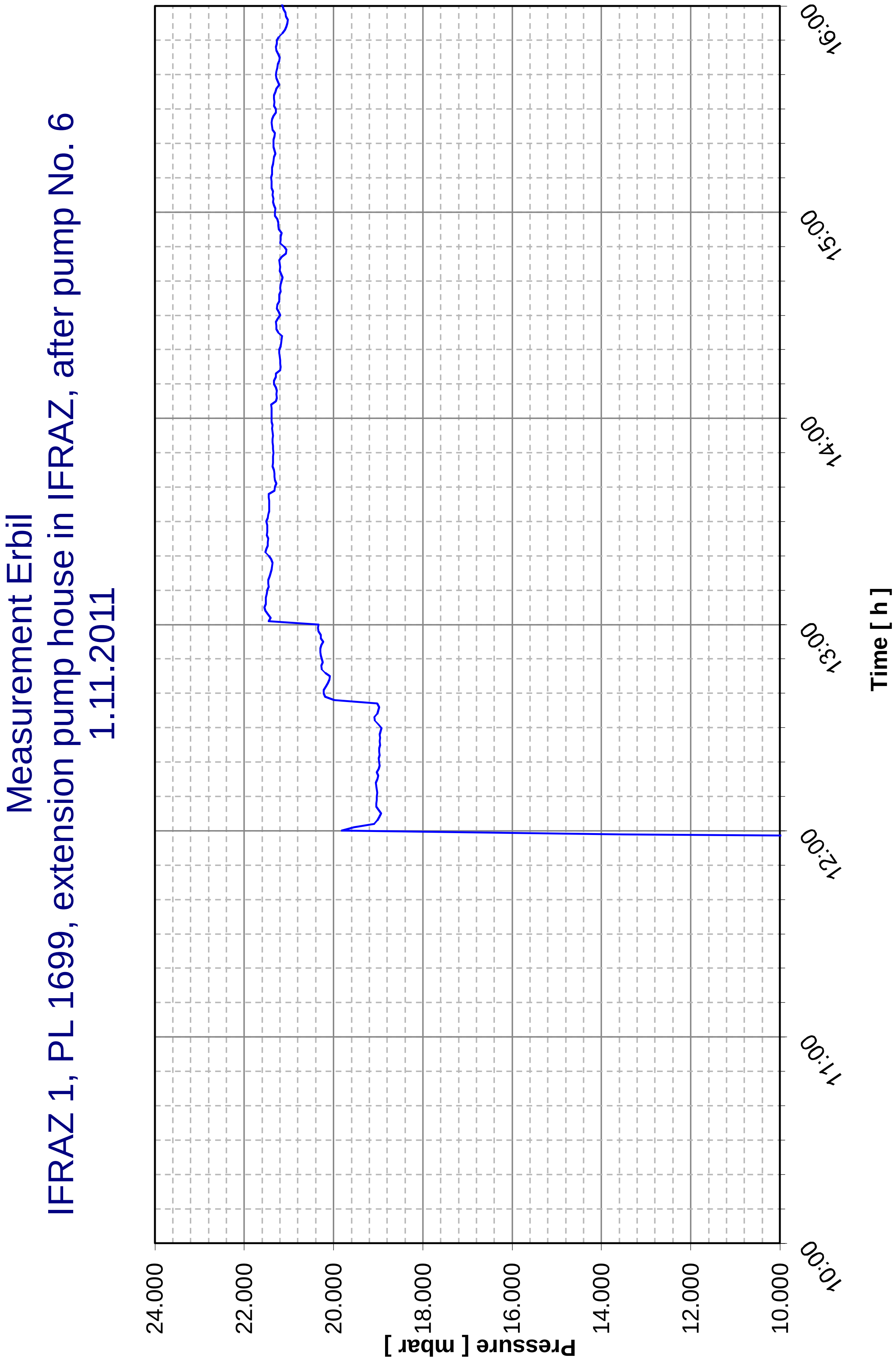
Sarbasty Area


Measurement Erbil
SA Sarbasty, Well Measurement
20.-21.11.2011
UFM Well South
UFM Well North
Flowrate [m³/h]
Date/Time [h]
0
10
20
30
40
50
60
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

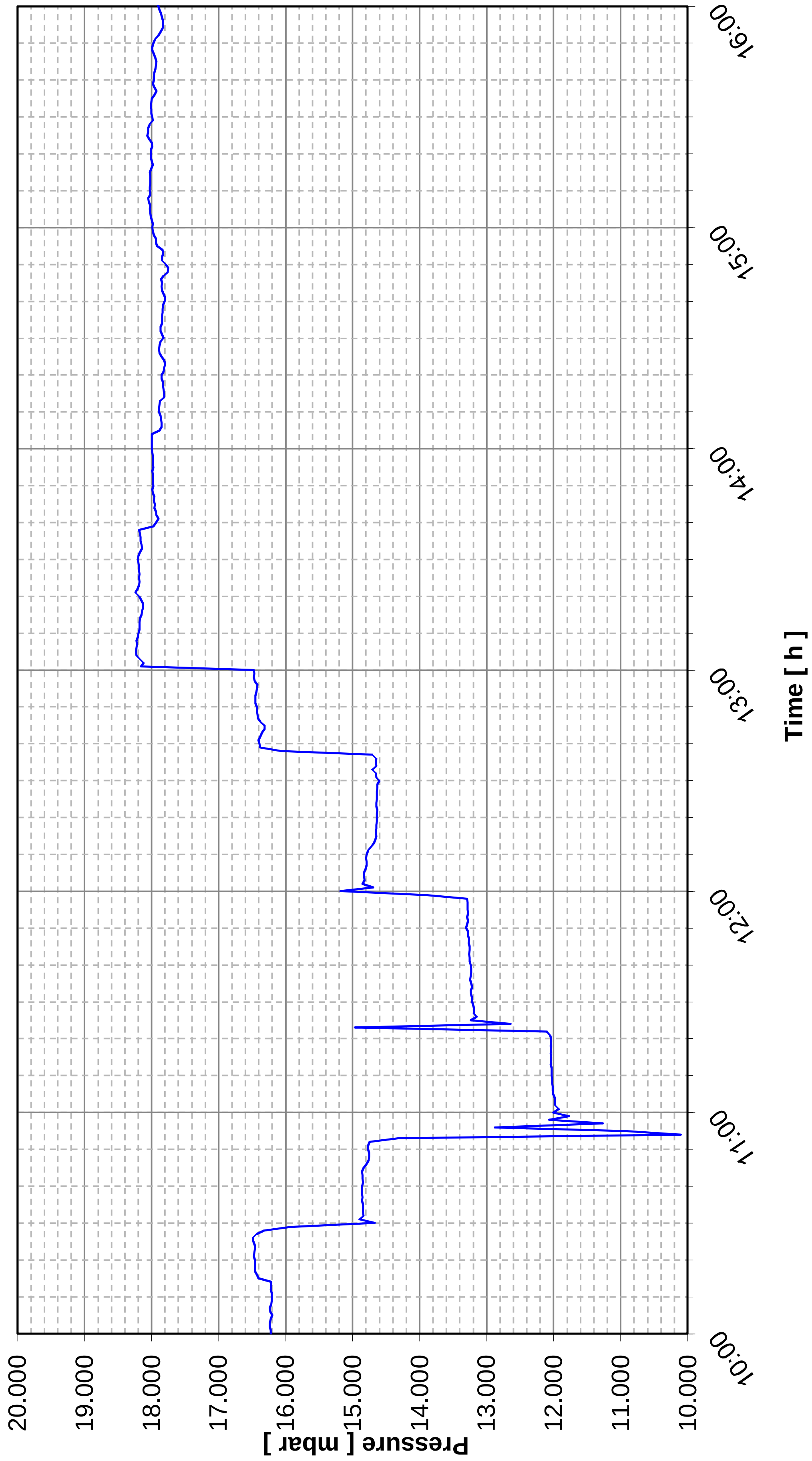
Flow- and Pressure Records

Pressure Logger Records

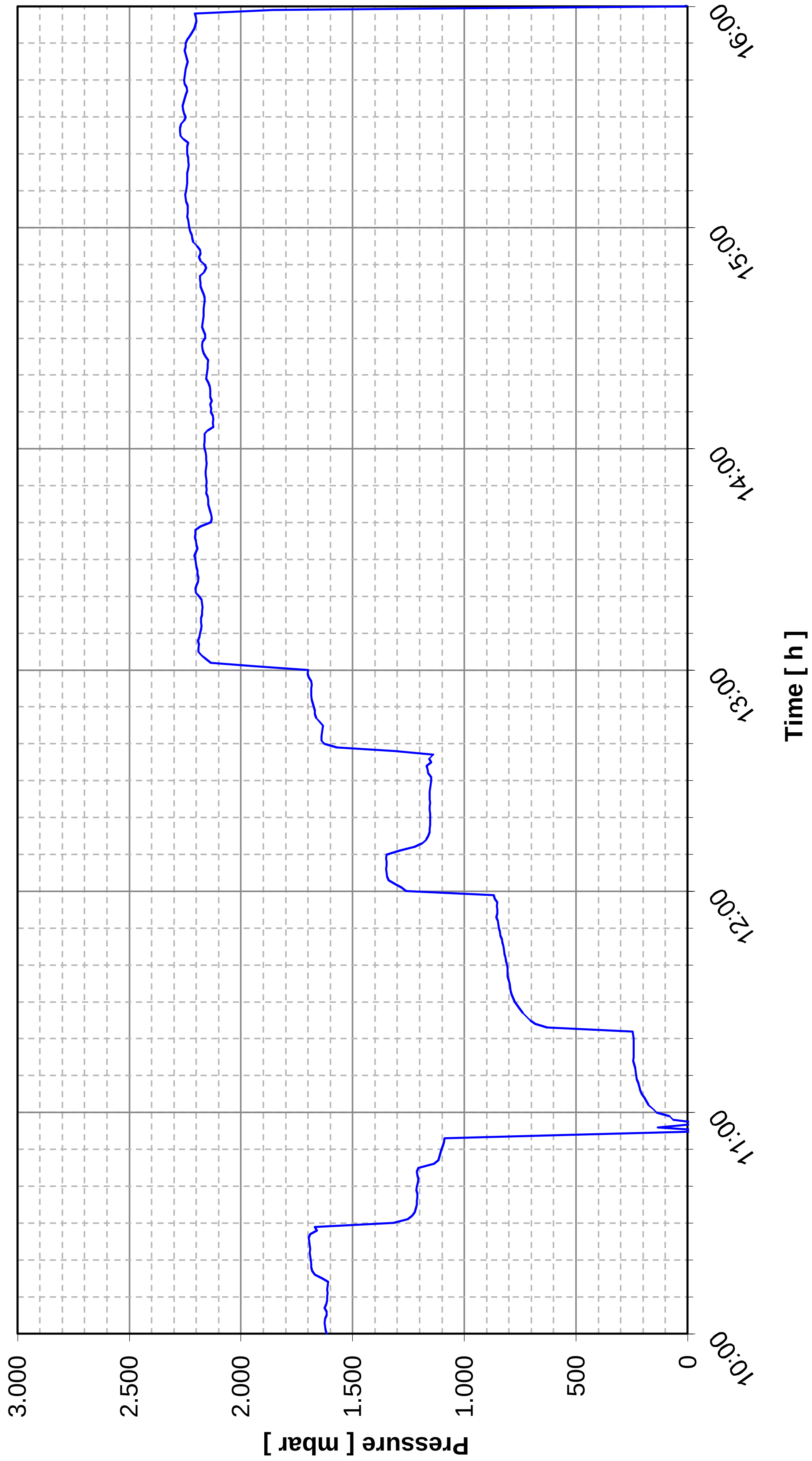
Ifraz I

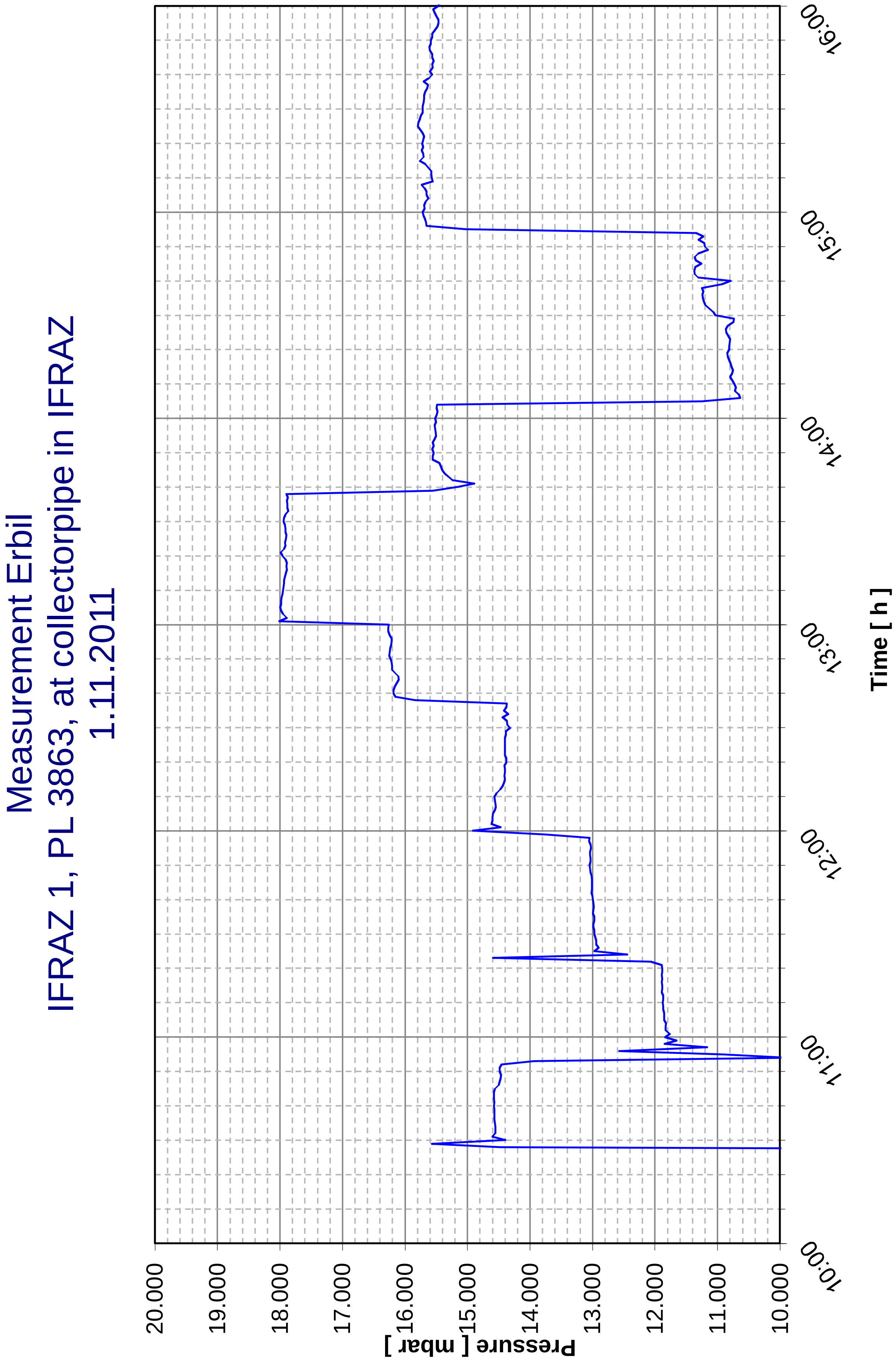

Measurement Erbil
IFRAZ 1, PL 1699, extension pump house in IFRAZ, after pump No. 6
1.11.2011
Pressure [mbar]
24.000
22.000
20.000
18.000
16.000
14.000
12.000
10.000
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00

Measurement Erbil
IFRAZ 1, PL 4673, old pump house in IFRAZ, after pump No. 4
1.11.2011



Measurement Erbil
IFRAZ 1, PL 4676, manhole at old IFRAZ 1 pump station
1.11.2011

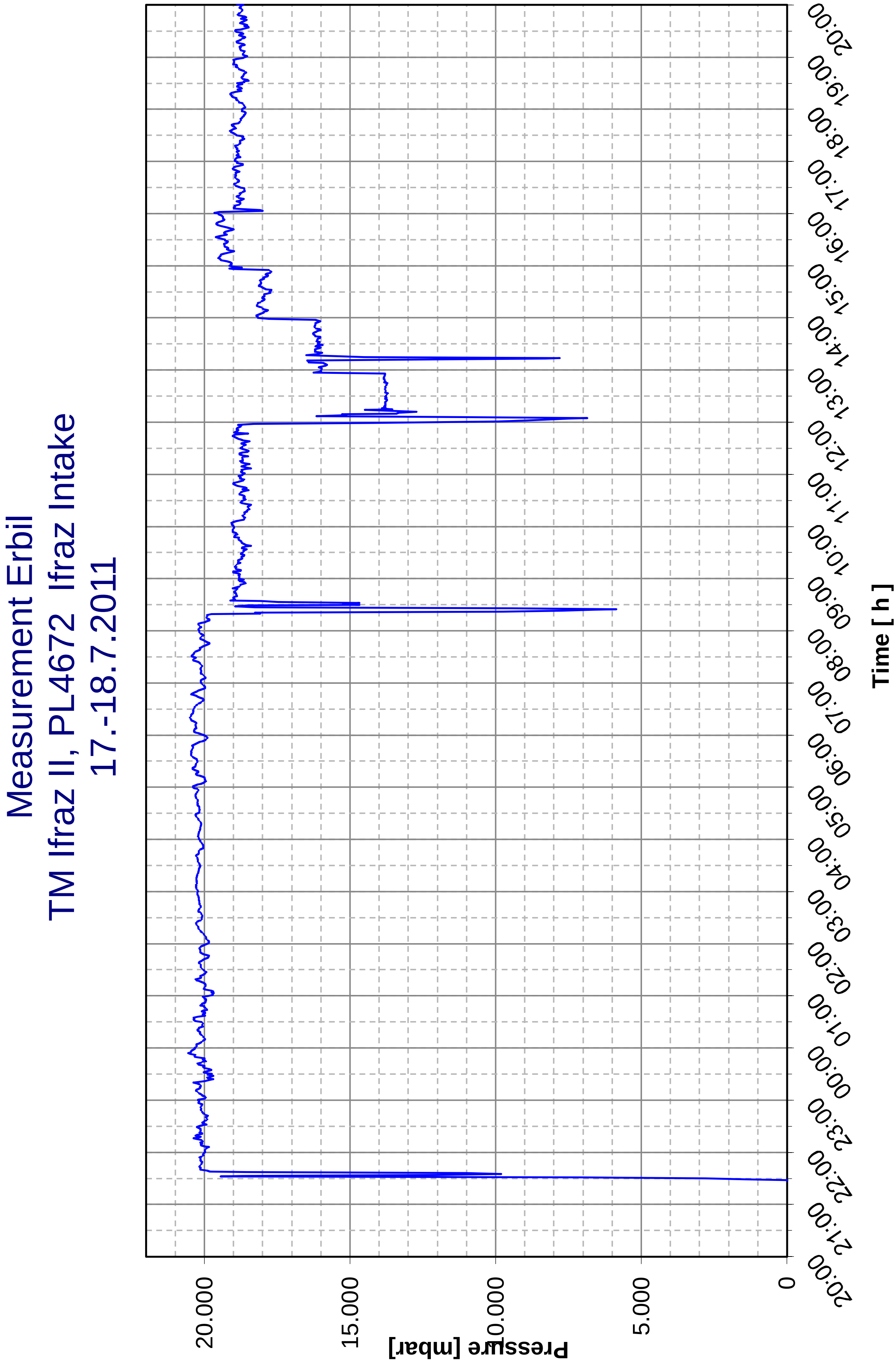


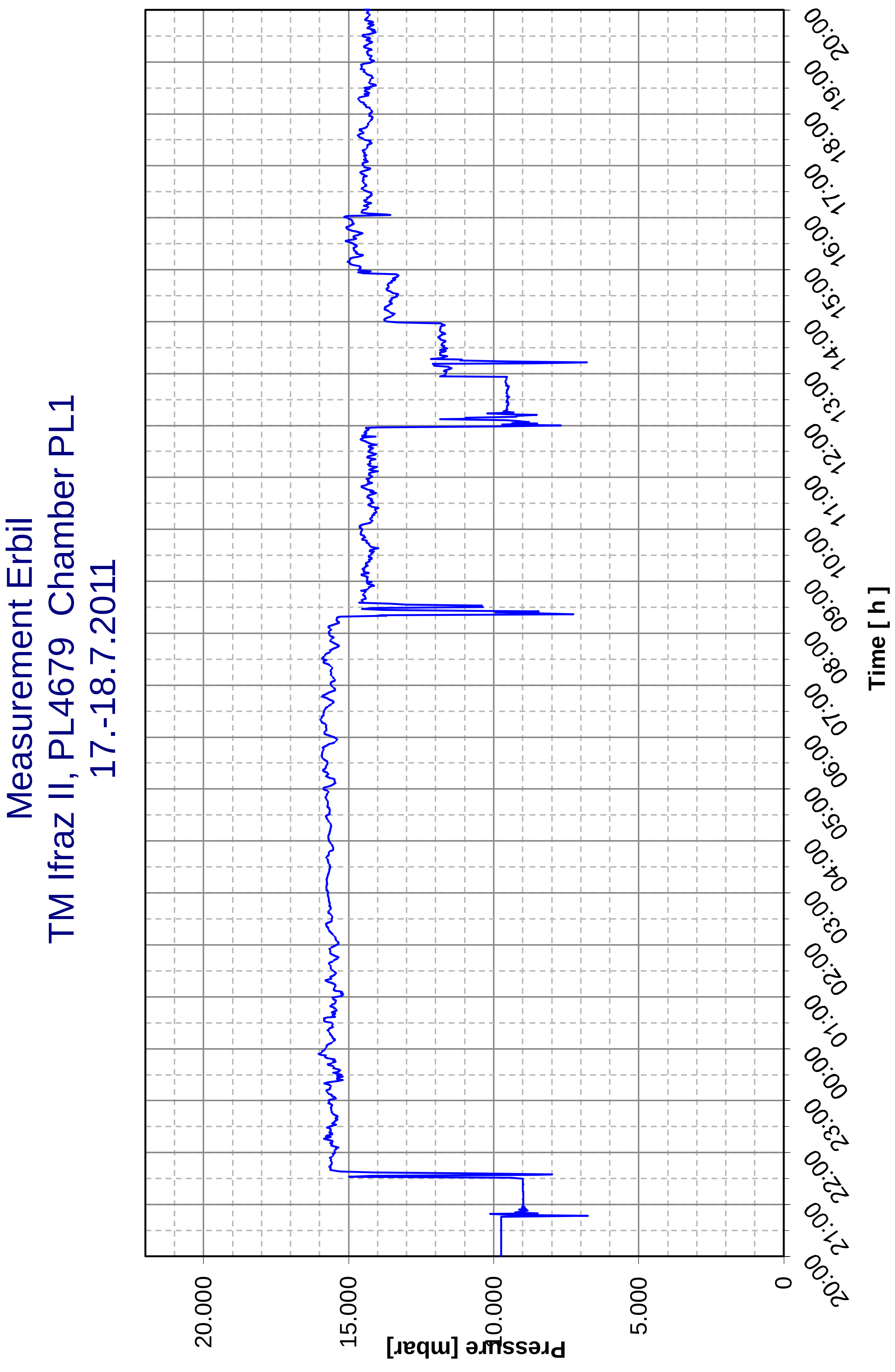

Measurement Erbil
IFRAZ 1, PL 3863, at collectorpipe in IFRAZ
1.11.2011
Pressure [mbar]
20.000
19.000
18.000
17.000
16.000
15.000
14.000
13.000
12.000
11.000
10.000
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00

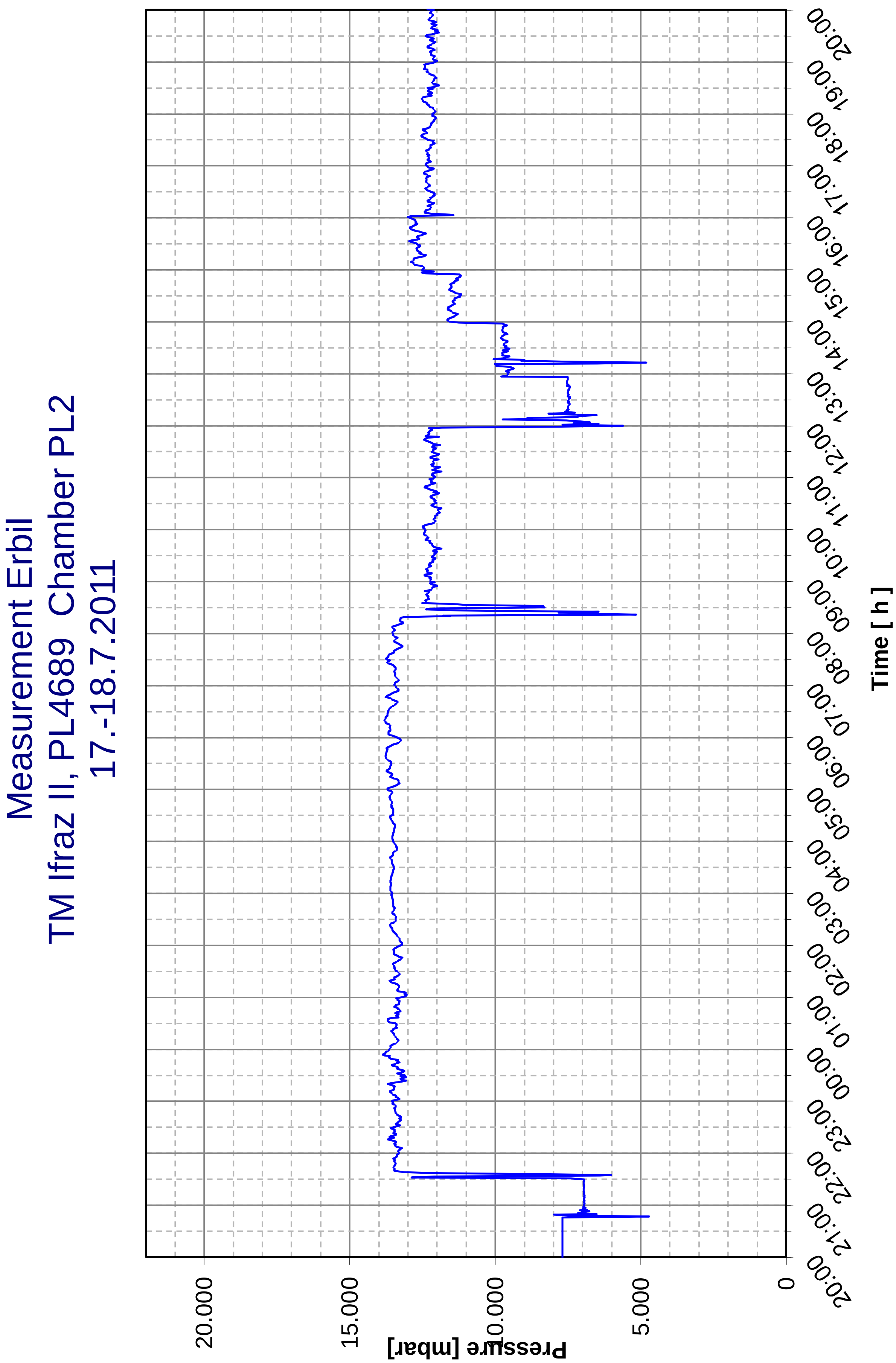
Flow- and Pressure Records

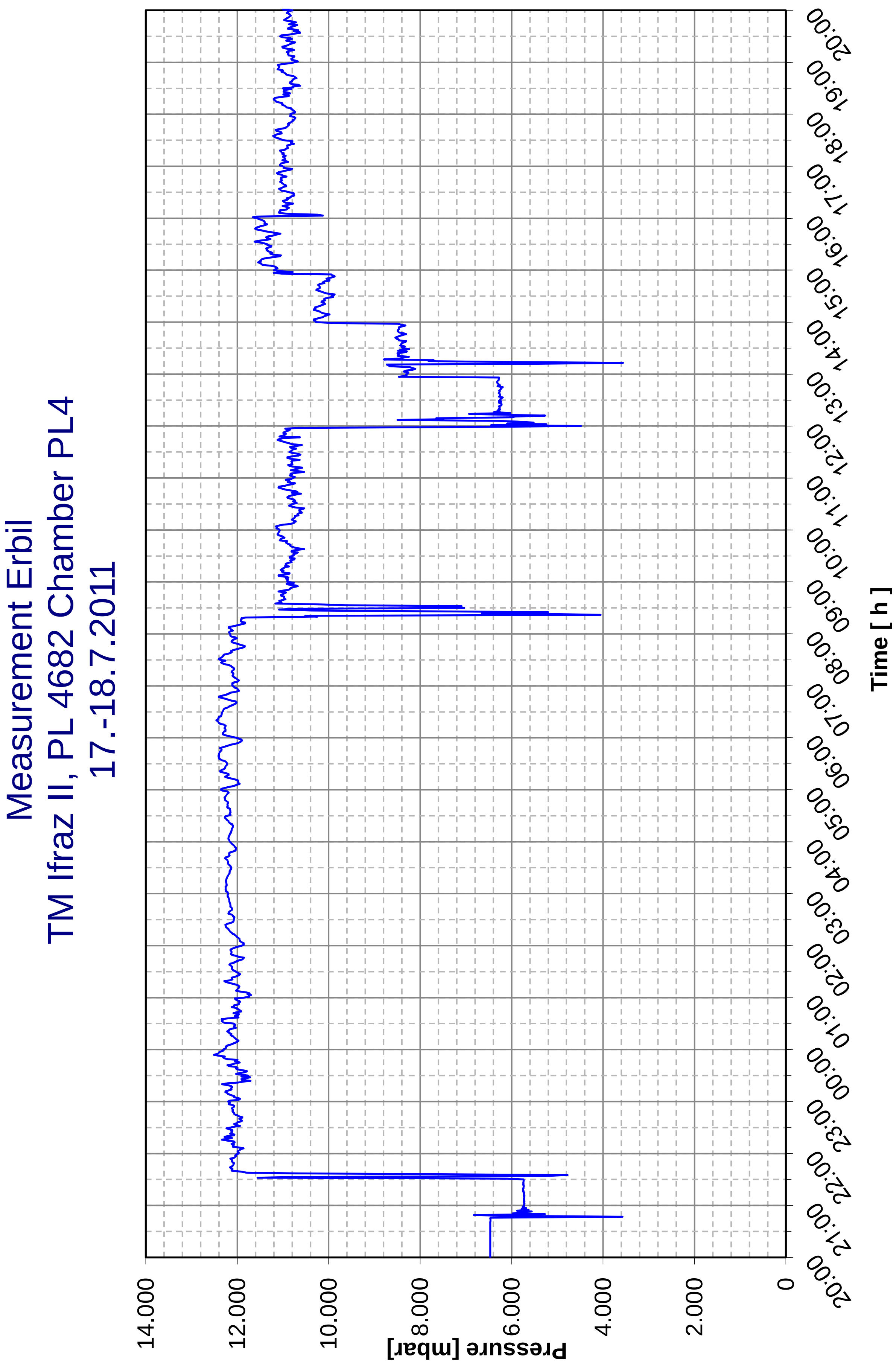
Pressure Logger Records

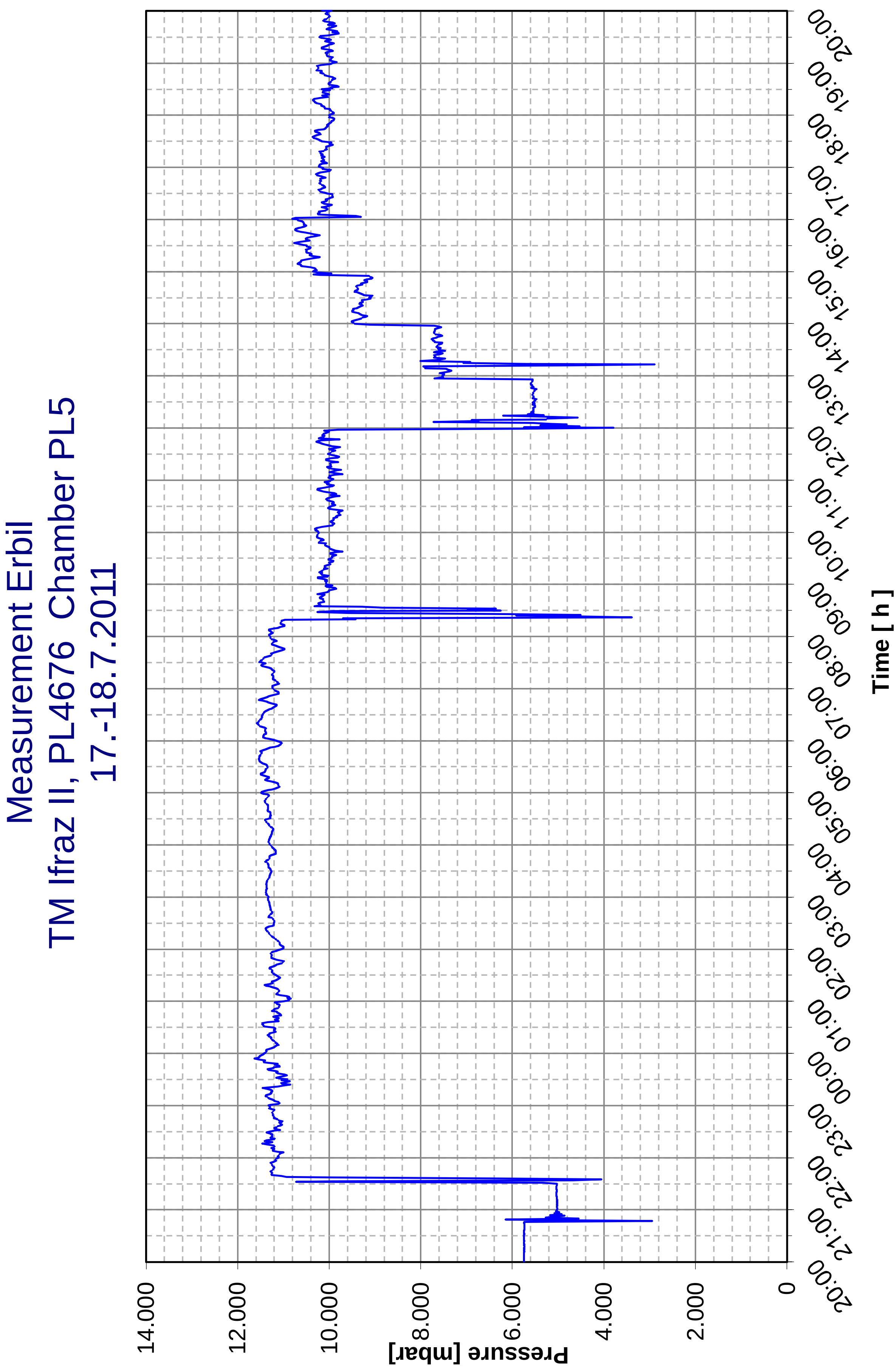
Ifraz II

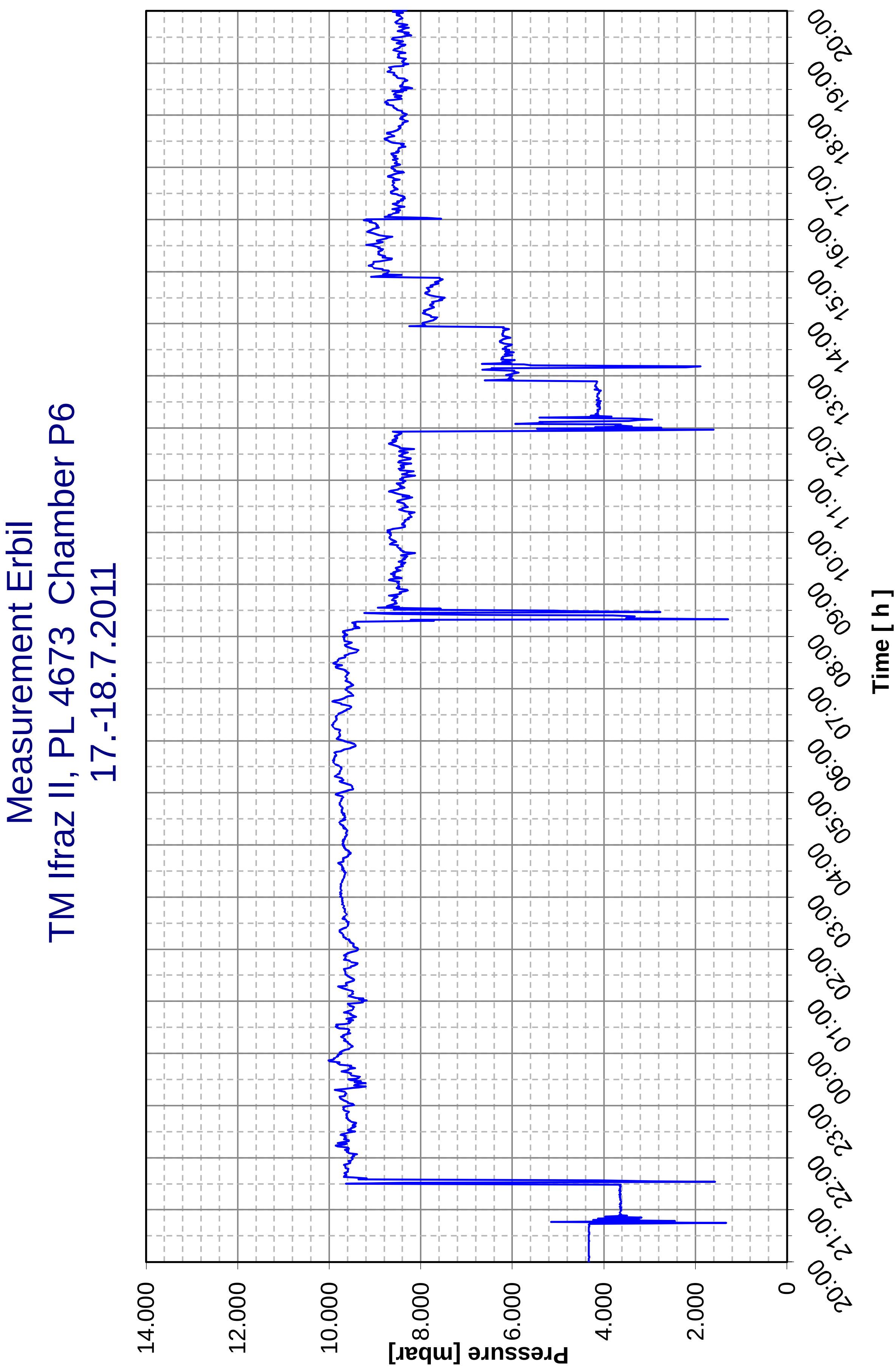

Measurement Erbil
TM Ifraz II, PL4672 Ifraz Intake
17.-18.7.2011
Pressure [mbar]
Time [h]
0
5.000
10.000
15.000
20.000
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

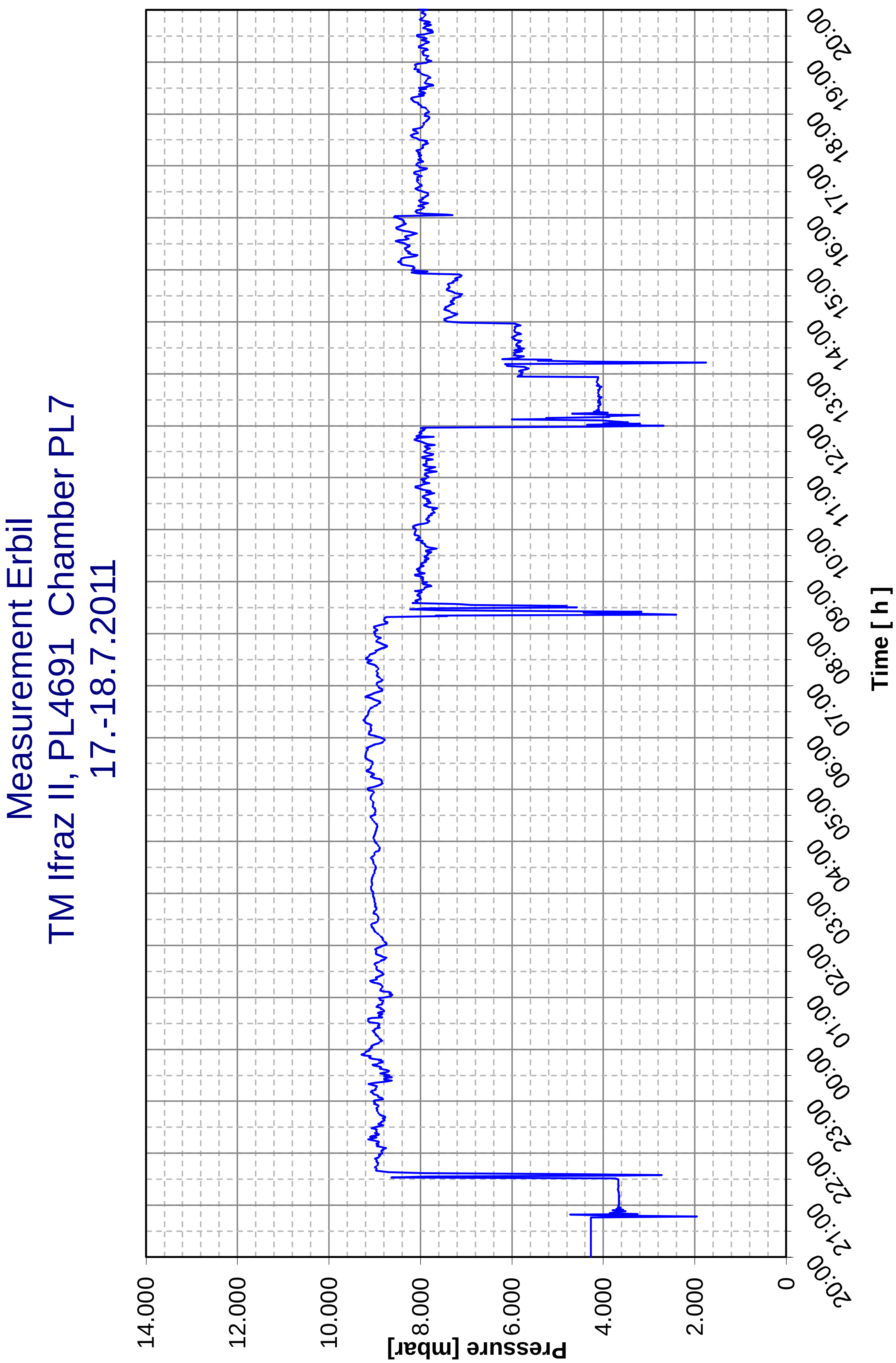

Measurement Erbil
TM Ifraz II, PL4679 Chamber PL1
17.-18.7.2011
Pressure [mbar]
20.000
15.000
10.000
5.000
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

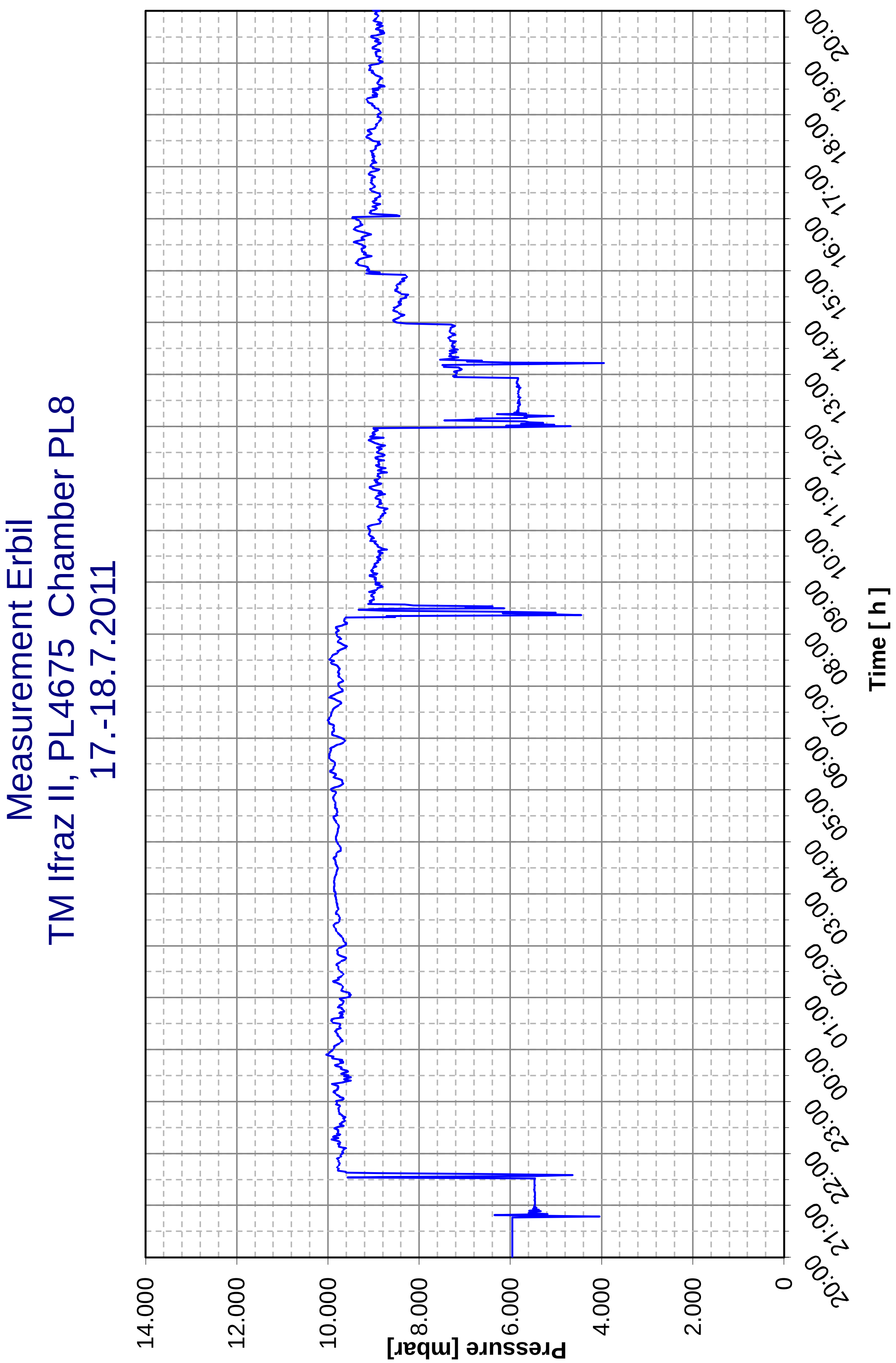

Measurement Erbil
TM Ifraz II, PL4689 Chamber PL2
17.-18.7.2011
Pressure [mbar]
0
5.000
10.000
15.000
20.000
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

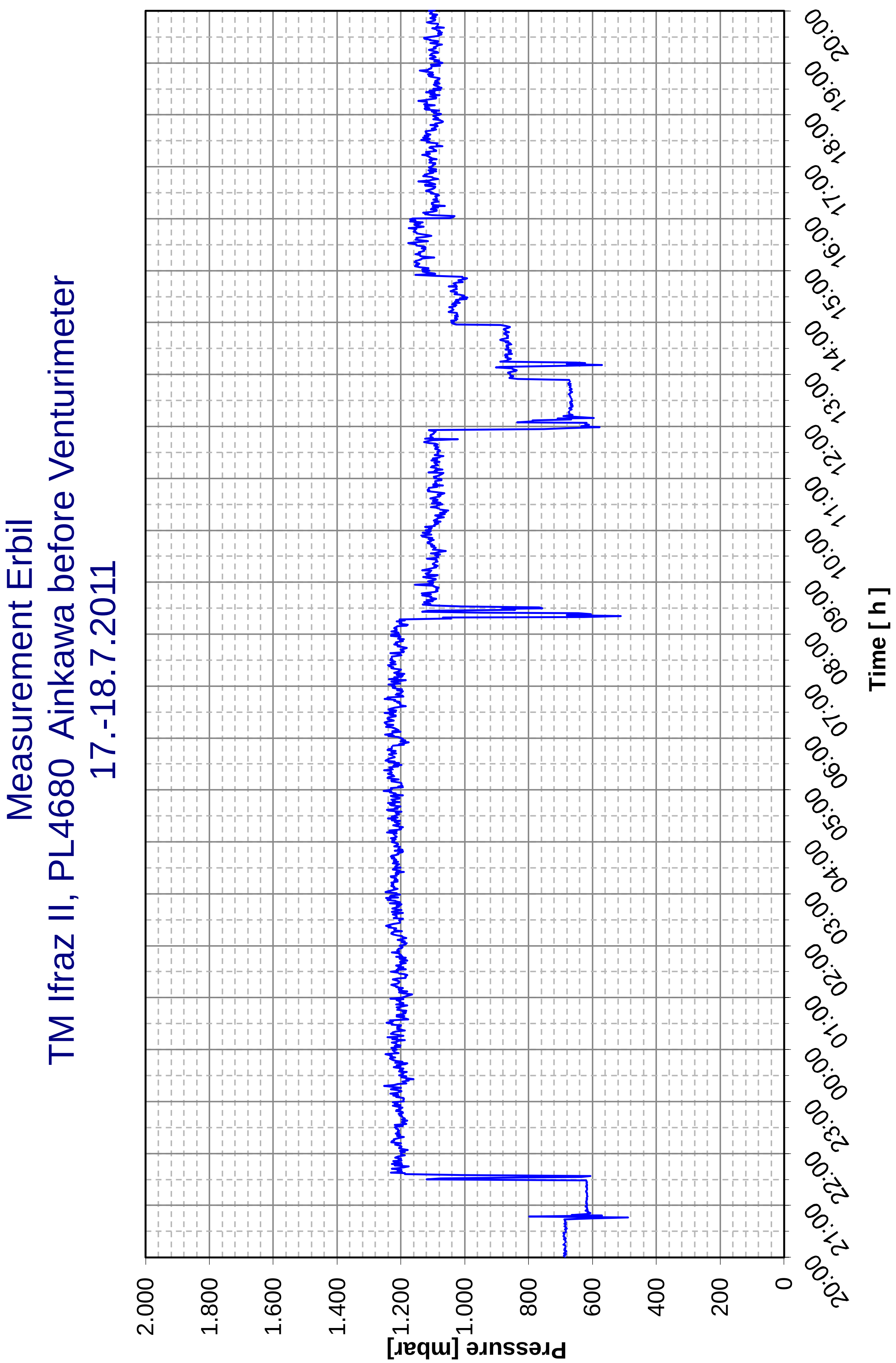

Measurement Erbil
TM Ifraz II, PL 4682 Chamber PL4
17.-18.7.2011
Pressure [mbar]
Time [h]
0
2.000
4.000
6.000
8.000
10.000
12.000
14.000
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

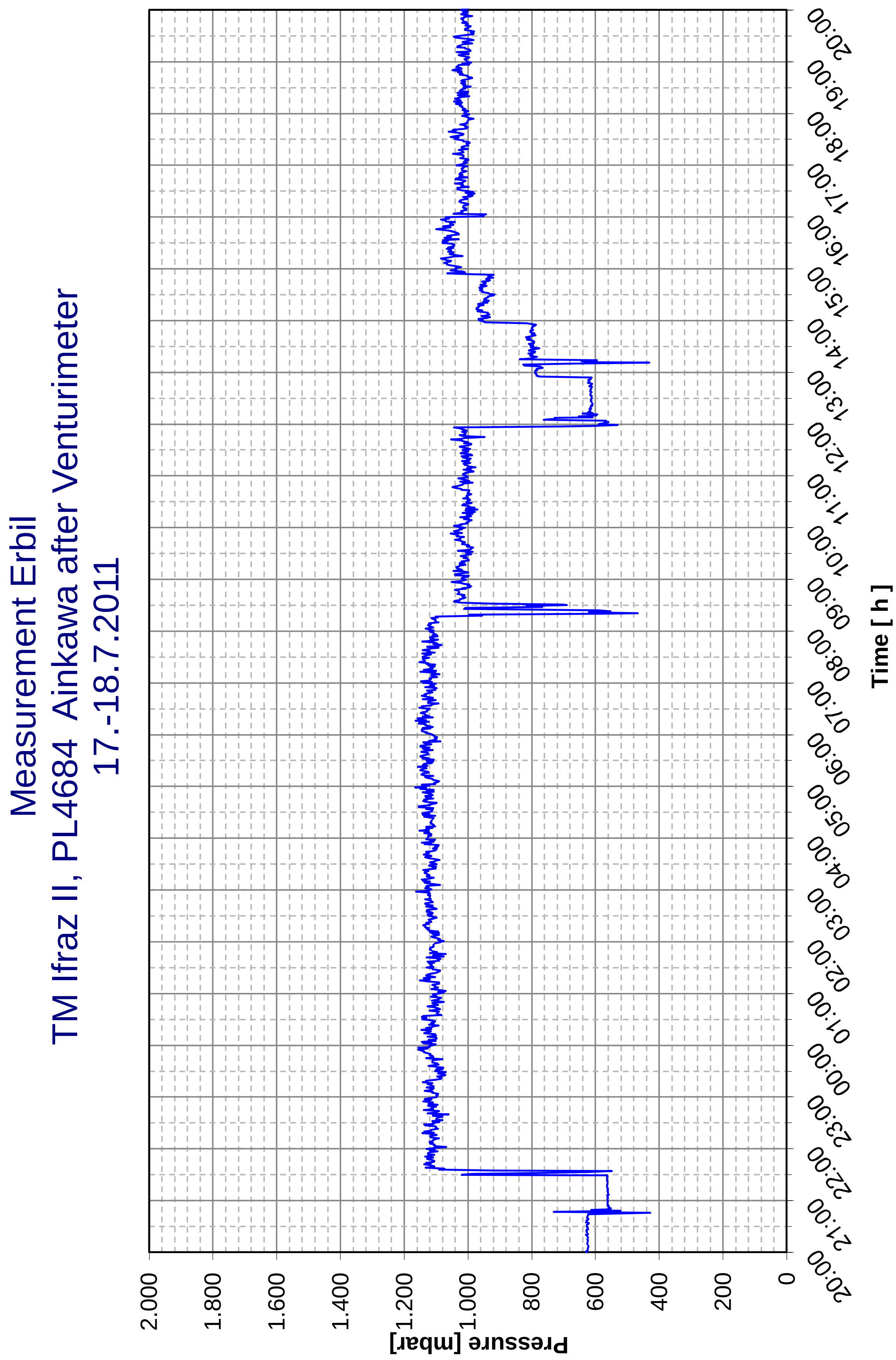

Measurement Erbil
TM Ifraz II, PL4676 Chamber PL5
17.-18.7.2011
Pressure [mbar]
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00


Measurement Erbil
TM Ifraz II, PL 4673 Chamber P6
17.-18.7.2011
Pressure [mbar]
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00


Measurement Erbil
TM Ifraz II, PL4691 Chamber PL7
17.-18.7.2011
Pressure [mbar]
0
2.000
4.000
6.000
8.000
10.000
12.000
14.000
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00


Measurement Erbil
TM Ifraz II, PL4675 Chamber PL8
17.-18.7.2011
Pressure [mbar]
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

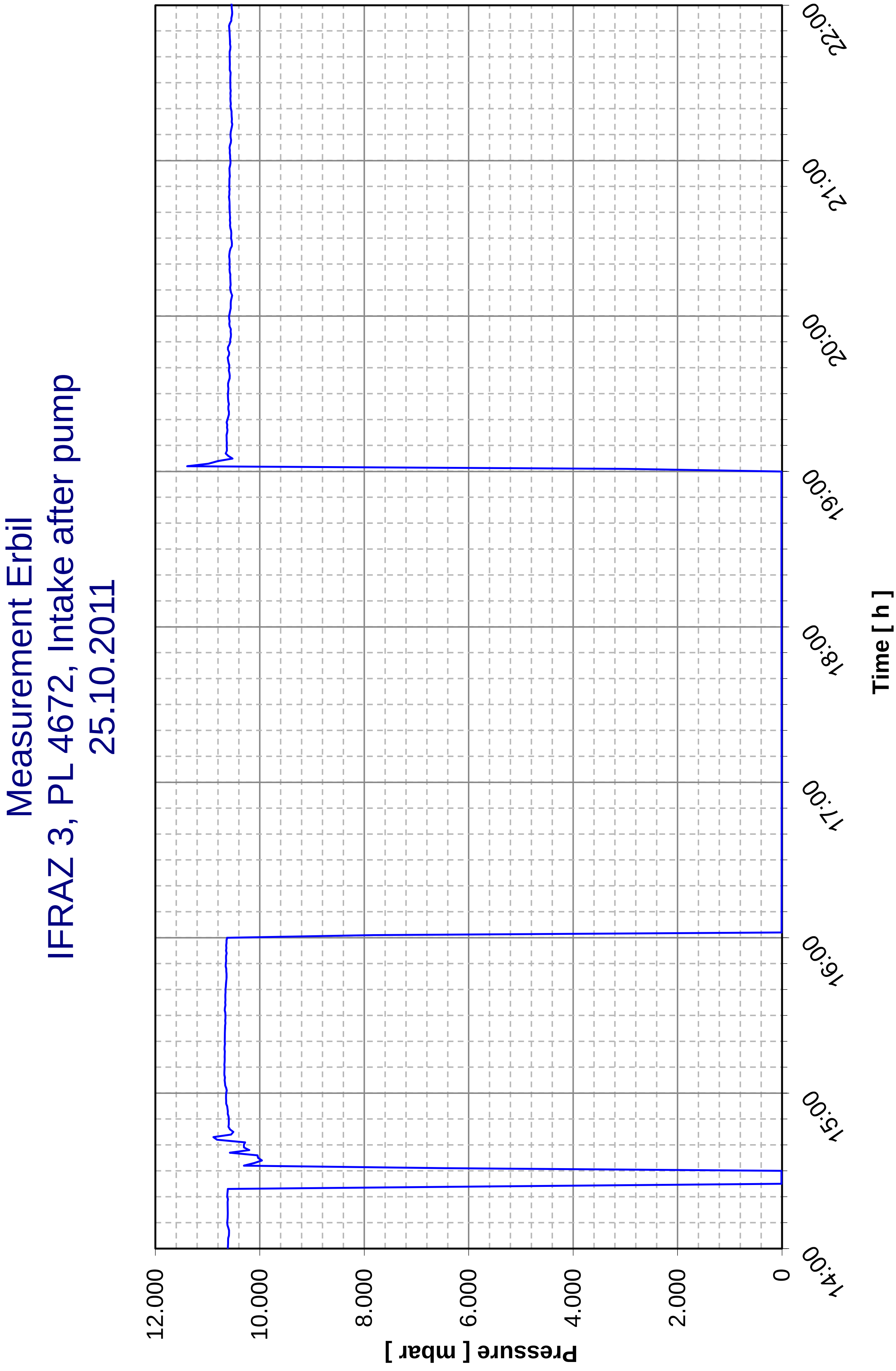

Measurement Erbil
TM Ifraz II, PL4680 Ainkawa before Venturimeter
17.-18.7.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00


Measurement Erbil
TM Ifraz II, PL4684 Ainkawa after Venturimeter
17.-18.7.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

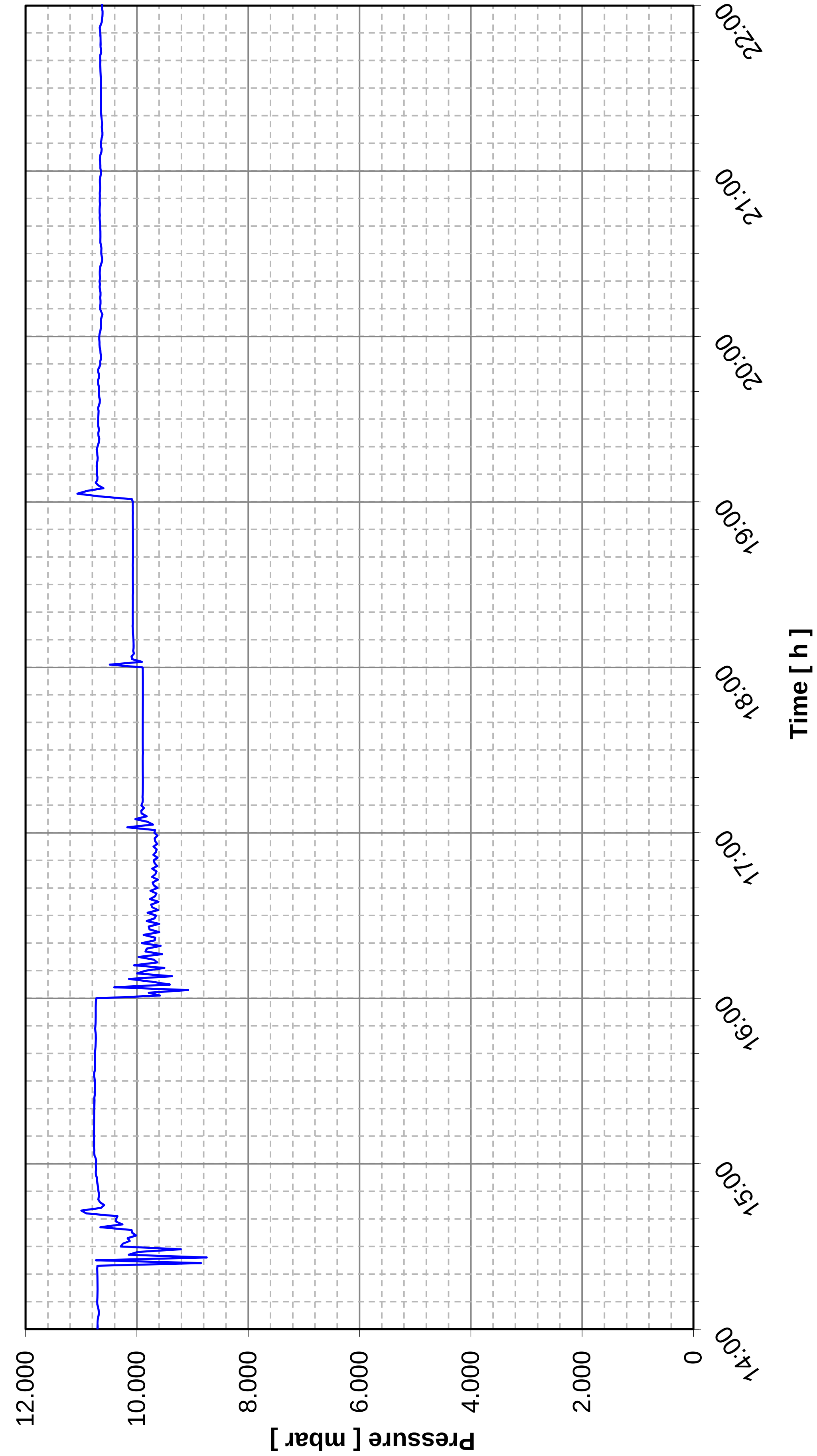
Flow- and Pressure Records

Pressure Logger Records

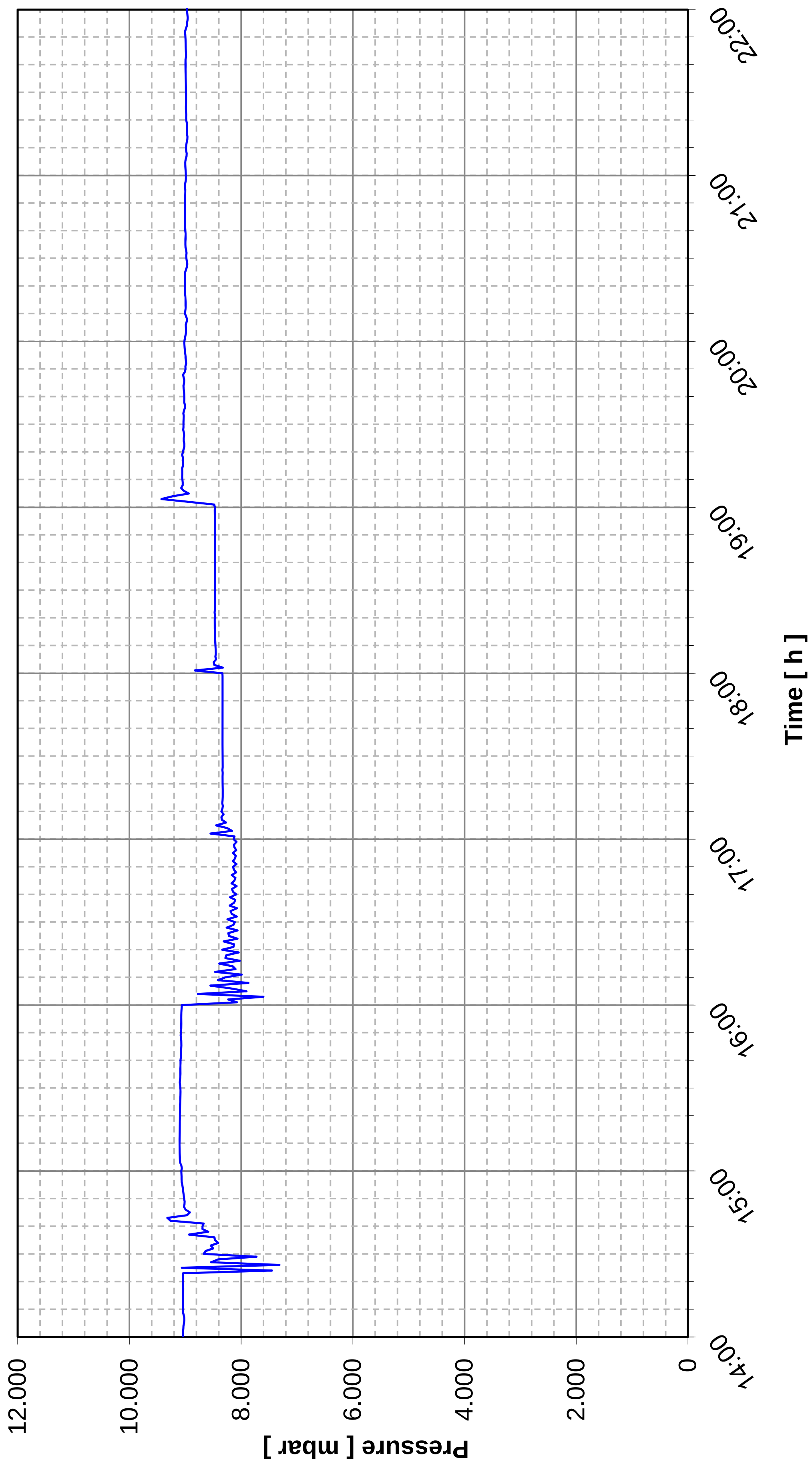
Ifraz III

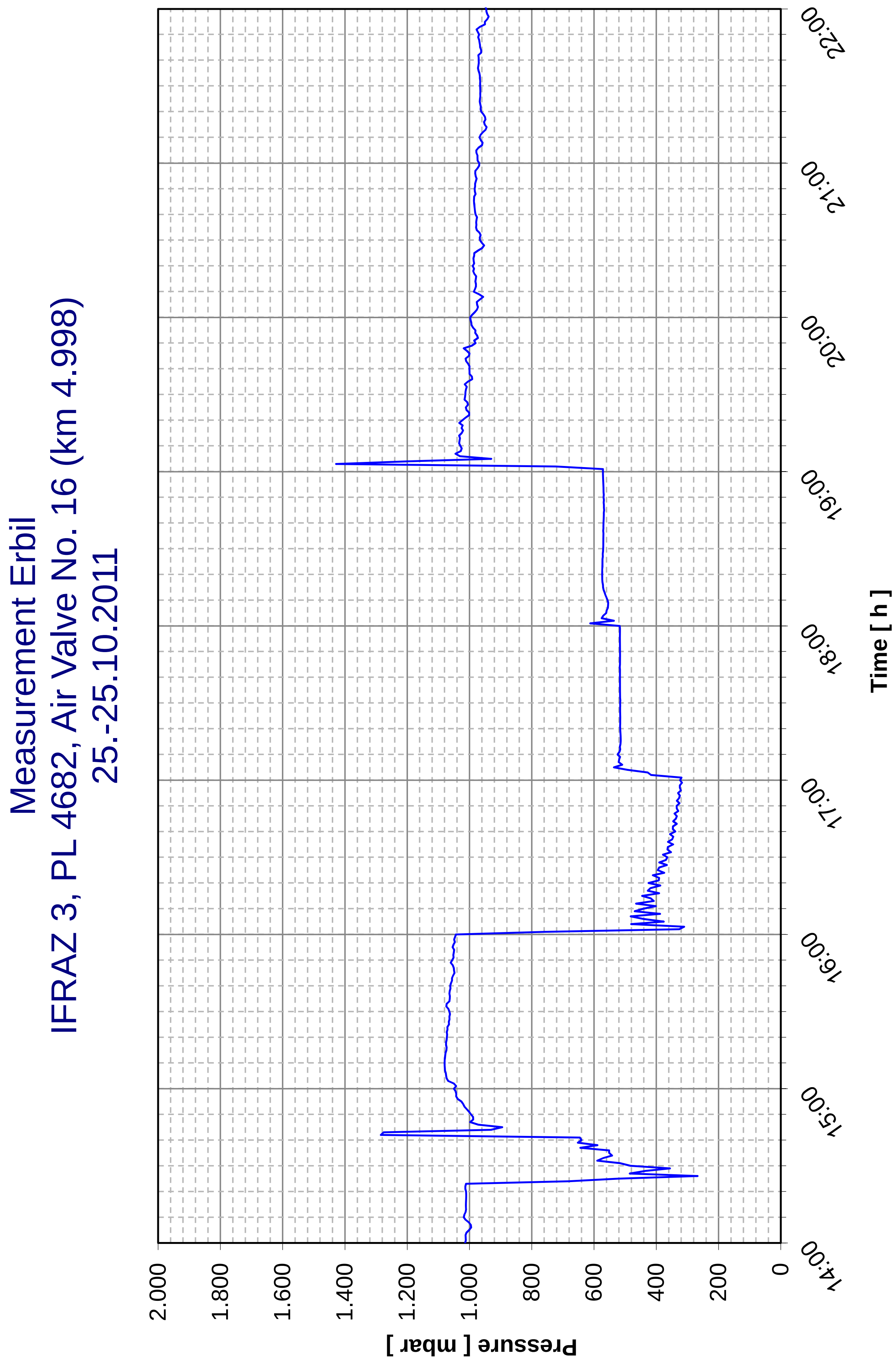

Measurement Erbil
IFRAZ 3, PL 4672, Intake after pump
25.10.2011
Pressure [mbar]
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

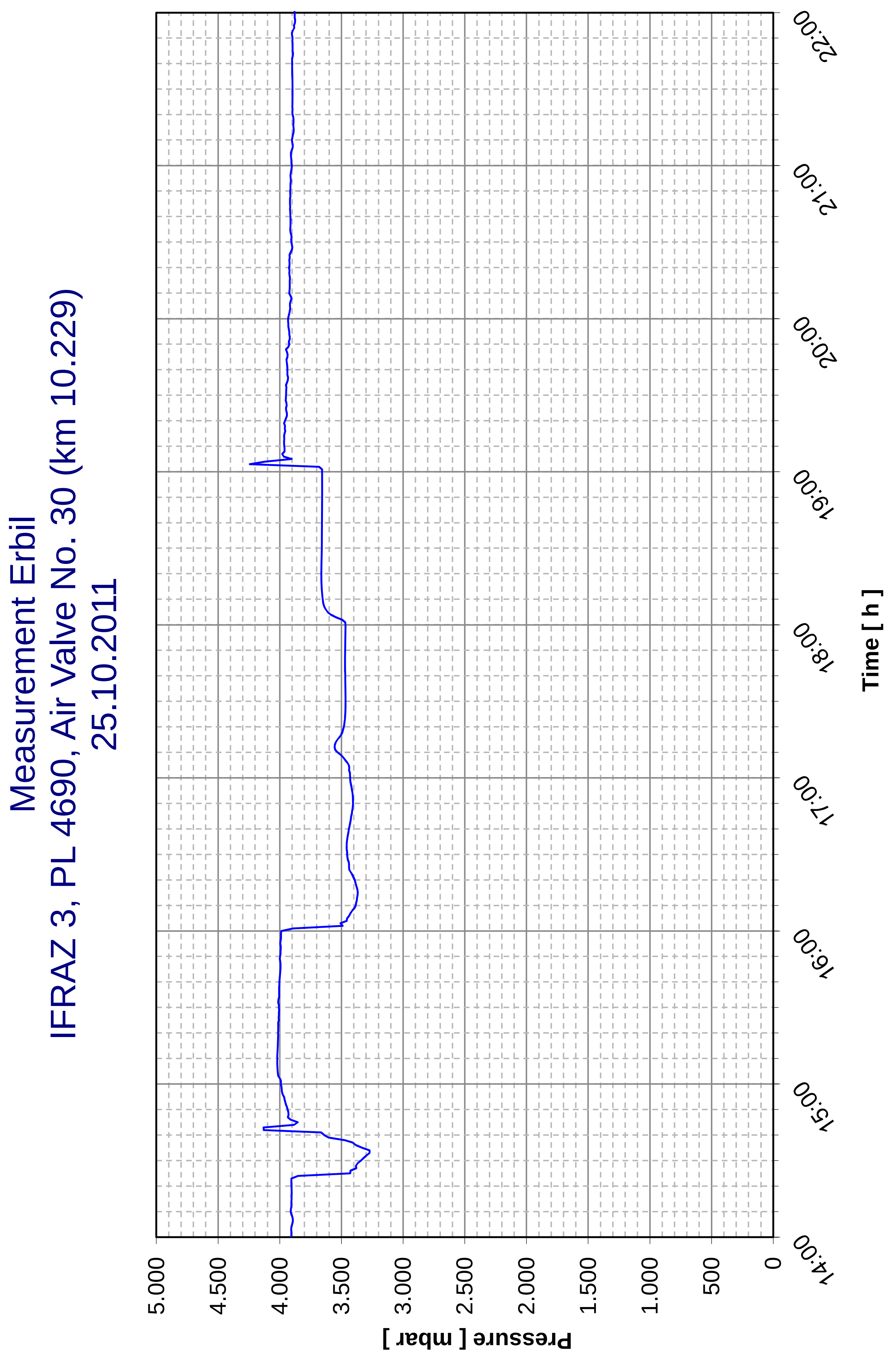
Measurement Erbil
IFRAZ 3, PL 4676, Intake at collector pipe
25.10.2011

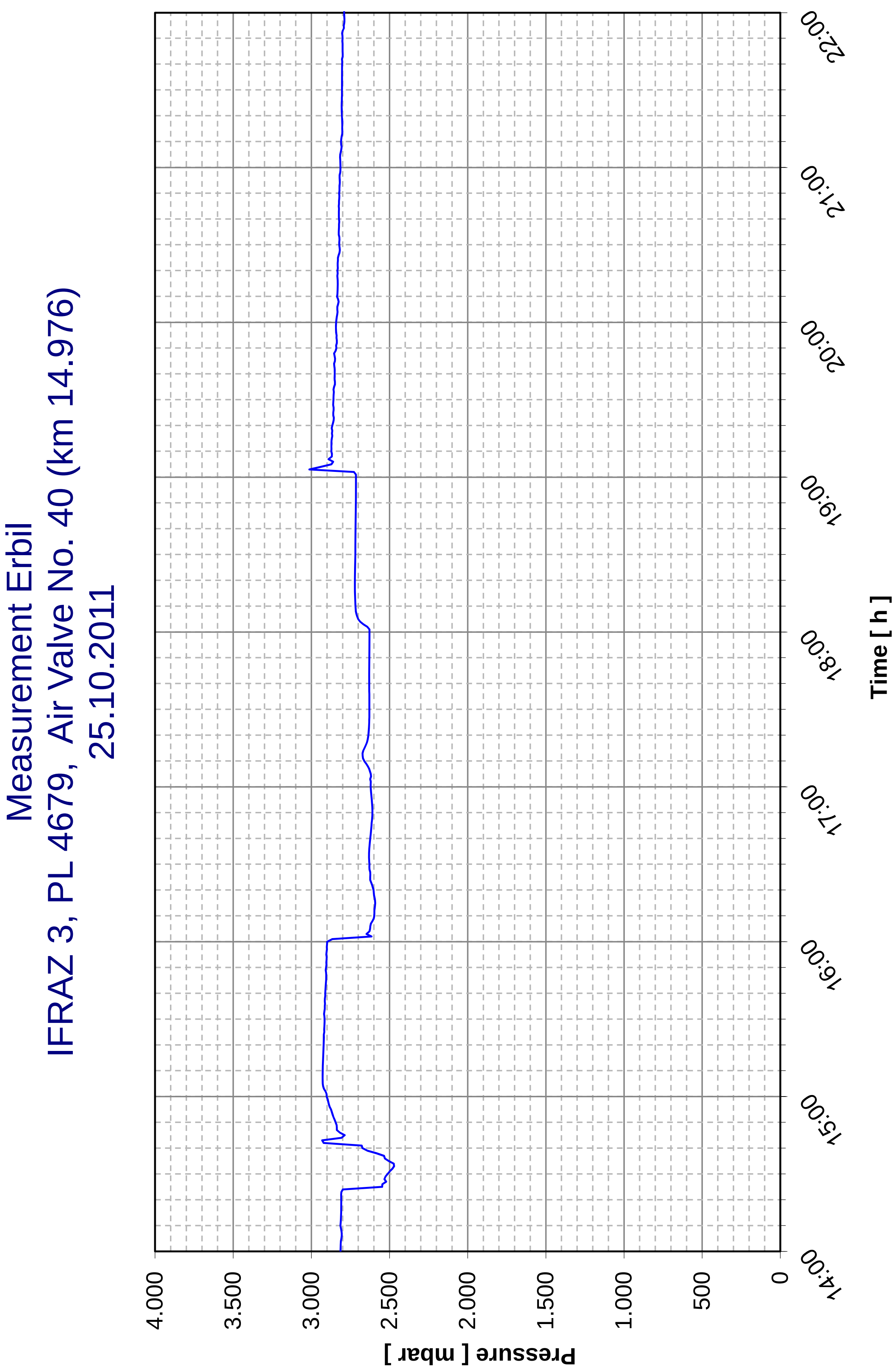


Measurement Erbil
IFRAZ 3, PL 4691, Air Valve No. 1 (km 0.566)
25.10.2011

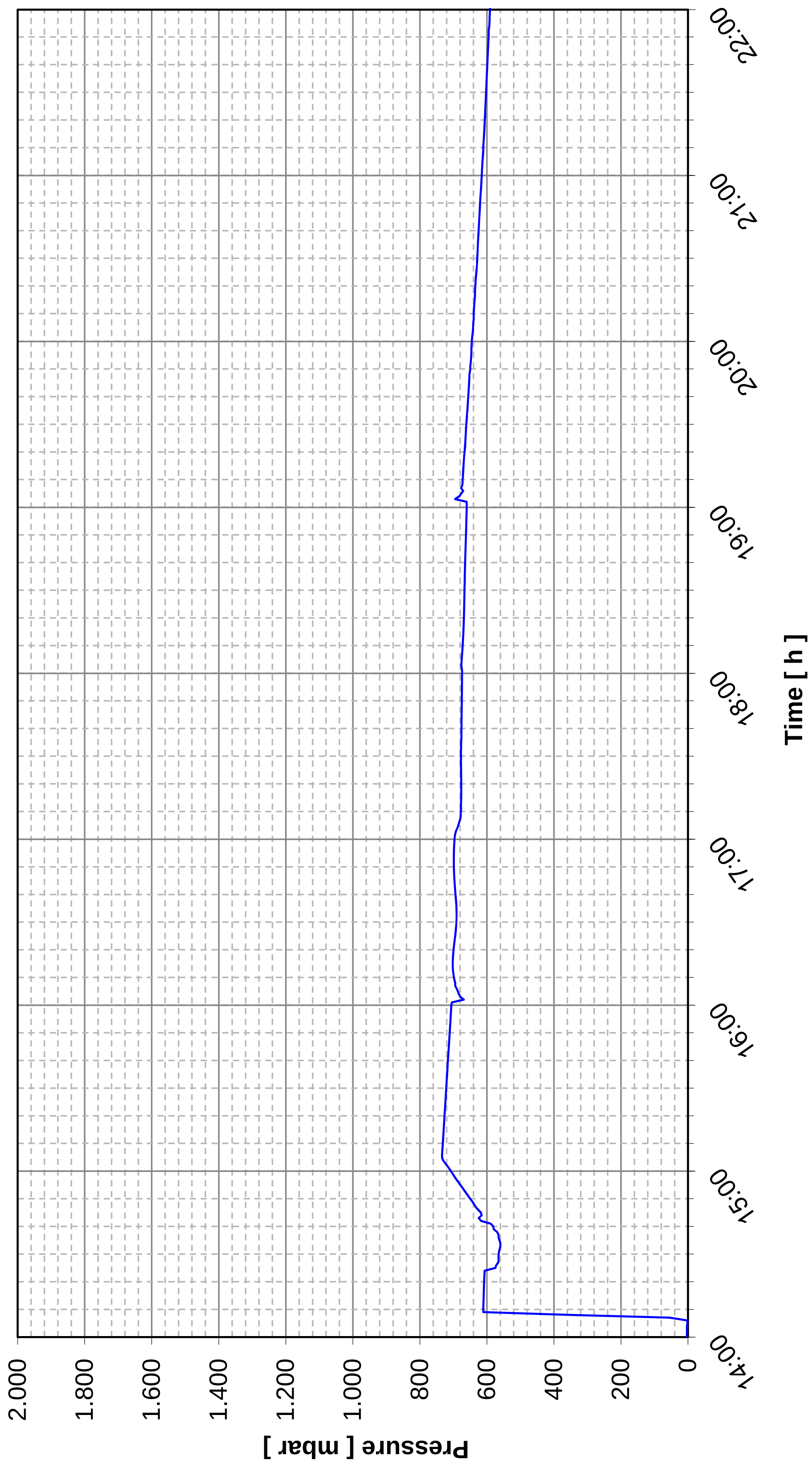


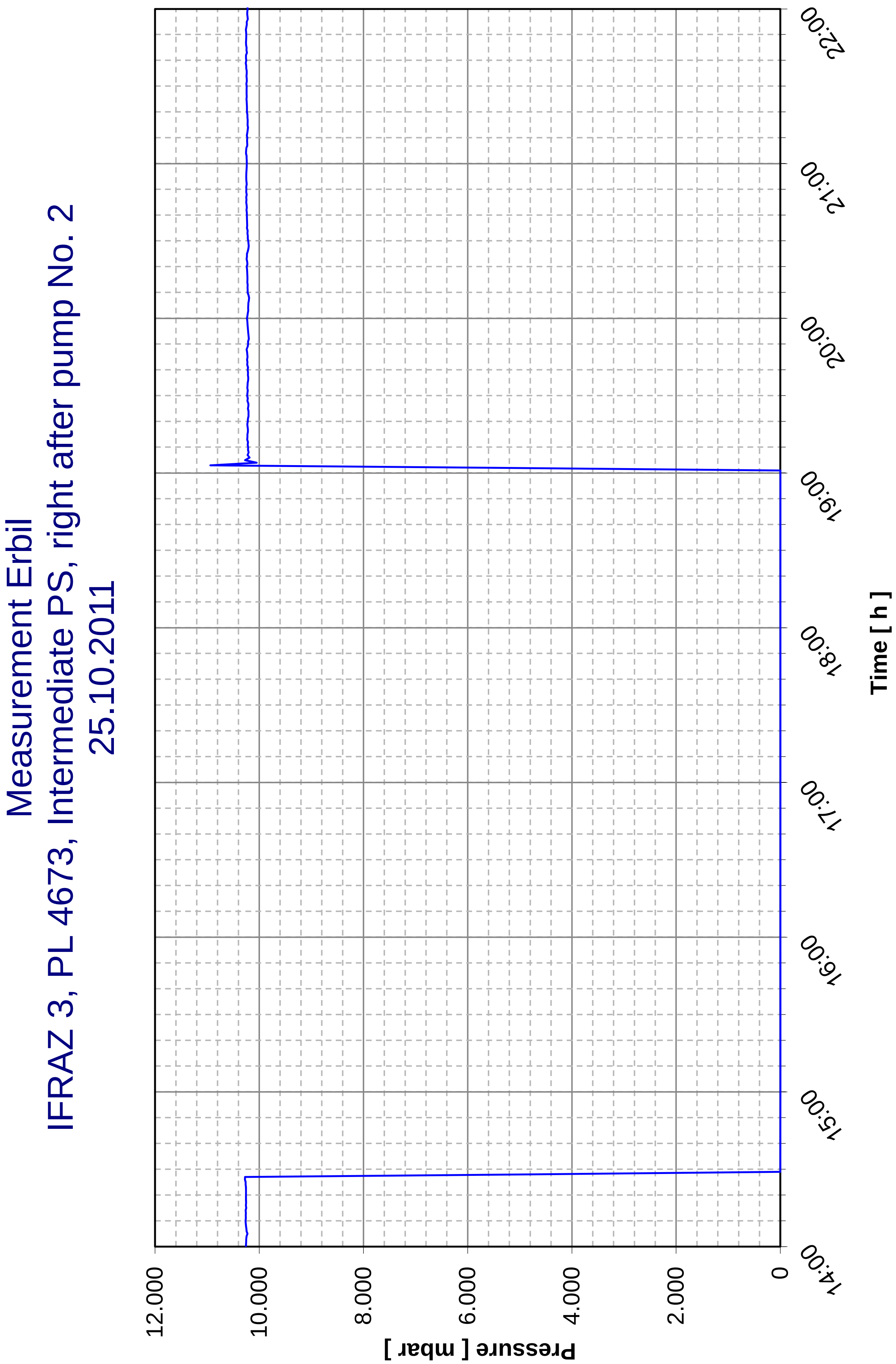

Measurement Erbil
IFRAZ 3, PL 4682, Air Valve No. 16 (km 4.998)
25.-25.10.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

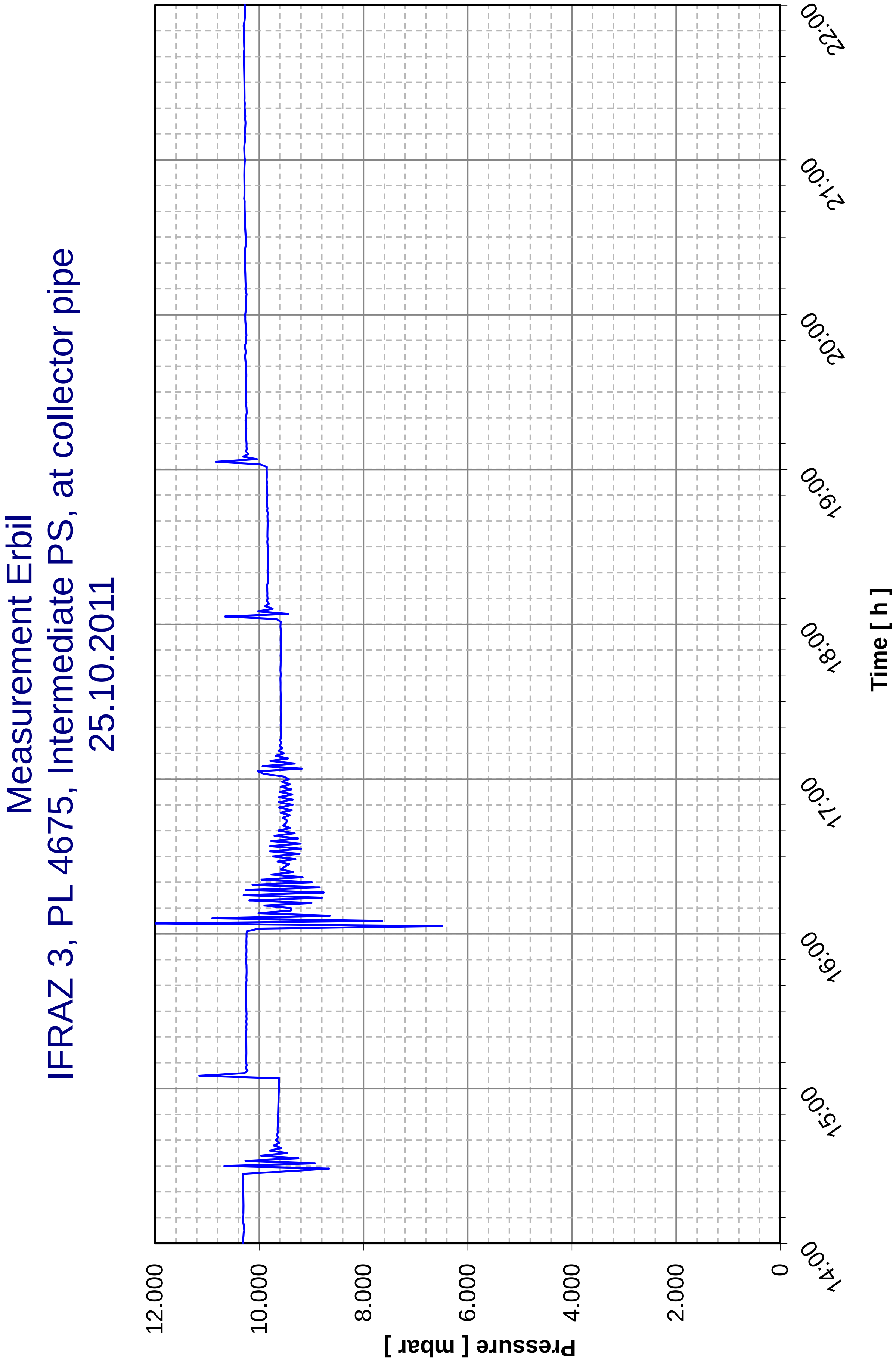

Measurement Erbil
IFRAZ 3, PL 4690, Air Valve No. 30 (km 10.229)
25.10.2011
Pressure [mbar]
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

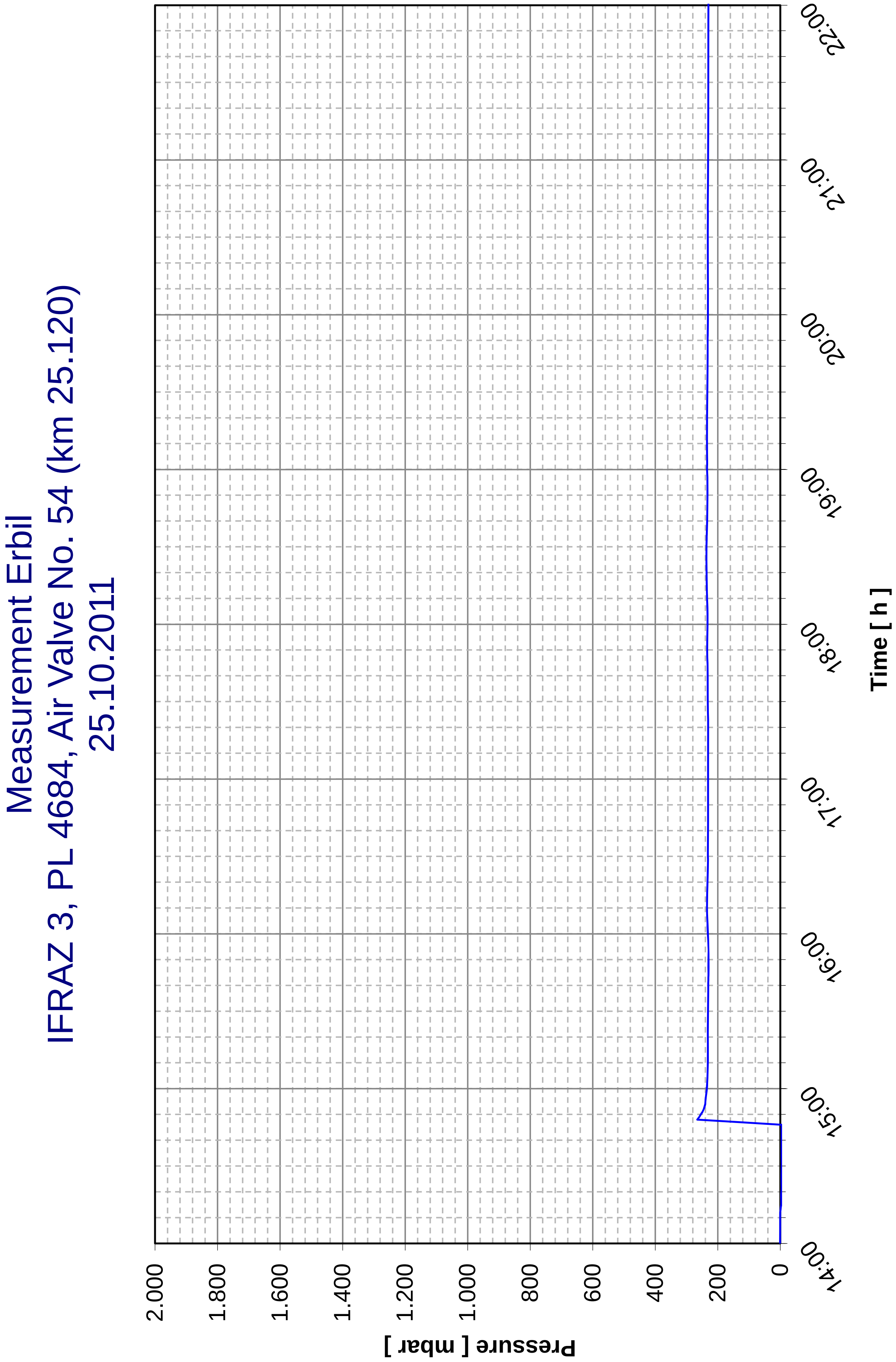

Measurement Erbil
IFRAZ 3, PL 4679, Air Valve No. 40 (km 14.976)
25.10.2011
Pressure [mbar]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

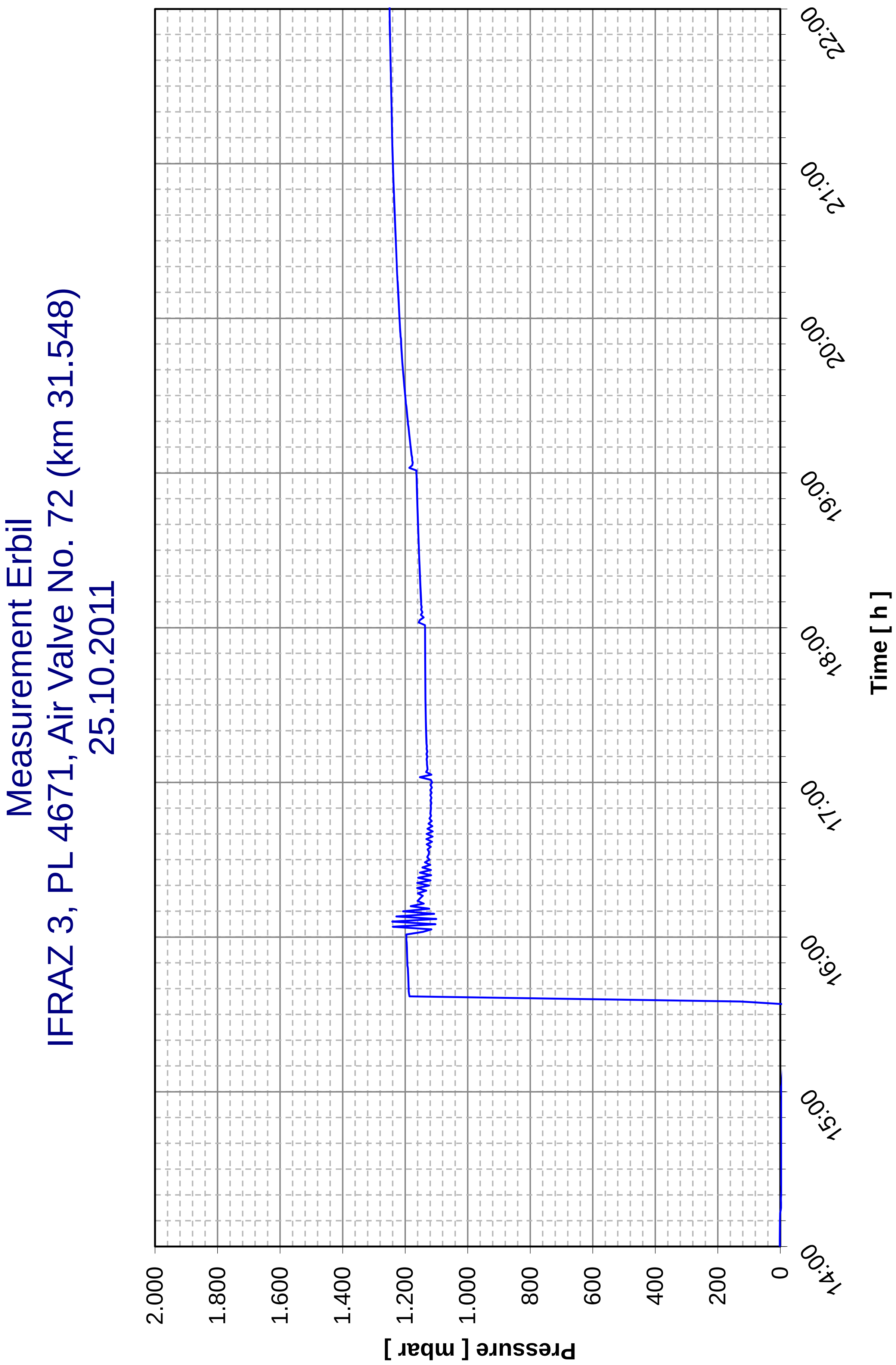
Measurement Erbil
IFRAZ 3, PL 4666, Air Valve No. 46 (km 19.654)
25.10.2011




Measurement Erbil
IFRAZ 3, PL 4673, Intermediate PS, right after pump No. 2
25.10.2011
Pressure [mbar]
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00


Measurement Erbil
IFRAZ 3, PL 4675, Intermediate PS, at collector pipe
25.10.2011
Pressure [mbar]
12.000
10.000
8.000
6.000
4.000
2.000
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

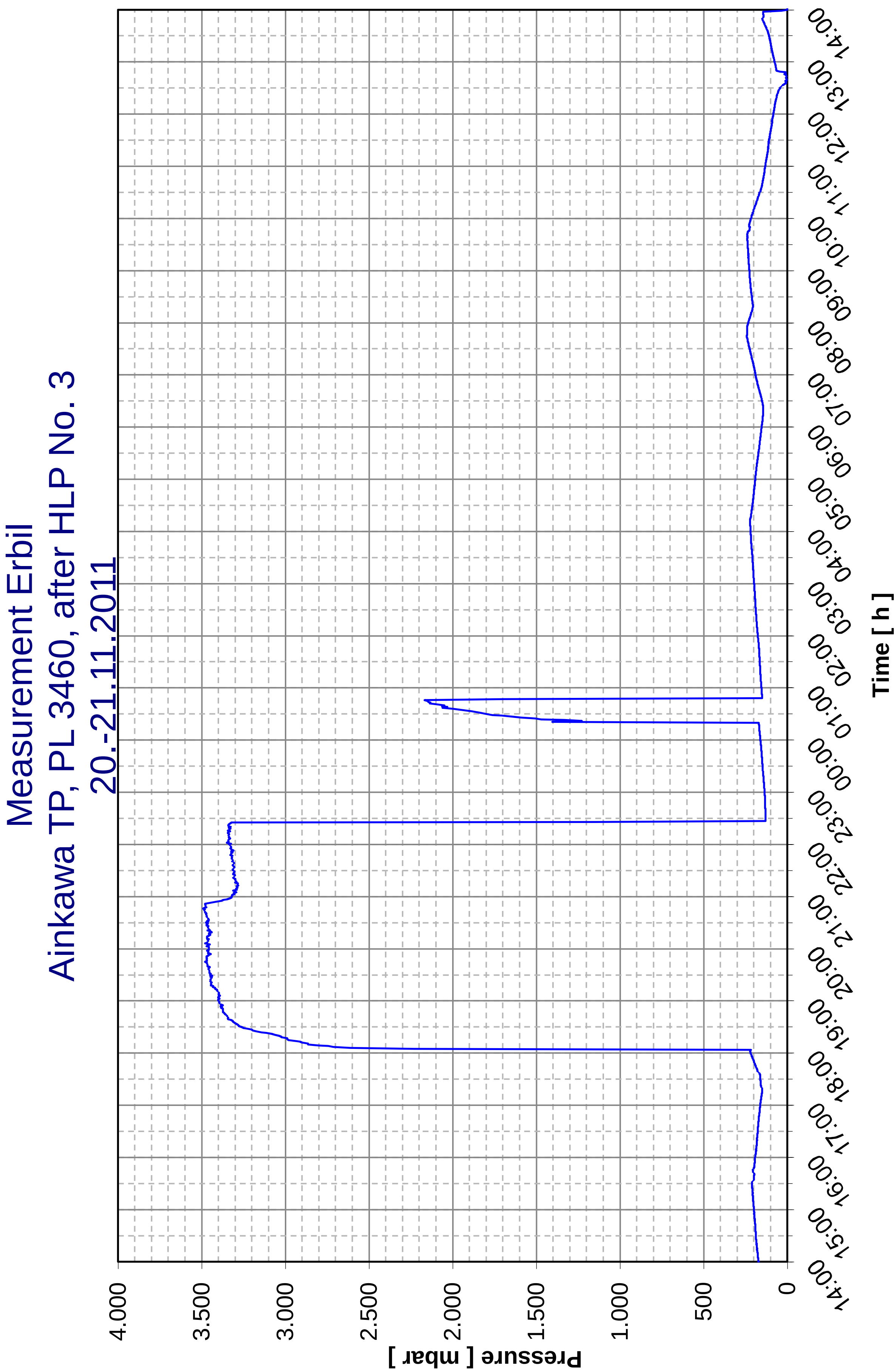

Measurement Erbil
IFRAZ 3, PL 4684, Air Valve No. 54 (km 25.120)
25.10.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00


Measurement Erbil
IFRAZ 3, PL 4671, Air Valve No. 72 (km 31.548)
25.10.2011
Pressure [mbar]
Time [h]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00

Flow- and Pressure Records

Pressure Logger Records

Ainkawa TP to Tayrawa Water Tower and to City


Measurement Erbil
Ainkawa TP, PL 3460, after HLP No. 3
20.-21.11.2011
Pressure [mbar]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
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06:00
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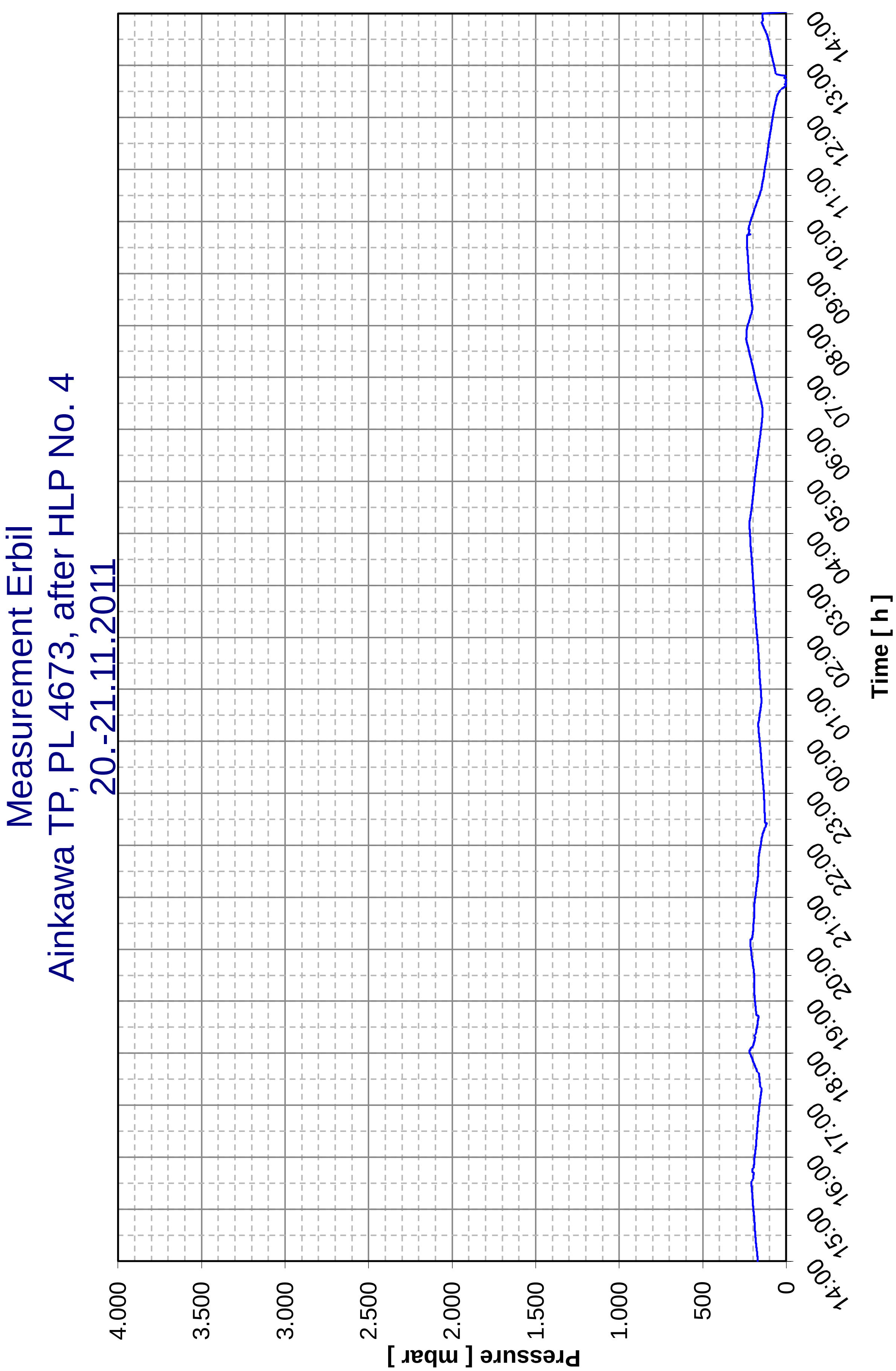
11:00
12:00
13:00
14:00


Measurement Erbil
Ainkawa TP, PL 4673, after HLP No. 4
20.-21.11.2011
Pressure [mbar]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
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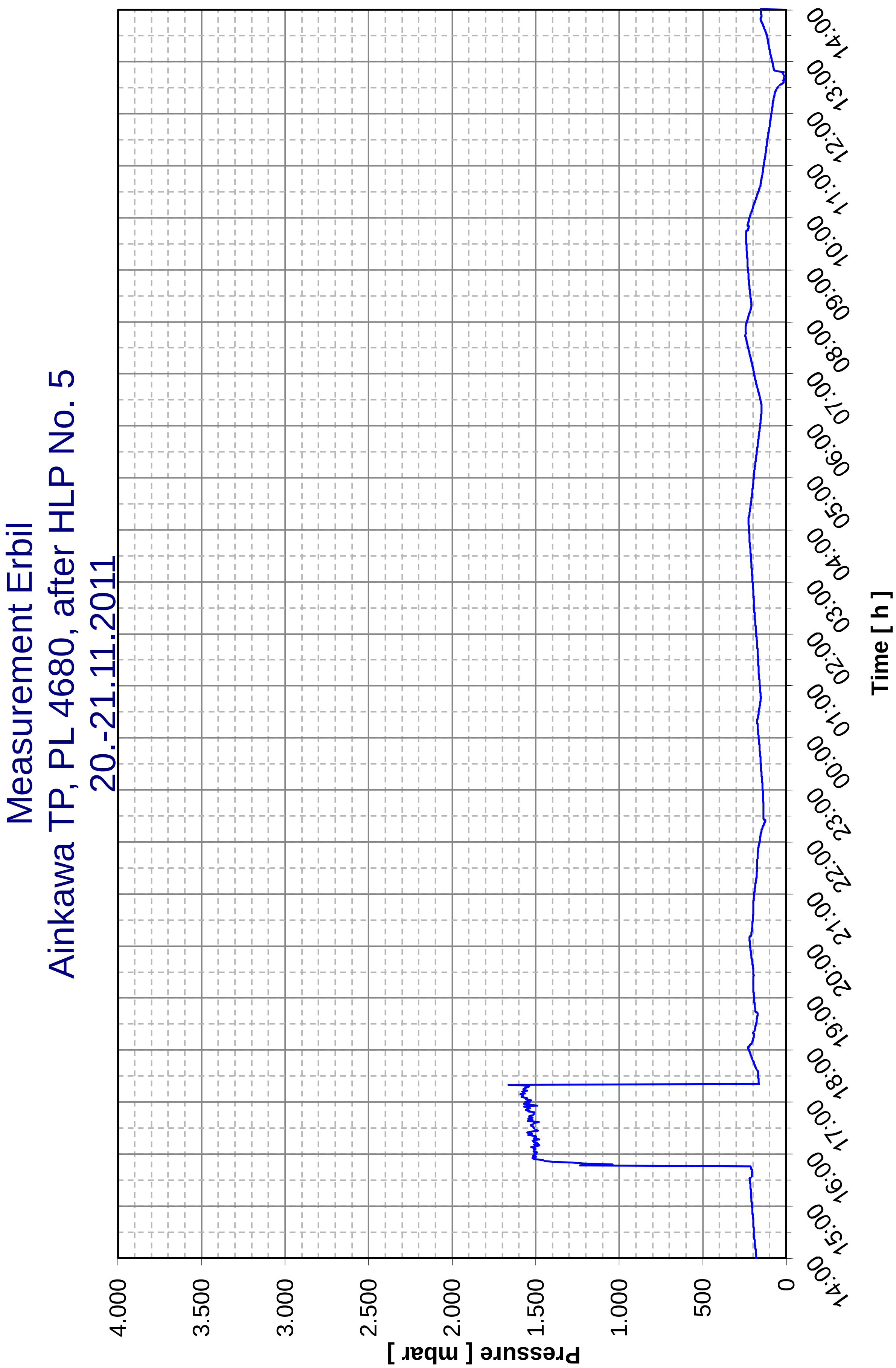
12:00
13:00
14:00


Measurement Erbil
Ainkawa TP, PL 4680, after HLP No. 5
20.-21.11.2011
Pressure [mbar]
0
500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
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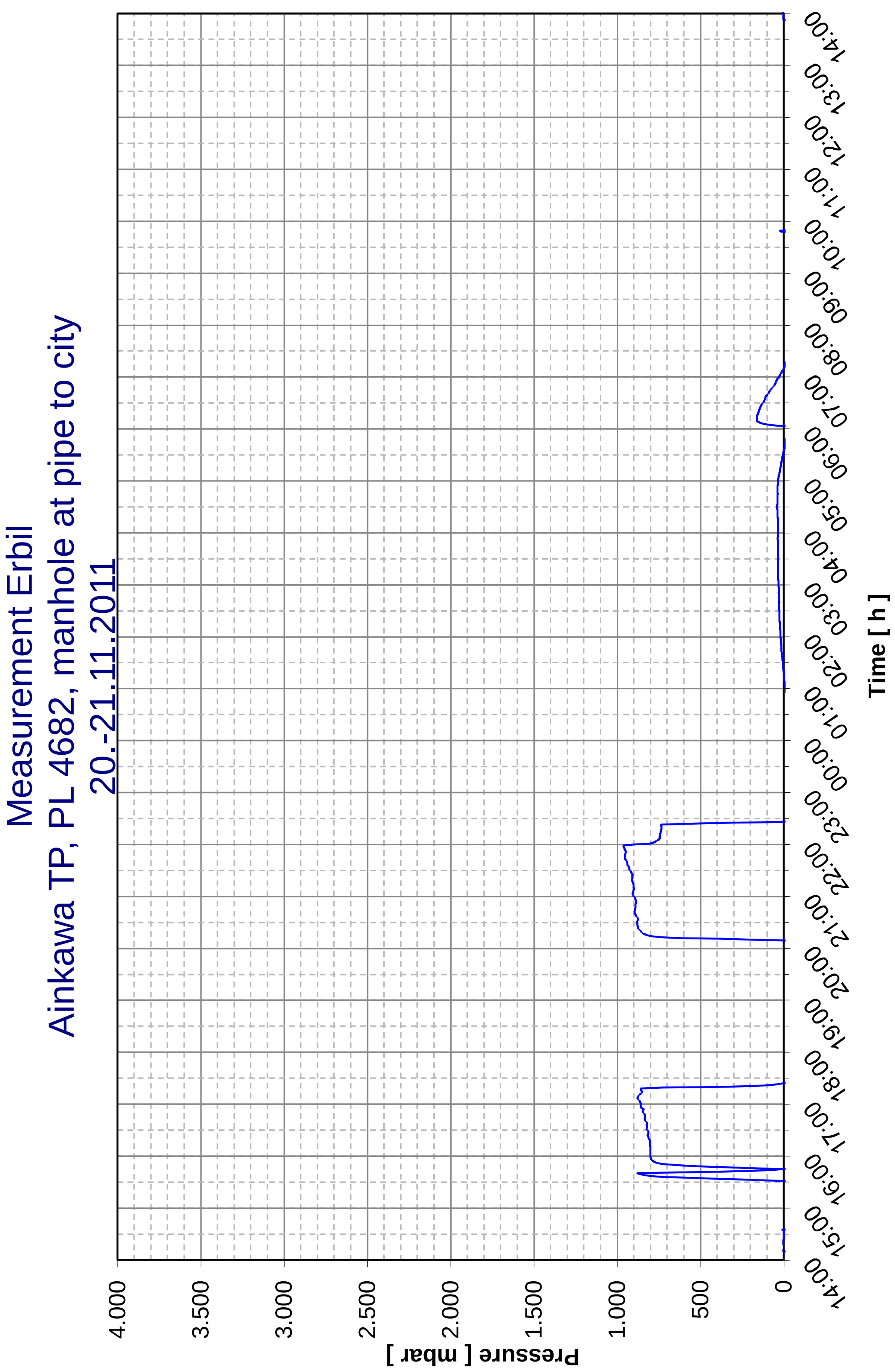
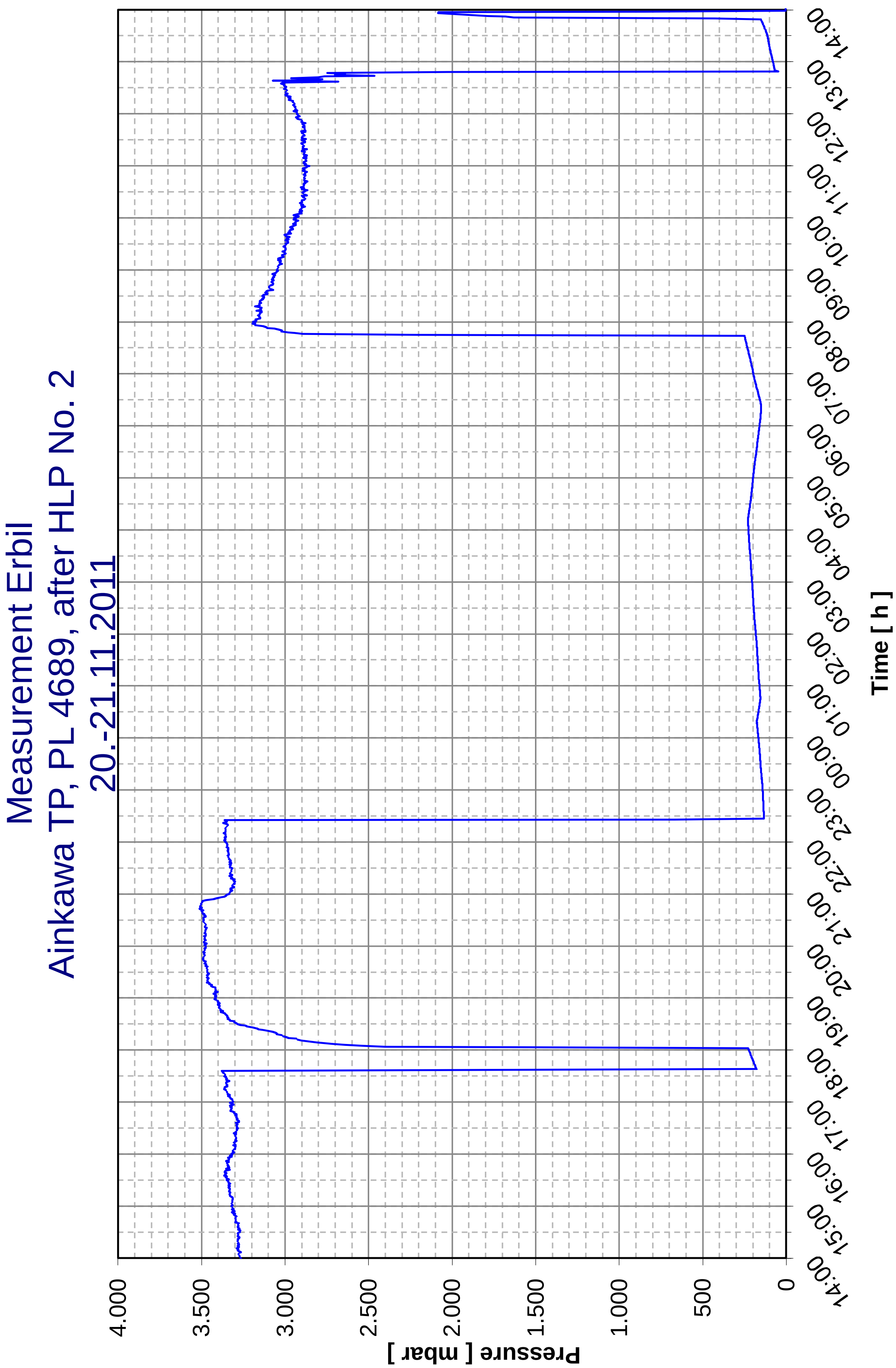
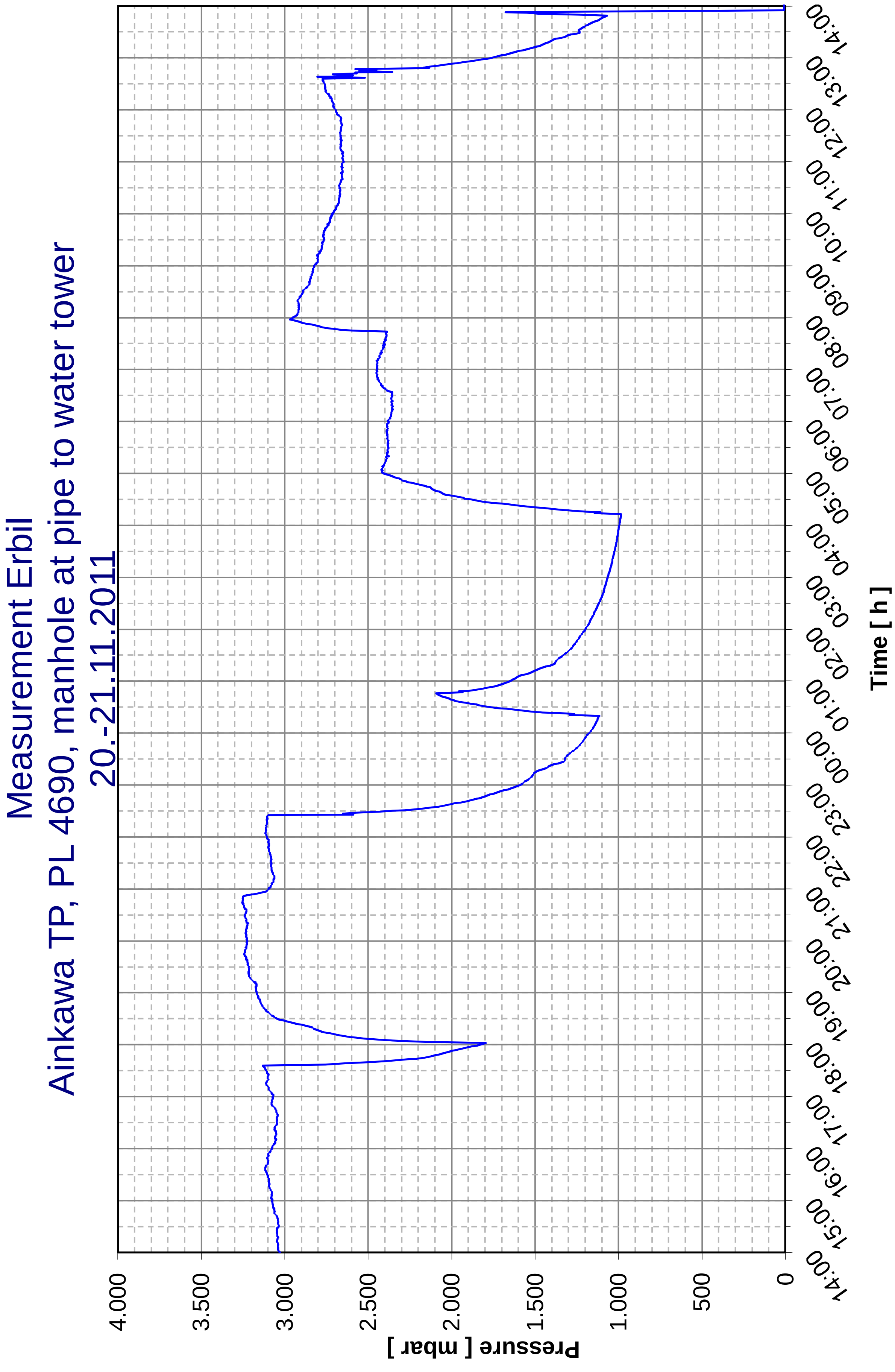
08:00
09:00
10:00
11:00
12:00
13:00
14:00


Measurement Erbil
Ainkawa TP, PL 4682, manhole at pipe to city
20.-21.11.2011
Pressure [mbar]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

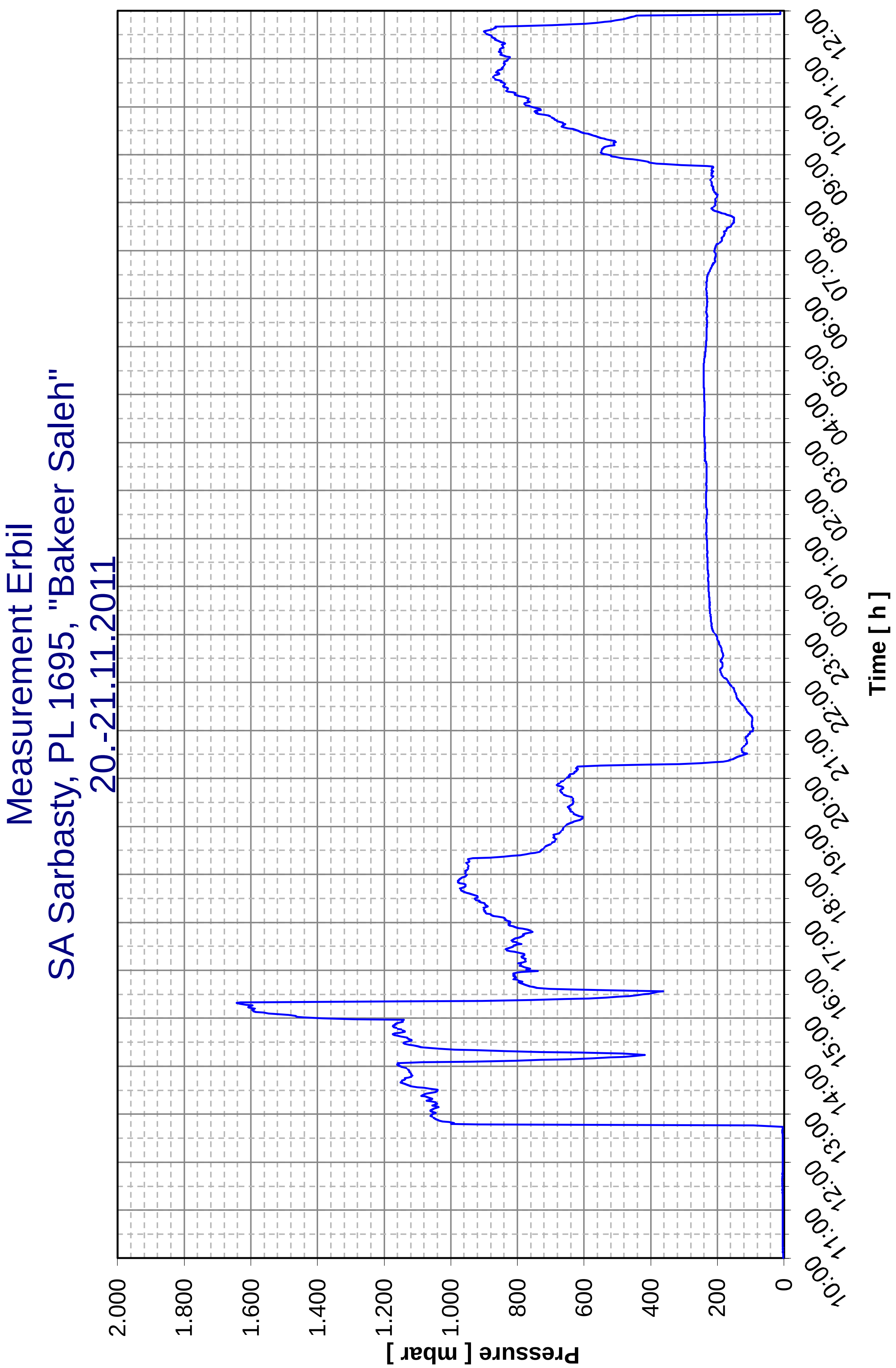

Measurement Erbil
Ainkawa TP, PL 4689, after HLP No. 2
20.-21.11.2011
Pressure [mbar]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

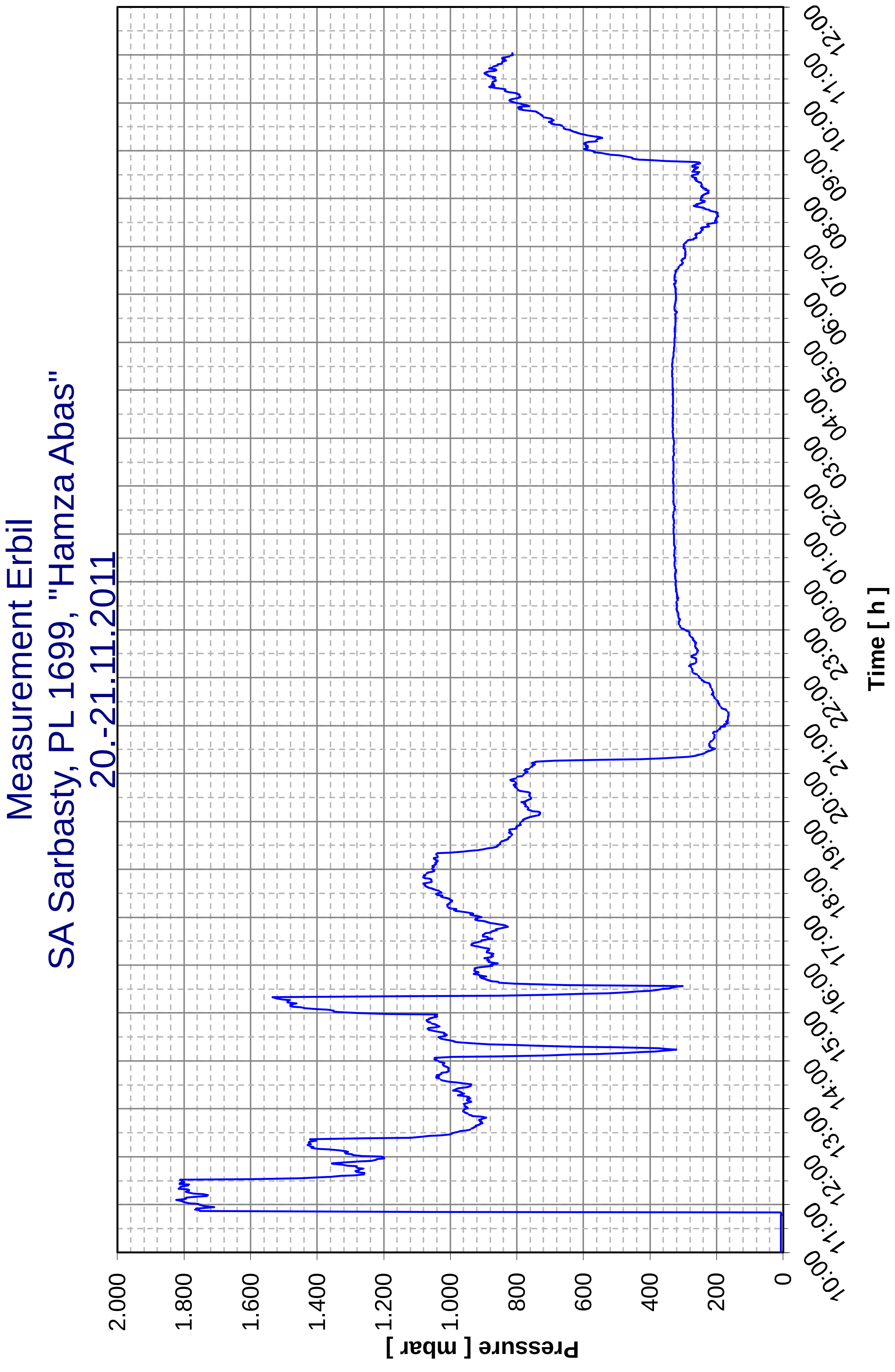

Measurement Erbil
Ainkawa TP, PL 4690, manhole at pipe to water tower
20.-21.11.2011
Pressure [mbar]
0
500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
Time [h]
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00

Flow- and Pressure Records

Pressure Logger Records

Sarbasty Area


Measurement Erbil
SA Sarbasty, PL 1695, "Bakeer Saleh"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 1699, "Hamza Abas"
20.-21.11.2011
Pressure [mbar]
0
200
400
600
800
1.000
1.200
1.400
1.600
1.800
2.000
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
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06:00
07:00
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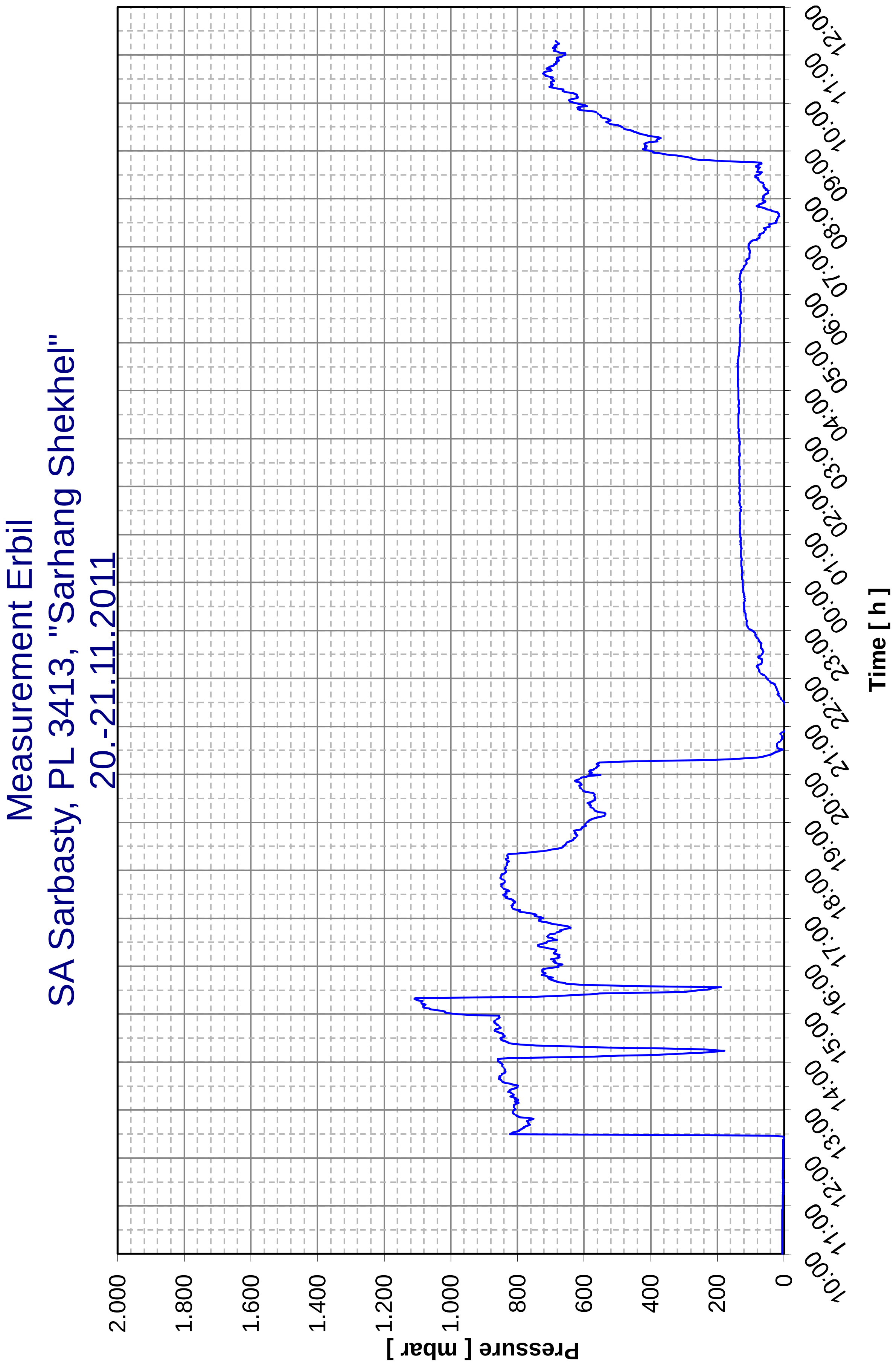
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 3413, "Sarhang Shekhel"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
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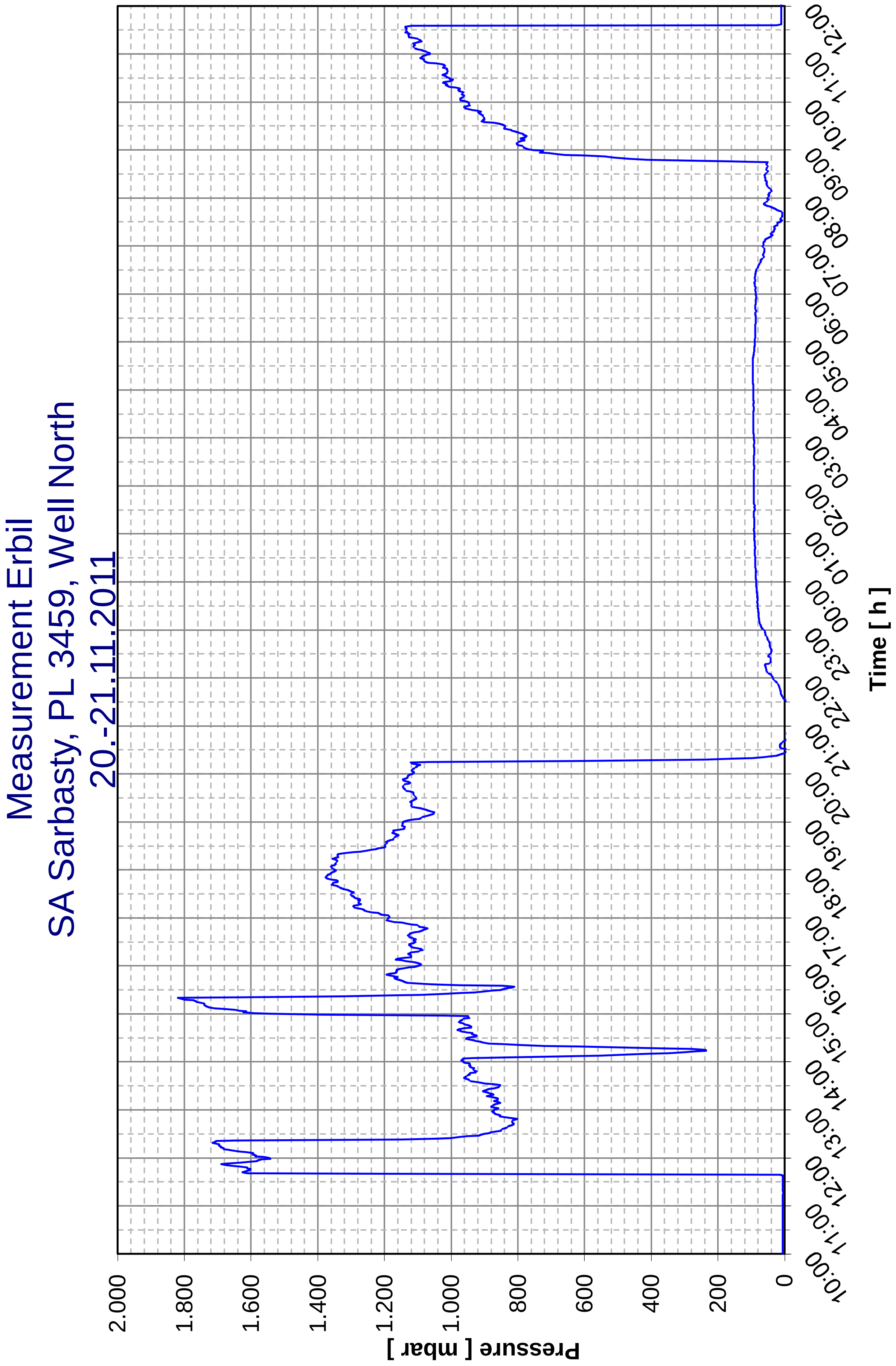
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 3459, Well North
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
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02:00
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04:00
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06:00
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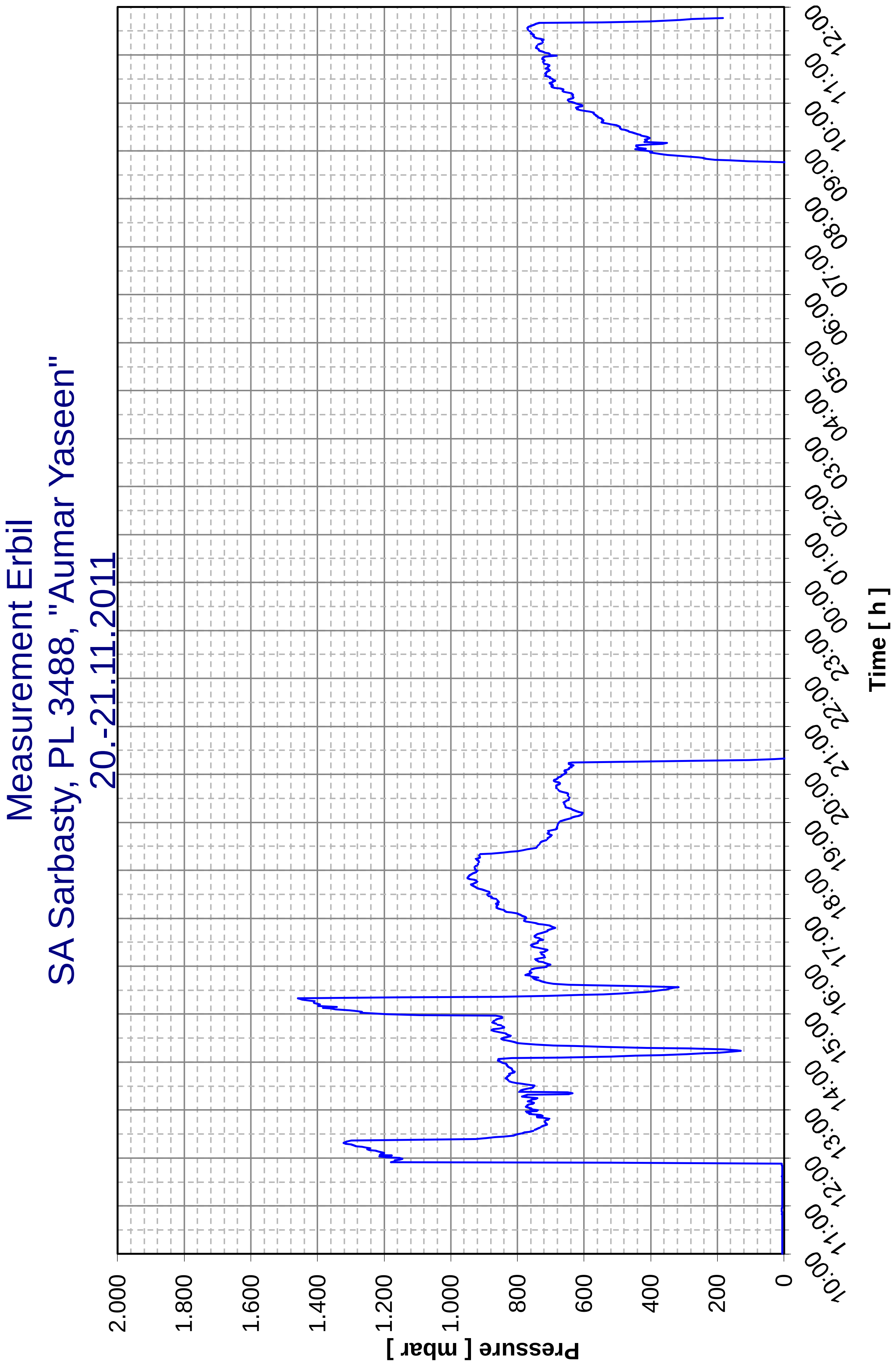
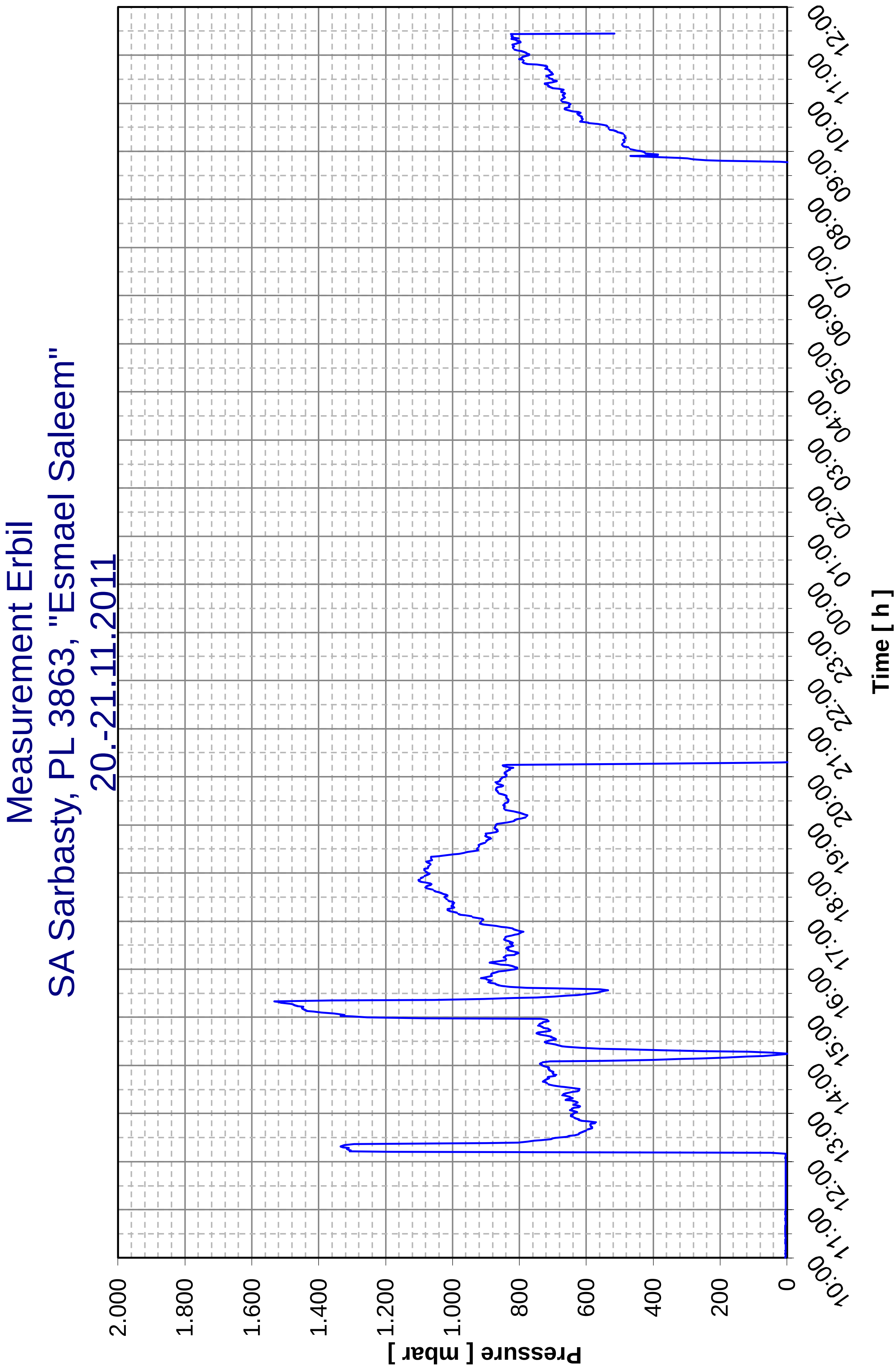
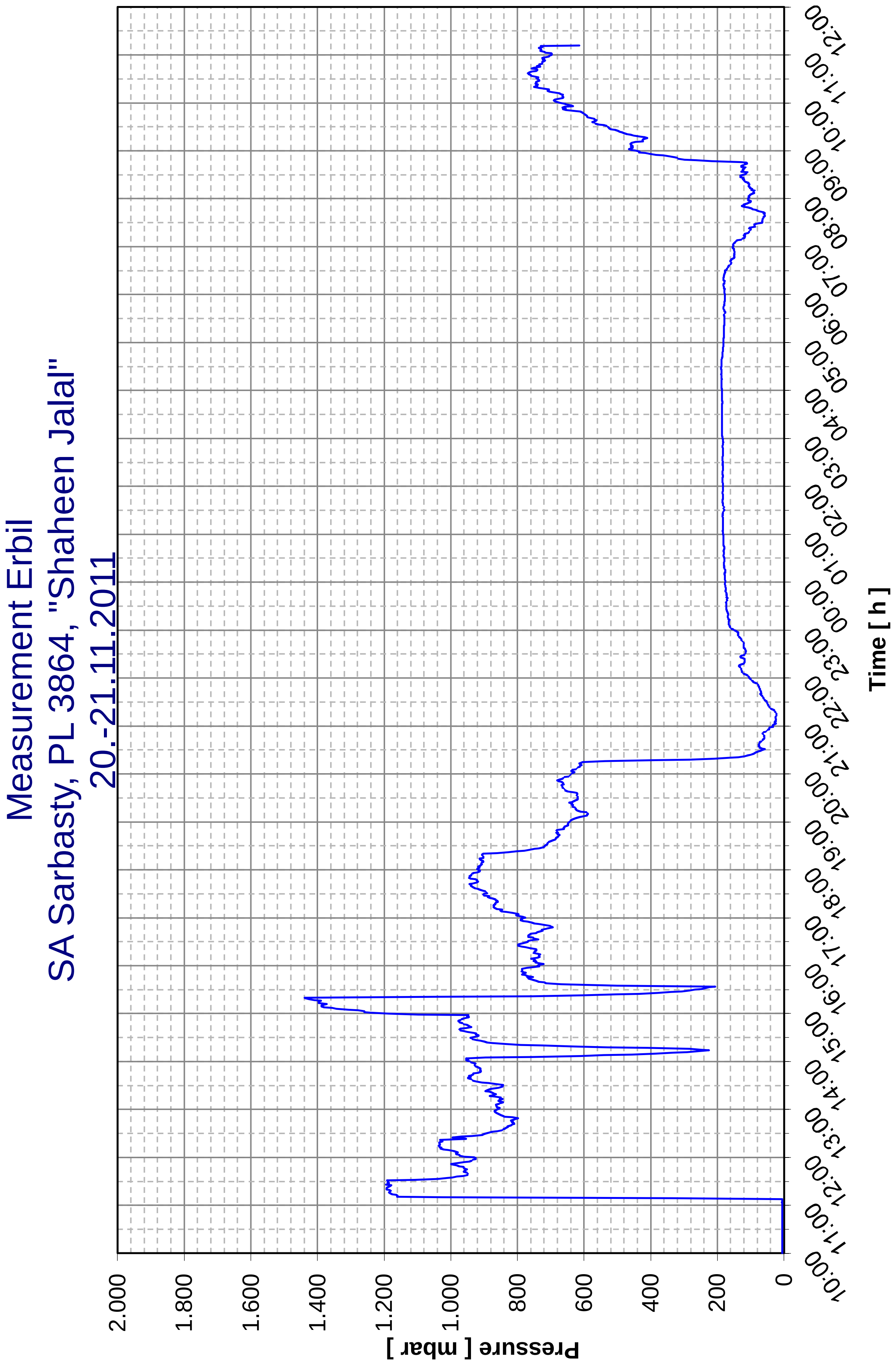
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 3488, "Aumar Yaseen"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 3863, "Esmael Saleem"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 3864, "Shaheen Jalal"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
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04:00
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06:00
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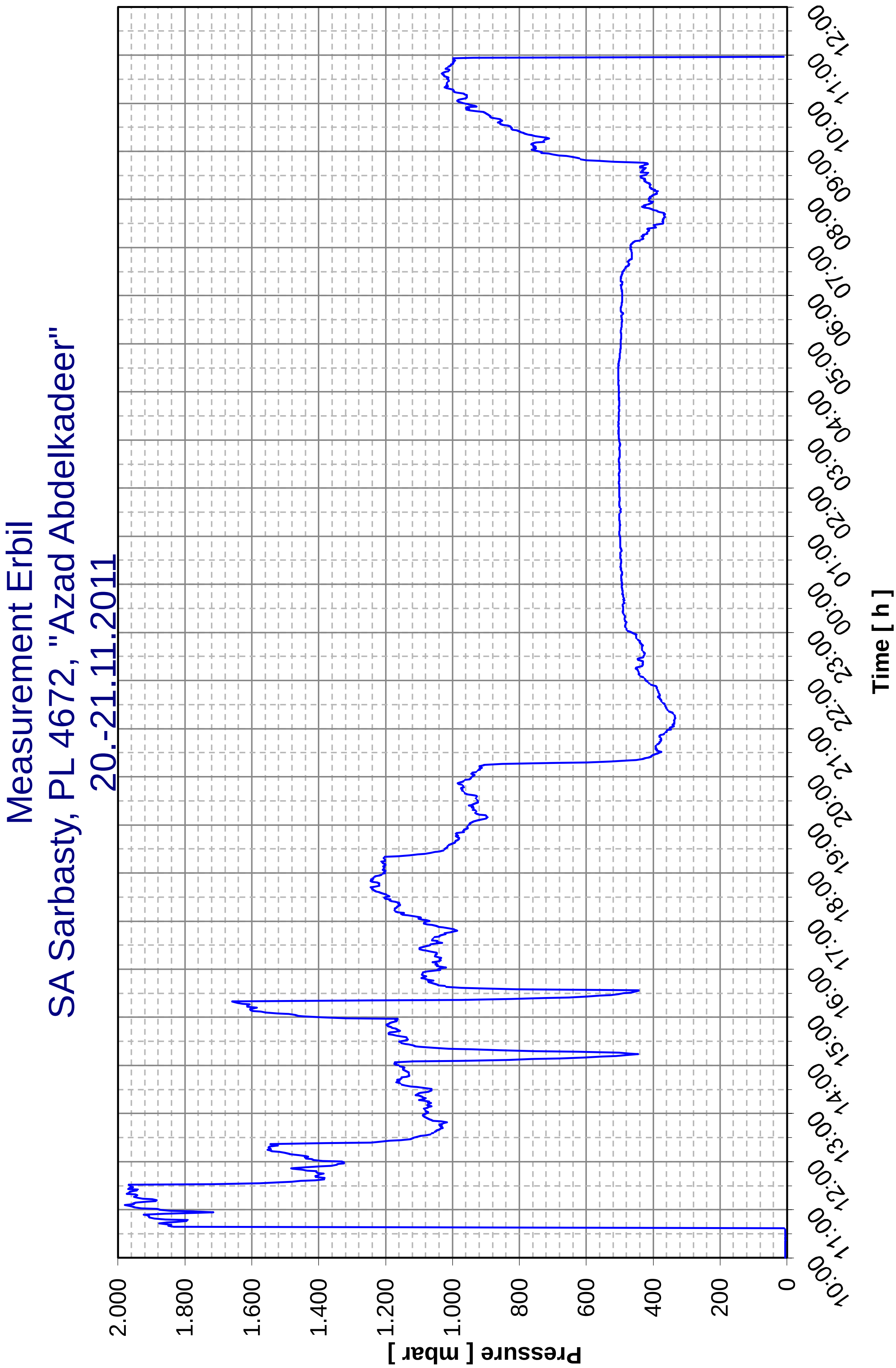
09:00
10:00
11:00
12:00


Measurement Erbil
SA Sarbasty, PL 4672, "Azad Abdelkadeer"
20.-21.11.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
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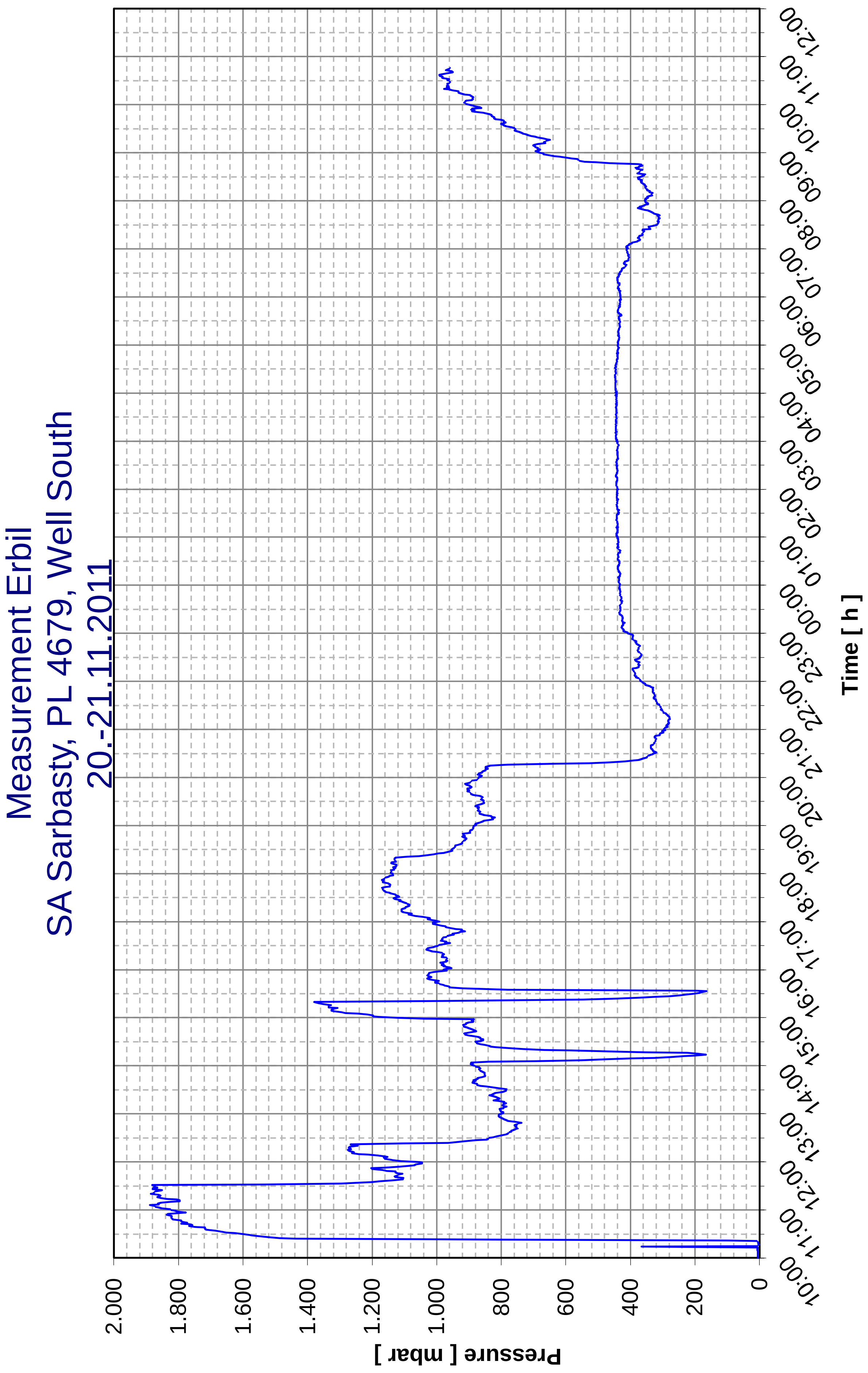
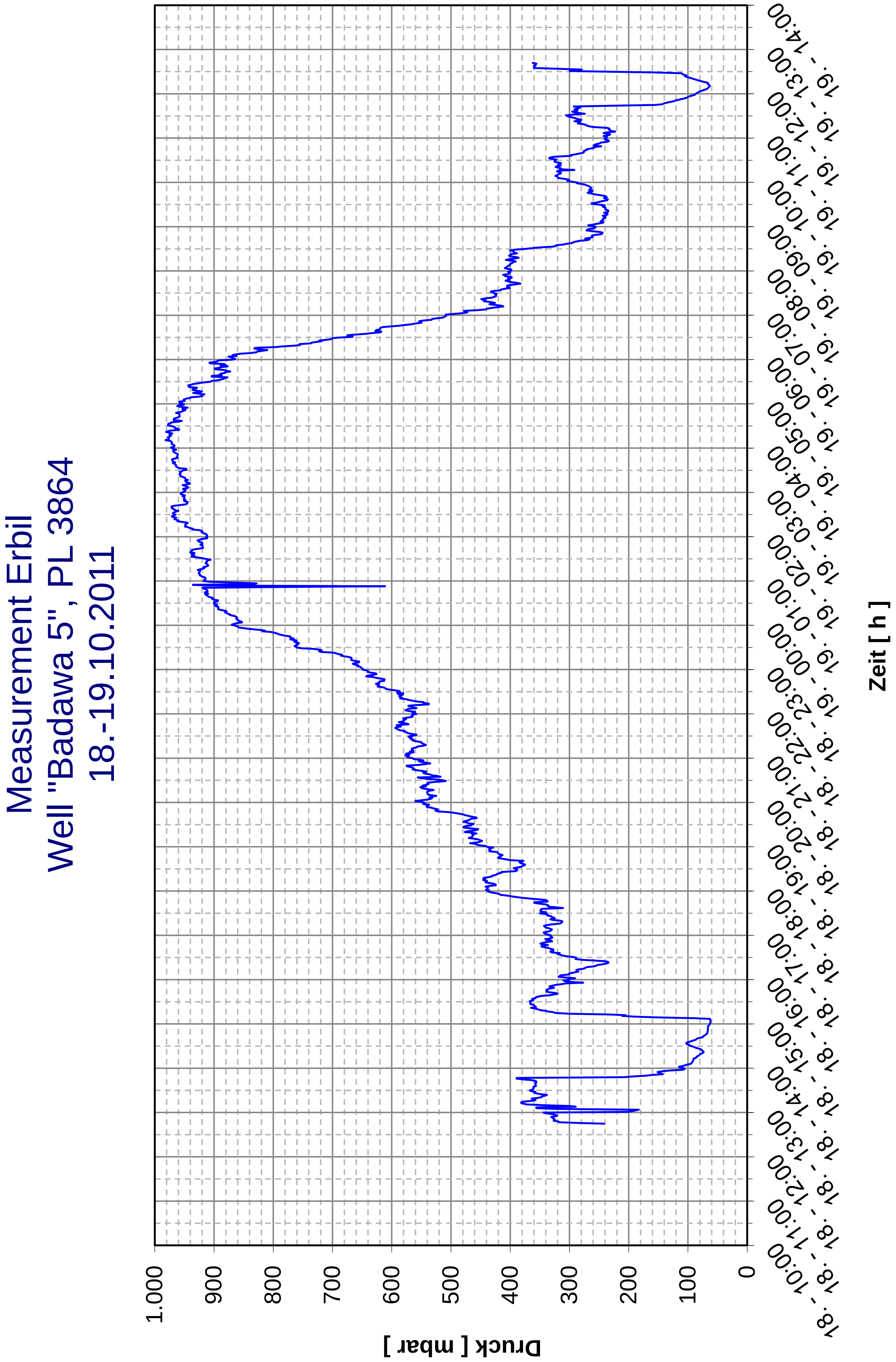
10:00
11:00
12:00

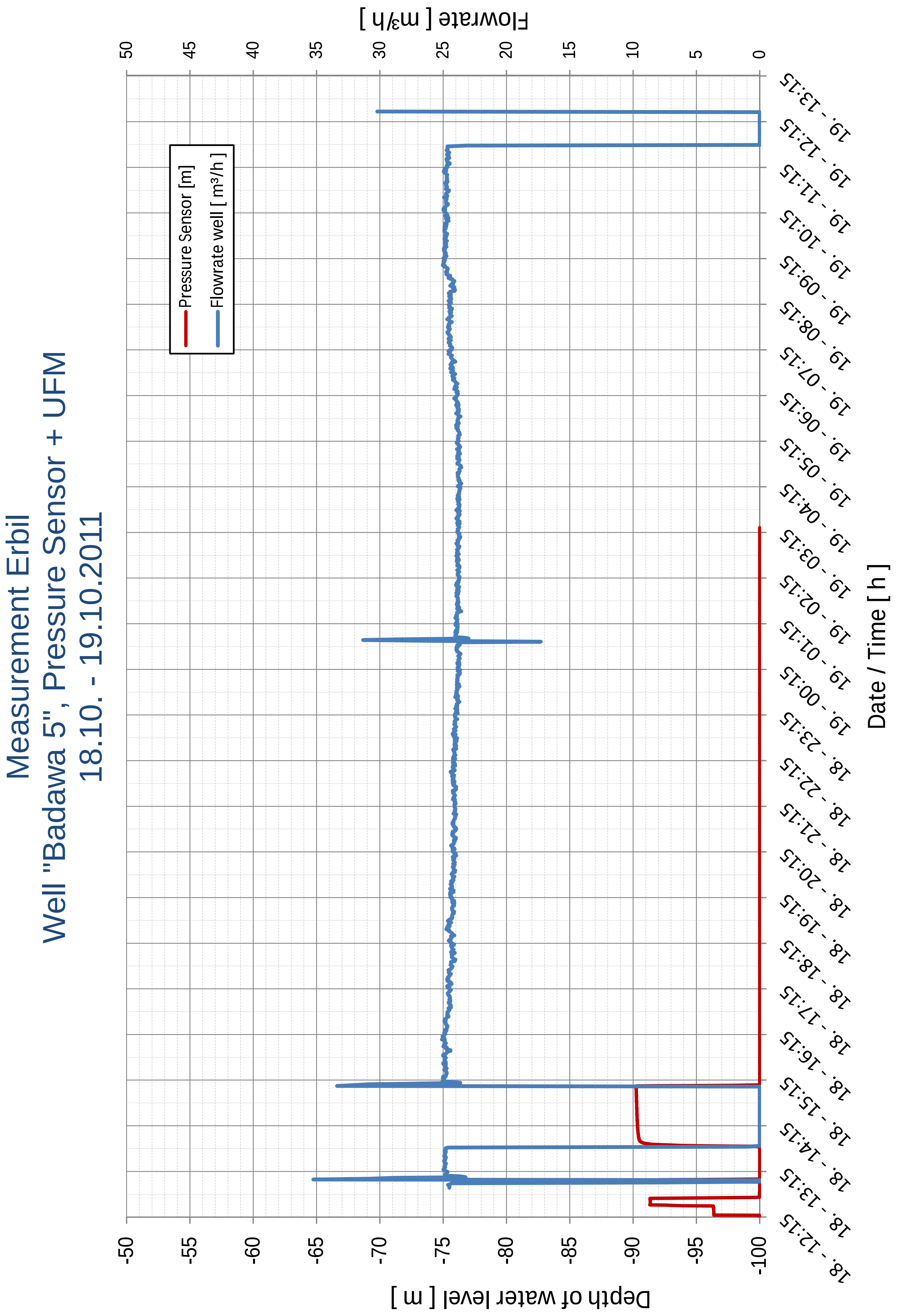

Measurement Erbil
SA Sarbasty, PL 4679, Well South
20.-21.11.2011
Pressure [mbar]
Time [h]
0
200
400
600
800
1.000
1.200
1.400
1.600
1.800
2.000
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00

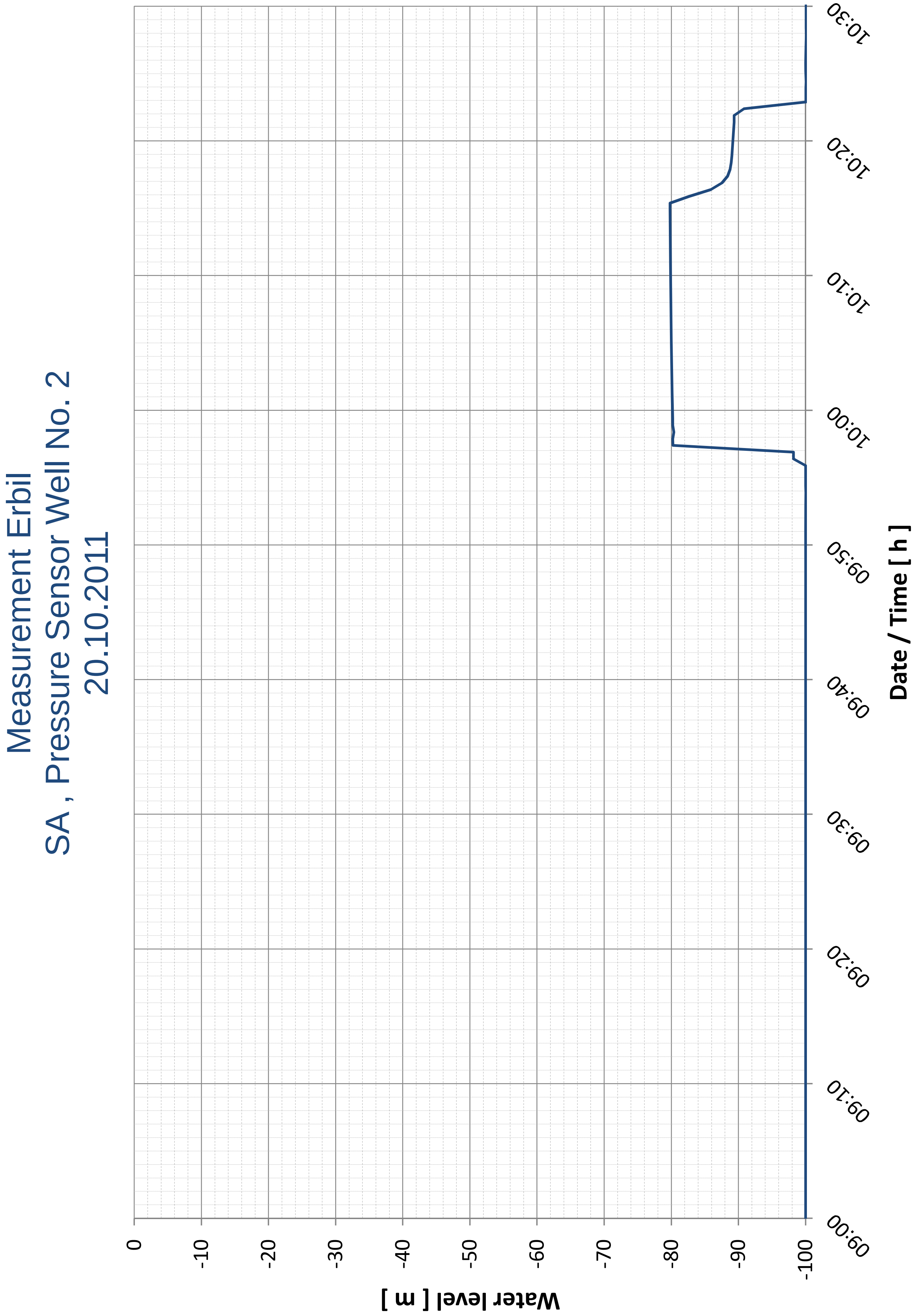
Flow- and Pressure Records

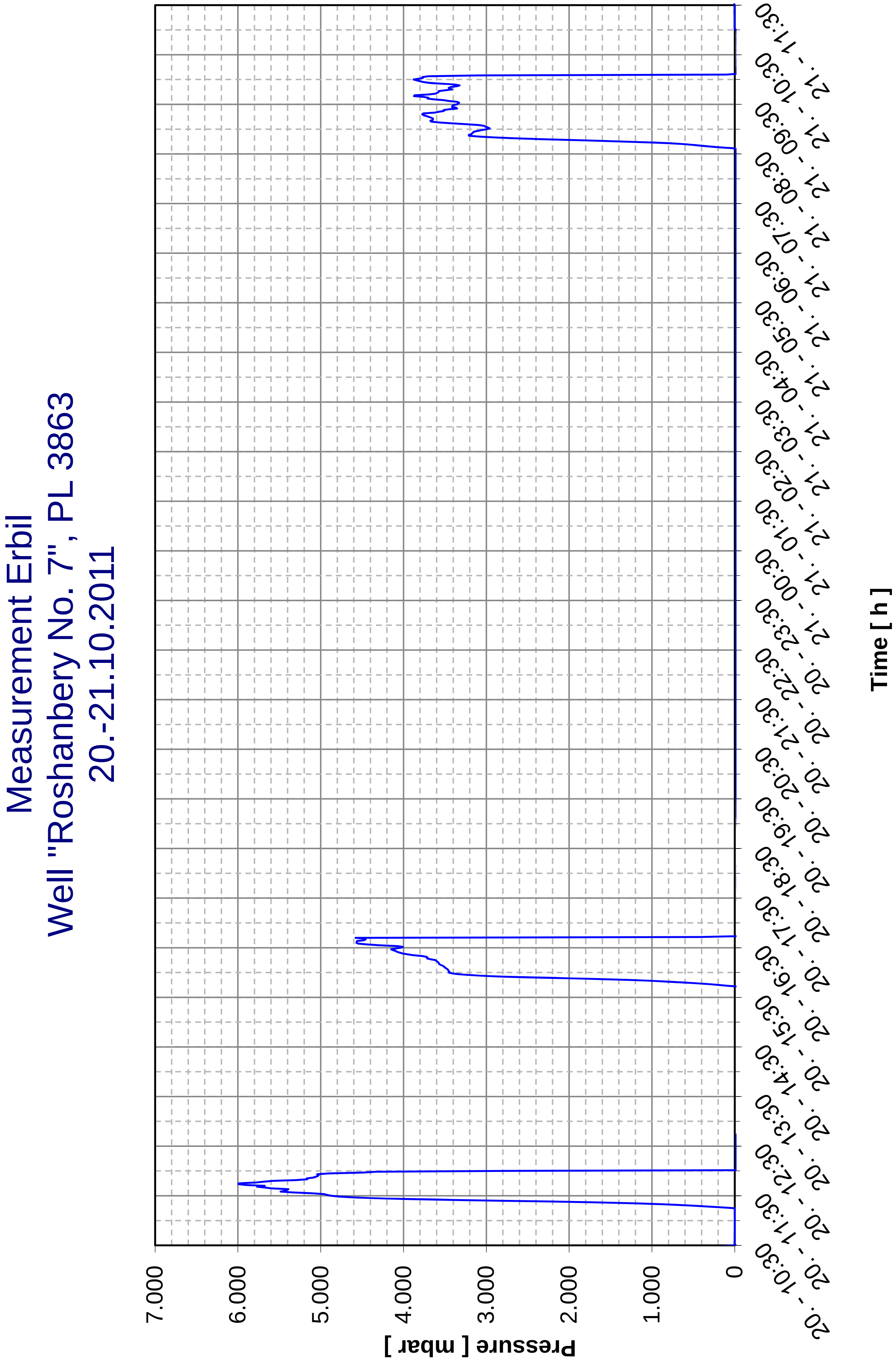
Flow-, Pressure Logger and Pressure Sensor Records

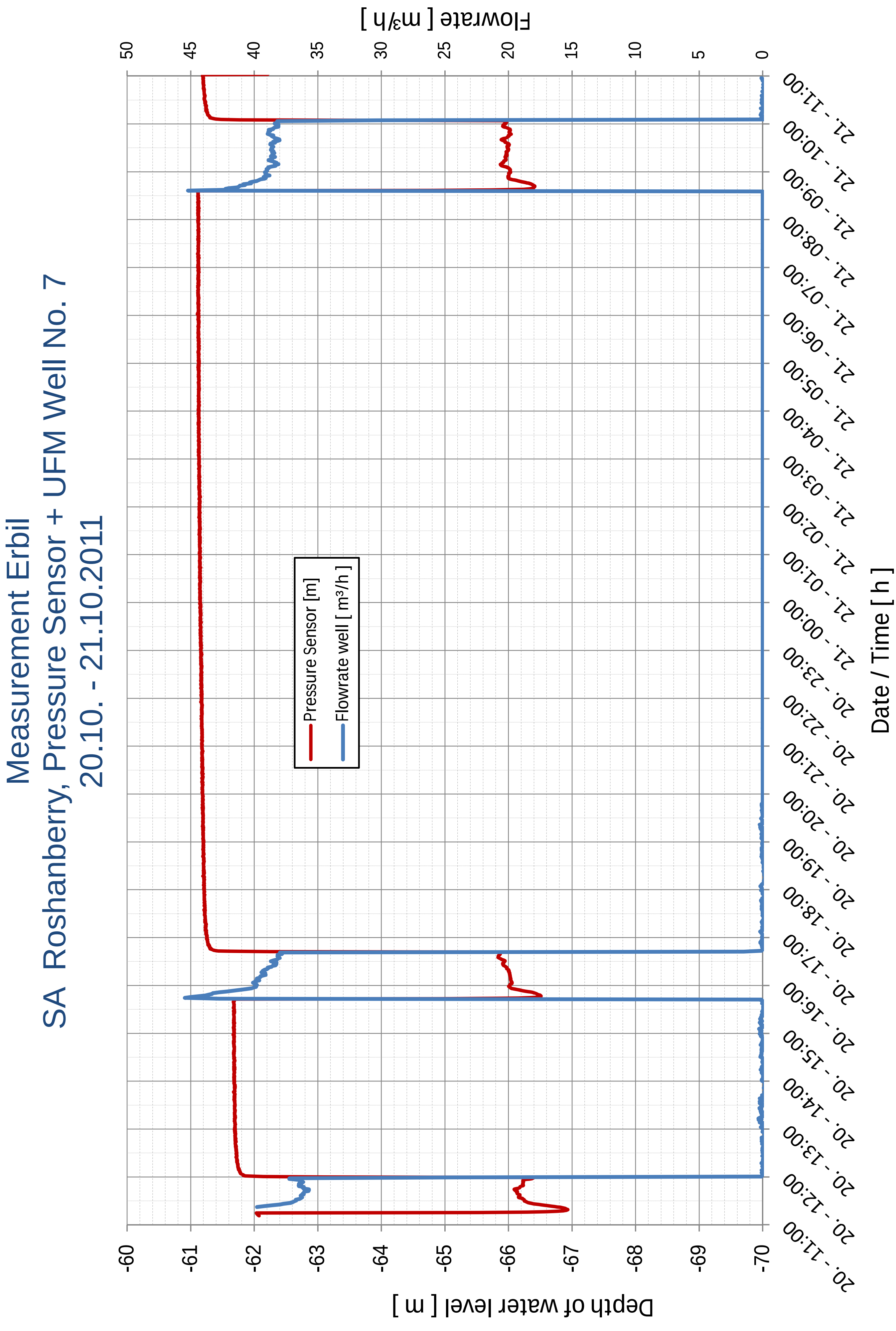
Well Measurement

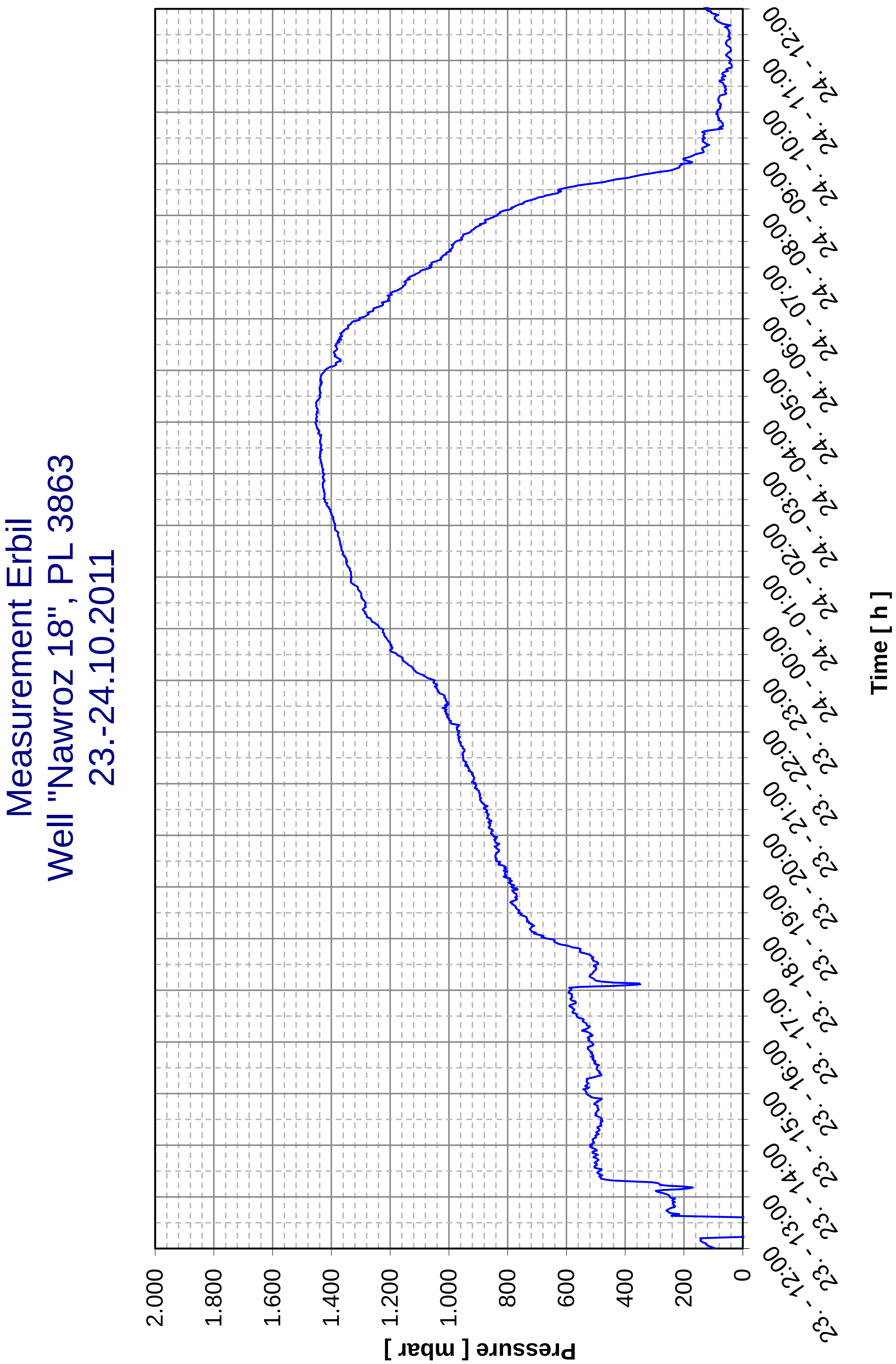

Measurement Erbil
Well "Badawa 5", PL 3864
18.-19.10.2011
Druck [mbar]
1.000
900
800
700
600
500
400
300
200
100
0
Zeit [h]
18. - 10:00
18. - 11:00
18. - 12:00
18. - 13:00
18. - 14:00
18. - 15:00
18. - 16:00
18. - 17:00
18. - 18:00
18. - 19:00
18. - 20:00
18. - 21:00
18. - 22:00
18. - 23:00
19. - 00:00
19. - 01:00
19. - 02:00
19. - 03:00
19. - 04:00
19. - 05:00
19. - 06:00
19. - 07:00
19. - 08:00
19. - 09:00
19. - 10:00
19. - 11:00
19. - 12:00
19. - 13:00
19. - 14:00

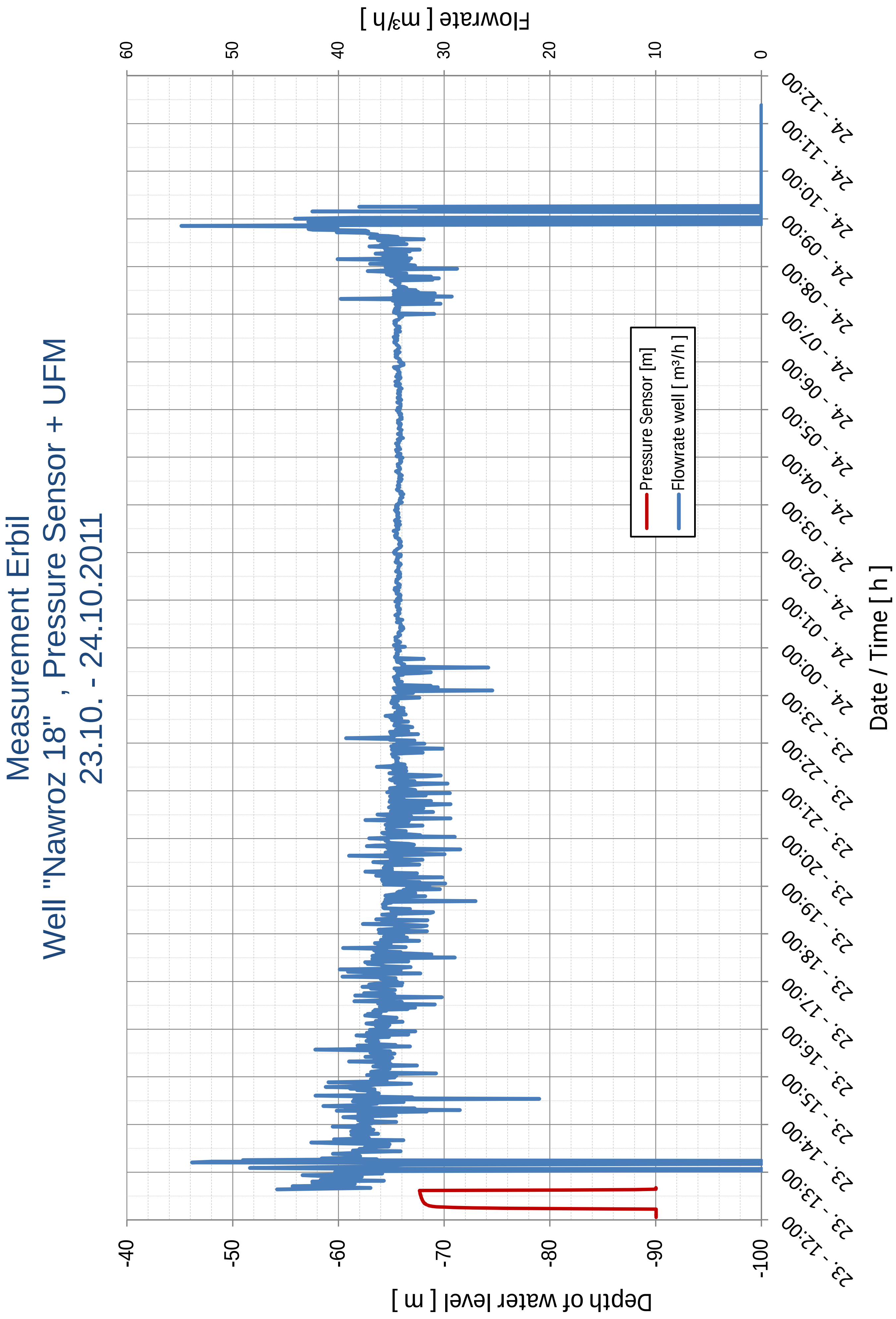

Measurement Erbil
Well "Badawa 5", Pressure Sensor + UFM
18.10. - 19.10.2011
Flowrate [m³/h]
Depth of water level [m]
Date / Time [h]
Pressure Sensor [m]
Flowrate well [m³/h]
50
45
40
35
30
25
20
15
10
5
0
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
18. - 12:15
18. - 13:15
18. - 14:15
18. - 15:15
18. - 16:15
18. - 17:15
18. - 18:15
18. - 19:15
18. - 20:15
18. - 21:15
18. - 22:15
18. - 23:15
19. - 00:15
19. - 01:15
19. - 02:15
19. - 03:15
19. - 04:15
19. - 05:15
19. - 06:15
19. - 07:15
19. - 08:15
19. - 09:15
19. - 10:15
19. - 11:15
19. - 12:15
19. - 13:15


Measurement Erbil
SA , Pressure Sensor Well No. 2
20.10.2011
Water level [m]
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Date / Time [h]
09:00
09:10
09:20
09:30
09:40
09:50
10:00
10:10
10:20
10:30

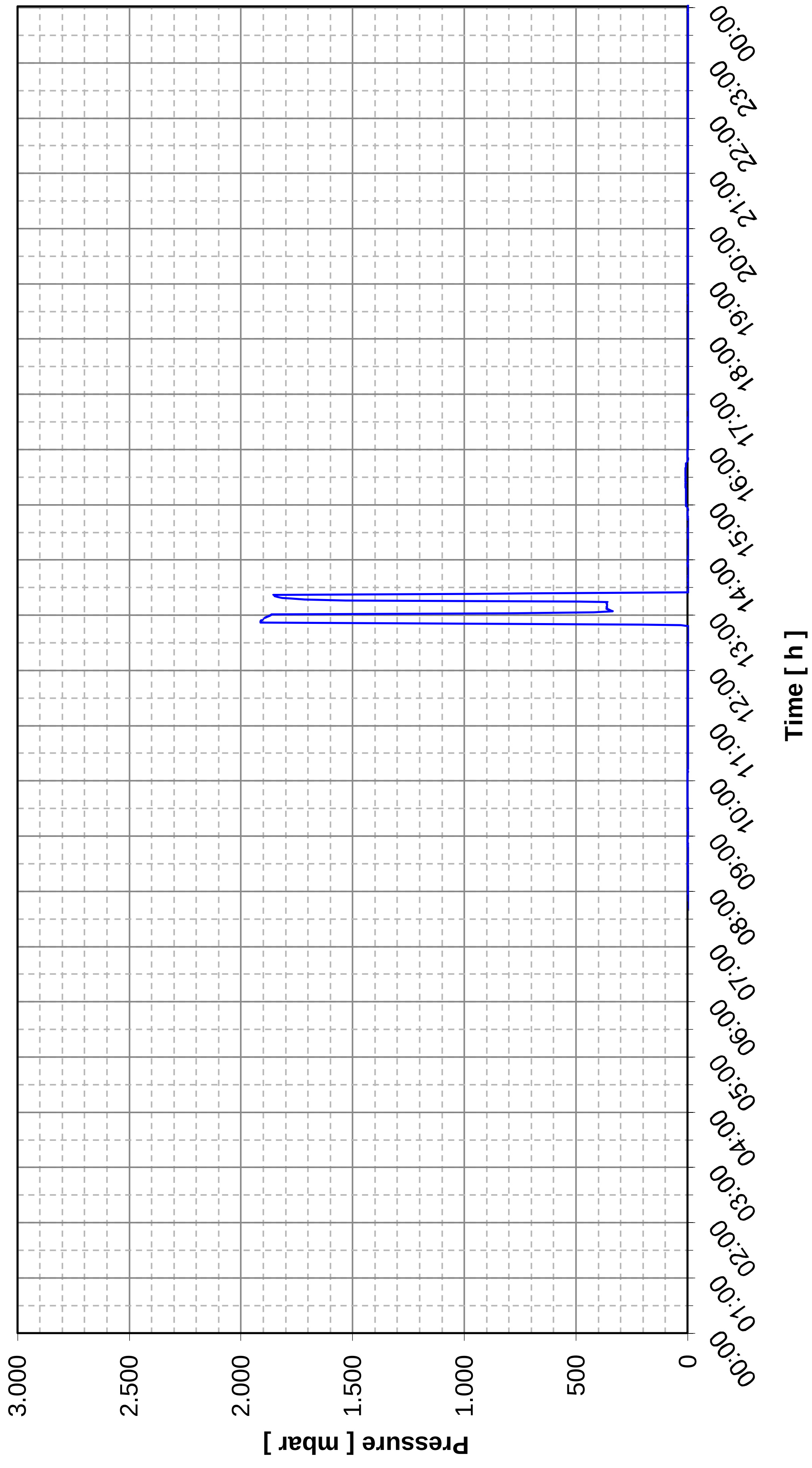

Measurement Erbil
Well "Roshanbery No. 7", PL 3863
20.-21.10.2011
Pressure [mbar]
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
Time [h]
20. - 10:30
20. - 11:30
20. - 12:30
20. - 13:30
20. - 14:30
20. - 15:30
20. - 16:30
20. - 17:30
20. - 18:30
20. - 19:30
20. - 20:30
20. - 21:30
20. - 22:30
20. - 23:30
21. - 00:30
21. - 01:30
21. - 02:30
21. - 03:30
21. - 04:30
21. - 05:30
21. - 06:30
21. - 07:30
21. - 08:30
21. - 09:30
21. - 10:30
21. - 11:30


Measurement Erbil
SA Roshanberry, Pressure Sensor + UFM Well No. 7
20.10. - 21.10.2011
Flowrate [m³/h]
0
5
10
15
20
25
30
35
40
45
50
Depth of water level [m]
-70
-69
-68
-67
-66
-65
-64
-63
-62
-61
-60
Date / Time [h]
20. - 11:00
20. - 12:00
20. - 13:00
20. - 14:00
20. - 15:00
20. - 16:00
20. - 17:00
20. - 18:00
20. - 19:00
20. - 20:00
20. - 21:00
20. - 22:00
20. - 23:00
21. - 00:00
21. - 01:00
21. - 02:00
21. - 03:00
21. - 04:00
21. - 05:00
21. - 06:00
21. - 07:00
21. - 08:00
21. - 09:00
21. - 10:00
21. - 11:00
Pressure Sensor [m]
Flowrate well [m³/h]

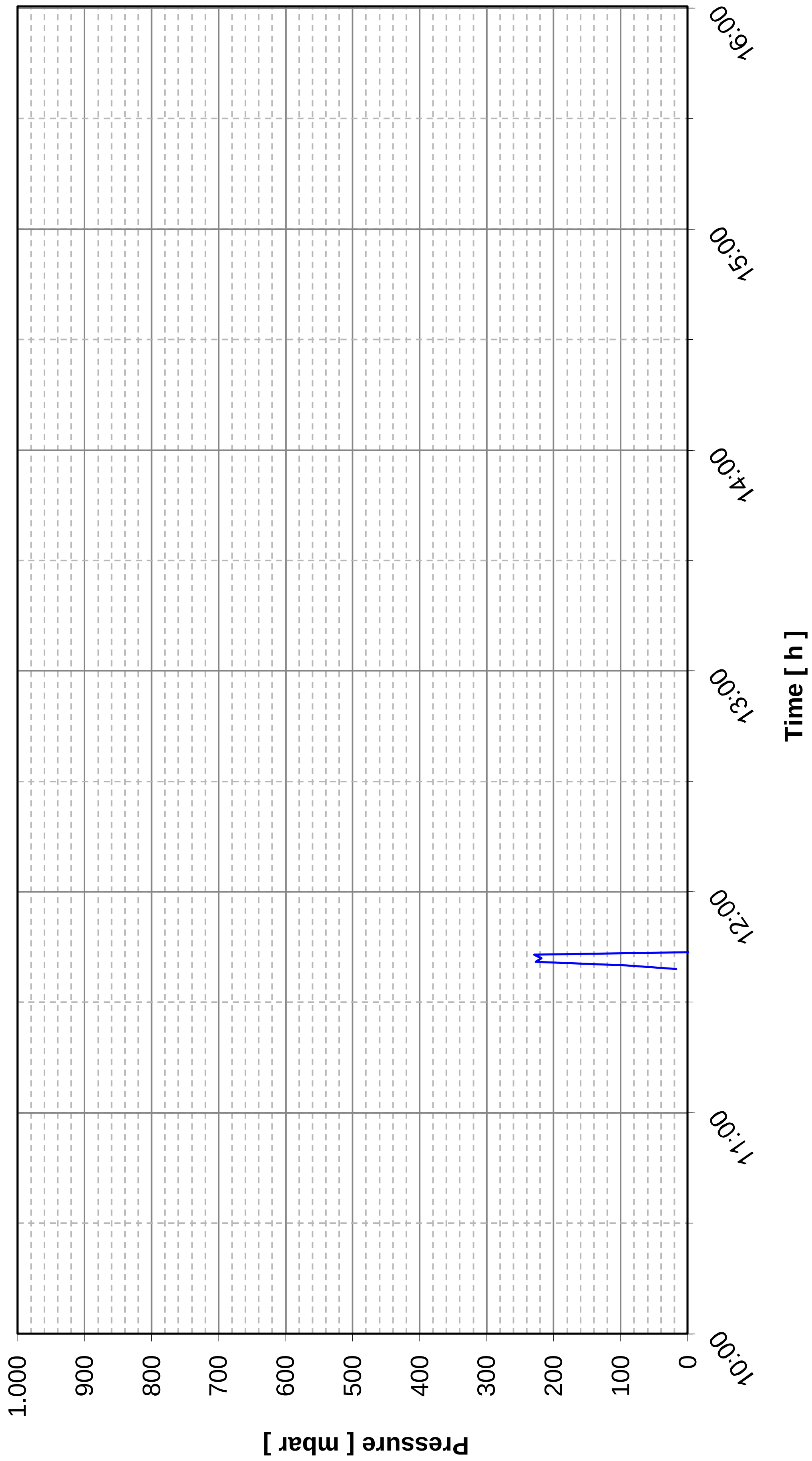

Measurement Erbil
Well "Nawroz 18", PL 3863
23.-24.10.2011
Pressure [mbar]
2.000
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
Time [h]
23. - 12:00
23. - 13:00
23. - 14:00
23. - 15:00
23. - 16:00
23. - 17:00
23. - 18:00
23. - 19:00
23. - 20:00
23. - 21:00
23. - 22:00
23. - 23:00
24. - 00:00
24. - 01:00
24. - 02:00
24. - 03:00
24. - 04:00
24. - 05:00
24. - 06:00
24. - 07:00
24. - 08:00
24. - 09:00
24. - 10:00
24. - 11:00
24. - 12:00

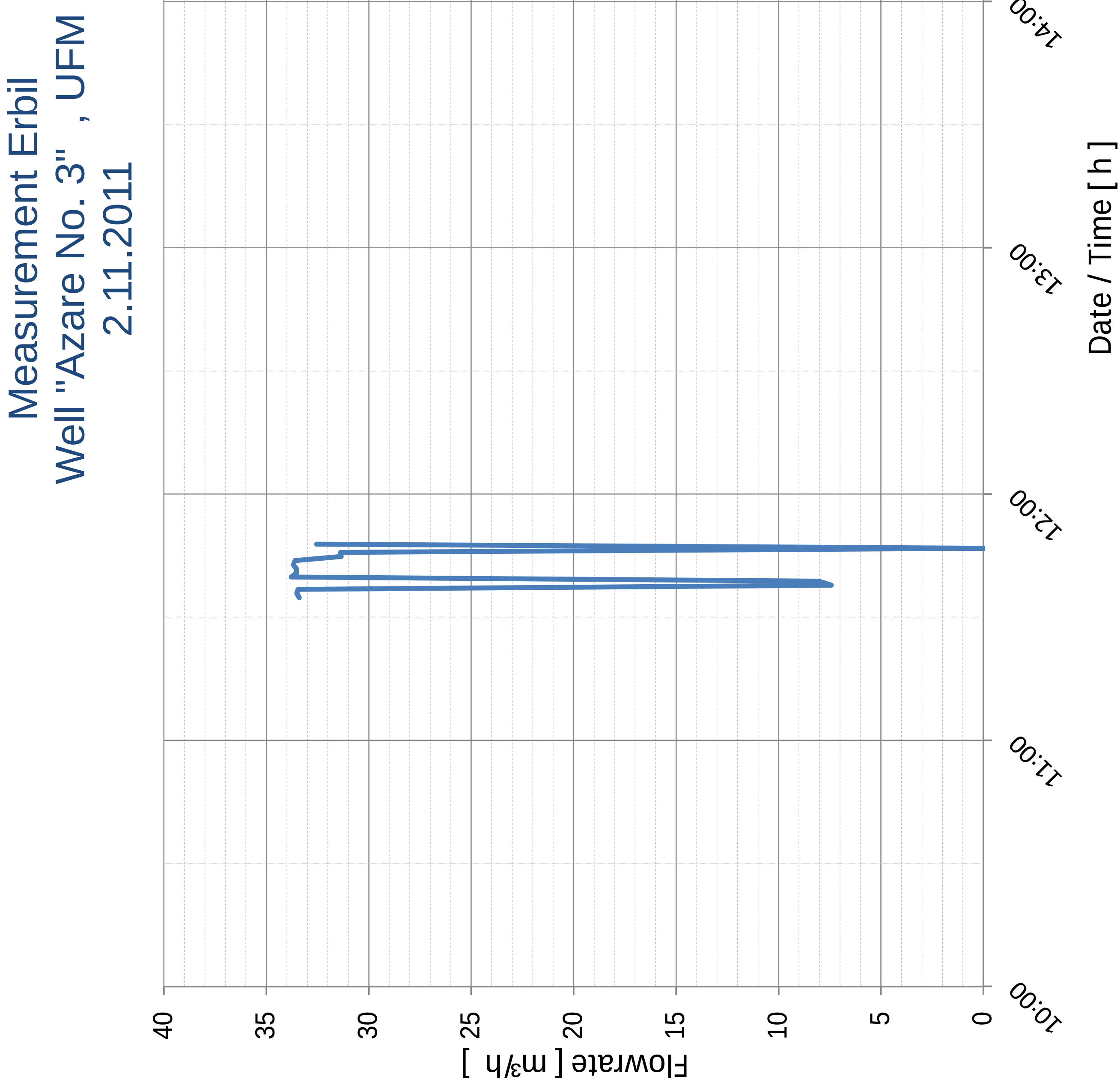

Measurement Erbil
Well "Nawroz 18" , Pressure Sensor + UFM
23.10. - 24.10.2011
Flowrate [m³/h]
Depth of water level [m]
Date / Time [h]
Pressure Sensor [m]
Flowrate well [m³/h]
0
10
20
30
40
50
60
-40
-50
-60
-70
-80
-90
-100
23. - 12:00
23. - 13:00
23. - 14:00
23. - 15:00
23. - 16:00
23. - 17:00
23. - 18:00
23. - 19:00
23. - 20:00
23. - 21:00
23. - 22:00
23. - 23:00
24. - 00:00
24. - 01:00
24. - 02:00
24. - 03:00
24. - 04:00
24. - 05:00
24. - 06:00
24. - 07:00
24. - 08:00
24. - 09:00
24. - 10:00
24. - 11:00
24. - 12:00

Measurement Erbil
Well "Ainkawa 3" , PL 4680
26.10.2011



Measurement Erbil
Well "Azare No. 3", PL 4691
2.11.2011




Measurement Erbil
Well "Azare No. 3" , UFM
2.11.2011
Flowrate [m³/h]
0
5
10
15
20
25
30
35
40
Date / Time [h]
10:00
11:00
12:00
13:00
14:00
15:00
16:00

APPENDIX 3

Overview Calculation Maps

KURDISTAN REGIONAL GOVERNMENT - IRAQ

MINISTRY OF MUNICIPALITIES AND TOURISM

Kurdistan Region Infrastructure

Water Sector Master Plan

HYDRAULIC CALCULATION

ERBIL

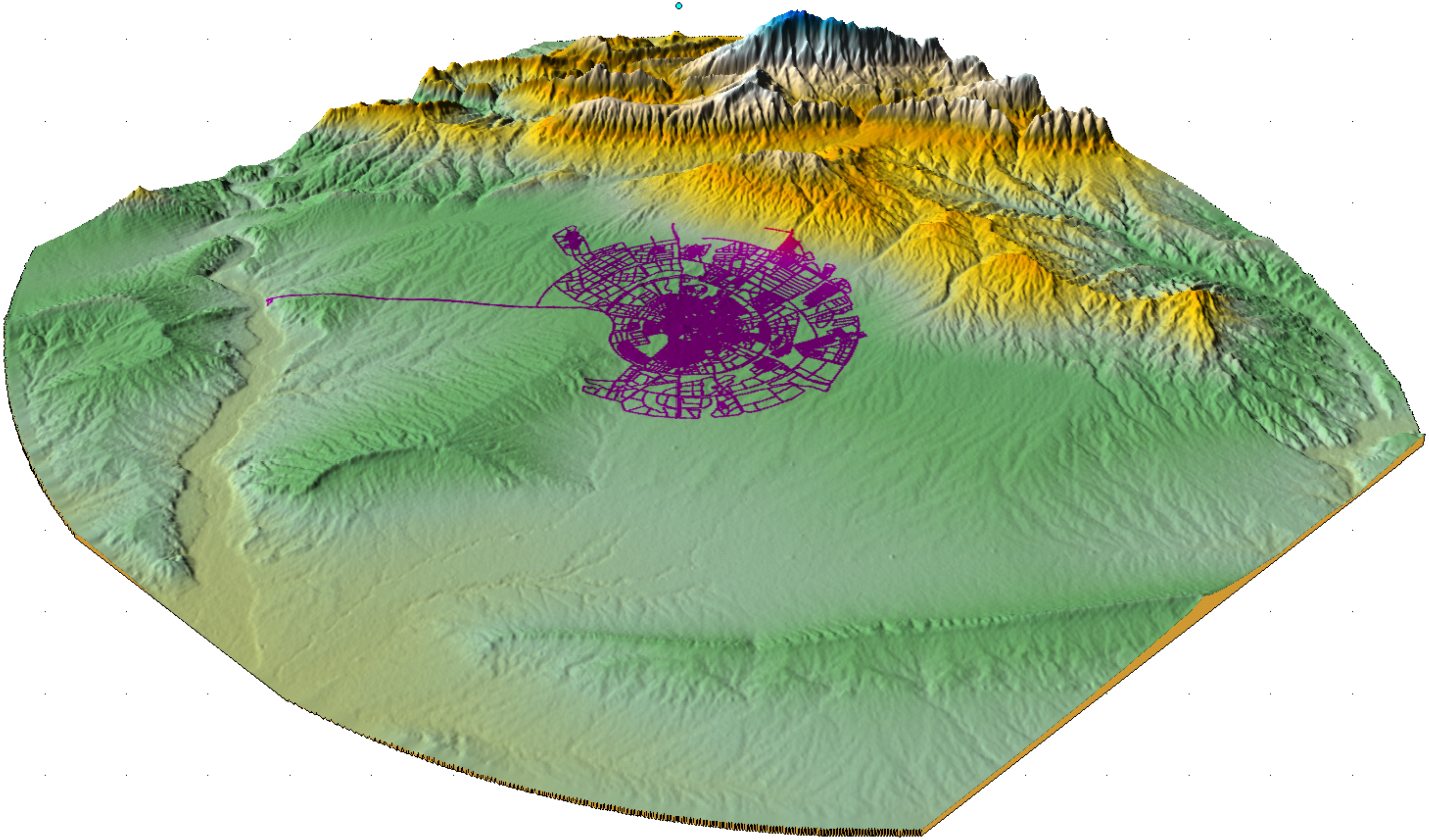
APPENDIX 3

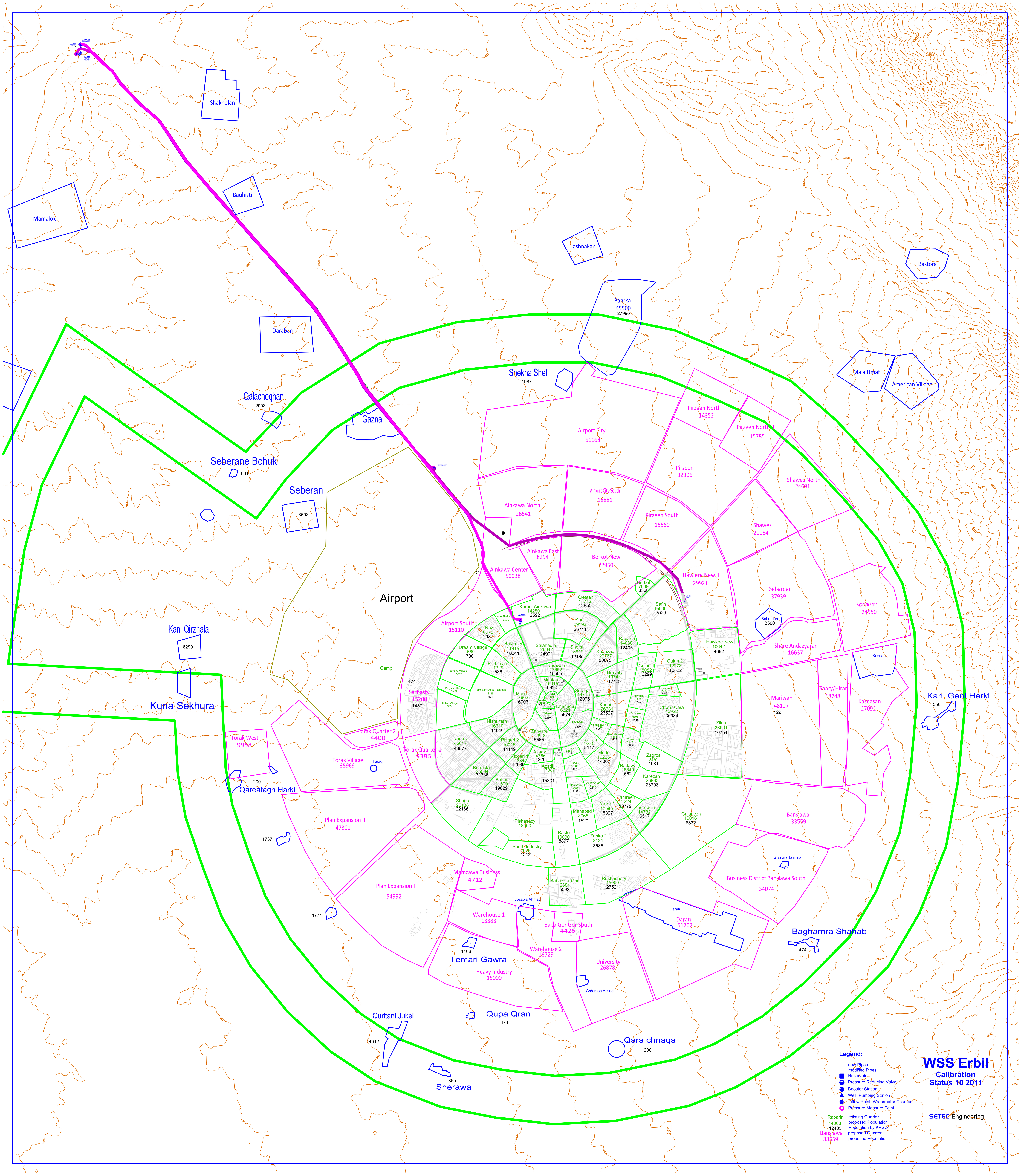
OVERVIEW CALCULATION MAPS

JUNE 2012

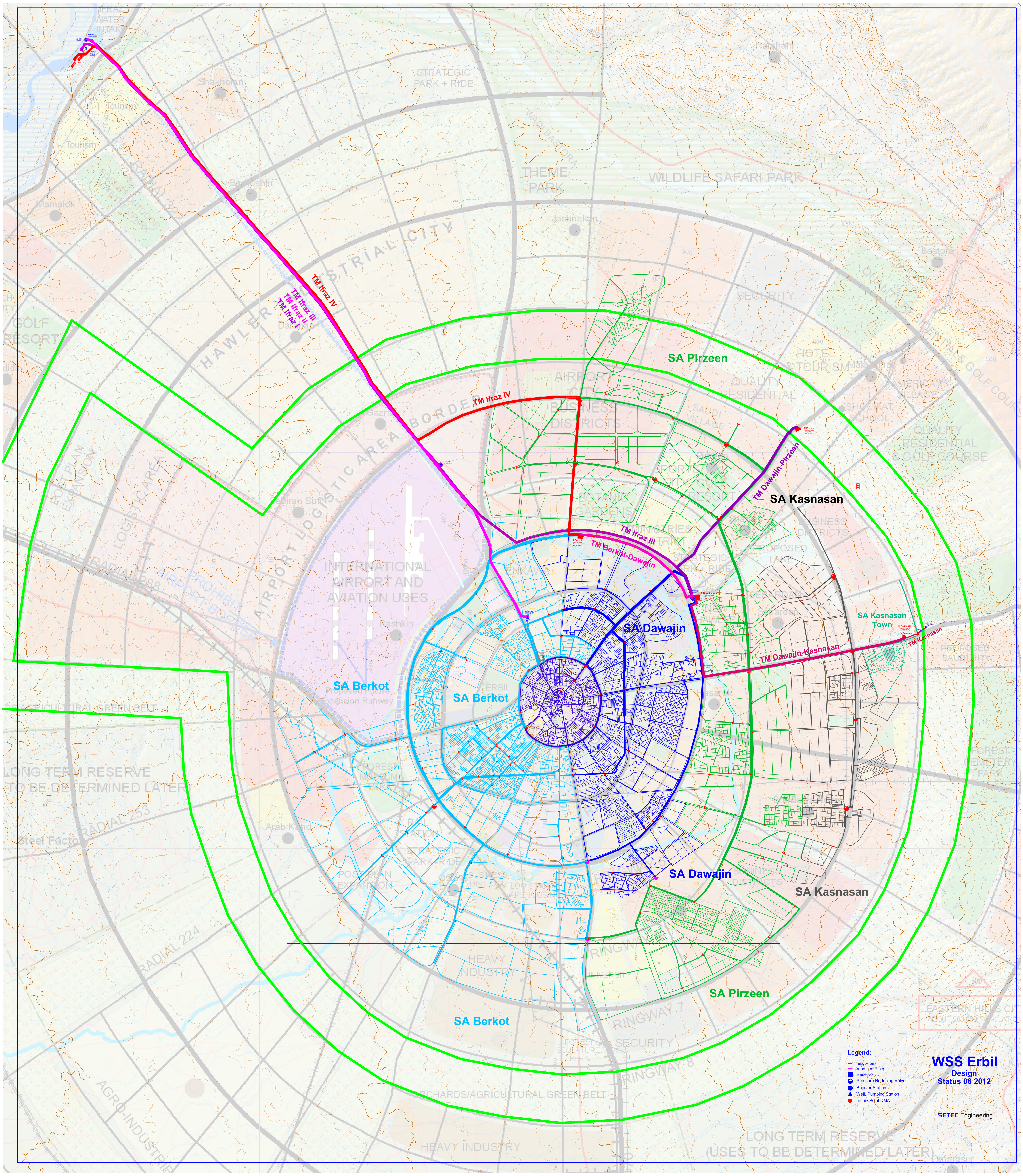
SETEC Engineering

HYDRAULIC CALCULATION *WD - ERBIL*
PANORAMA HORIZON: 2035

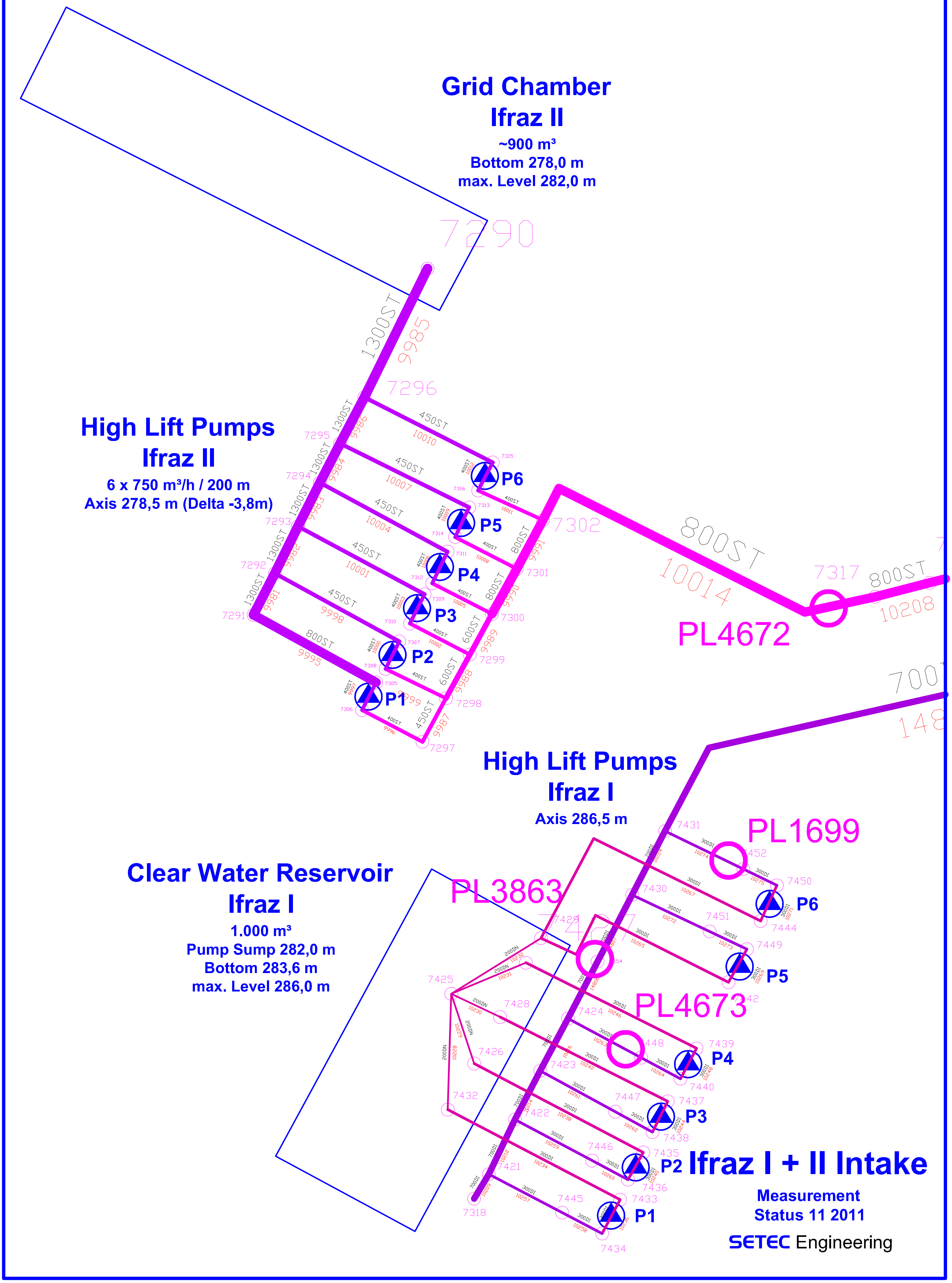




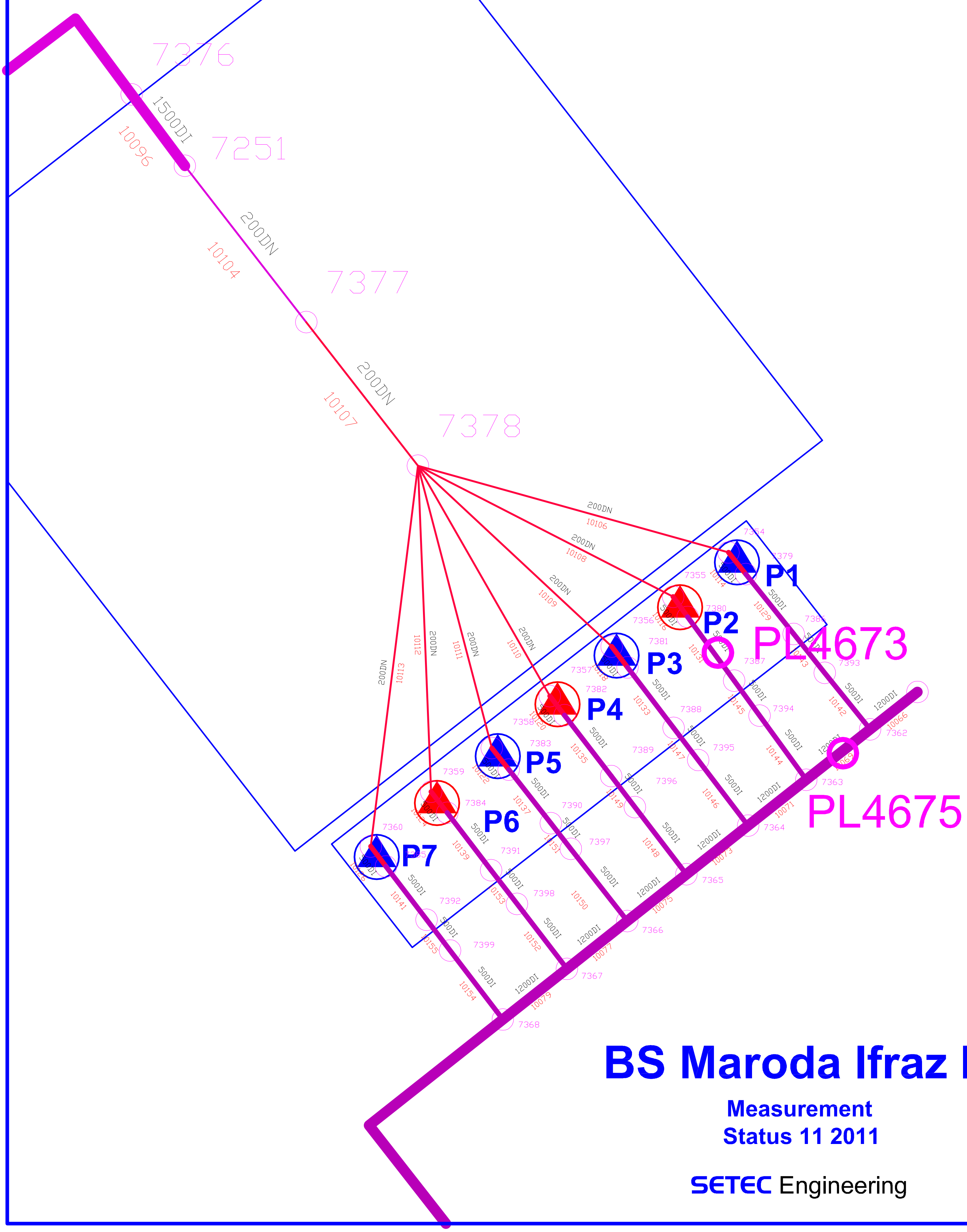
Shakholan
Mamalok
Bauhistir
Jashnakan
Bastora
Bahrka
45500
27996
Daraban
Shekha Shel
1987
Mala Umat
American Village
Qalachoqhan
2003
Gazna
Seberane Bchuk
631
Seberan
8698
Pirzeen North I
14352
Pirzeen North II
15785
Airport City
61168
Pirzeen
32306
Shawes North
24691
Airport City South
18881
Ainkawa North
26541
Pirzeen South
15560
Shawes
20054
Ainkawa East
8294
Berkot New
22950
Ainkawa Center
50038
Hawlere New II
29921
Sebardan
37939
Airport
Kani Qirzhala
6290
Kuna Sekhura
Airport South
15110
Sebardan
3500
Share Andazyaran
16637
Kasnasan North
24950
Kasnasan
Kani Gani Harki
556
Sarbasty
15200
1457
Mariwan
48127
129
Shary/Hiran
18748
Kamasan
27092
Camp
474
Torak Quarter 2
4400
Torak Quarter 1
9386
Torak West
9958
Torak Village
35969
Turaq
200
Qareatagh Harki
Plan Expansion II
47301
1737
Banslawa
33559
Grasur (Halmat)
Business District Banslawa South
34074
Plan Expansion I
54992
Mamzawa Business
4712
1771
Warehouse 1
13383
Baba Gor Gor South
4426
Daratu
Daratu
51702
Baghamra Shahab
474
1406
Temari Gawra
Warehouse 2
16729
Heavy Industry
15000
University
26878
Grdarash Assad
Quritani Jukel
4012
Qupa Qran
474
Qara chnaqa
200
365
Sherawa
Legend:
new Pipes
modified Pipes
Reservoir
Pressure Reducing Valve
Booster Station
Well, Pumping Station
Inflow Point, Watermeter Chamber
Pressure Measure Point
Raparin existing Quarter
14068 proposed Population
12405 Population by KRSO
Banslawa proposed Quarter
33559 proposed Population
WSS Erbil
Calibration
Status 10 2011
SETEC Engineering


TM Ifraz IV
TM Ifraz III
TM Ifraz II
TM Ifraz I
TM Ifraz IV
TM Ifraz III
TM Berkot-Dawajin
TM Dawajin-Pirzeen
TM Dawajin-Kasnasan
TM Kasnasan
SA Pirzeen
SA Kasnasan
SA Kasnasan Town
SA Dawajin
SA Berkot
SA Berkot
SA Berkot
SA Dawajin
SA Kasnasan
SA Pirzeen
STRATEGIC PARK + RIDE
THEME PARK
WILDLIFE SAFARI PARK
HAWLER INDUSTRIAL CITY
GOLF RESORT
AIRPORT LOGISTIC AREA BORDER
INTERNATIONAL AIRPORT AND AVIATION USES
LONG TERM RESERVE TO BE DETERMINED LATER
AGRICULTURAL GREEN BELT
HEAVY INDUSTRY
ORCHARDS/AGRICULTURAL GREEN BELT
HEAVY INDUSTRY
LONG TERM RESERVE (USES TO BE DETERMINED LATER)
EASTERN HILLS CITY
ABOUT 200,000 POPULATION
Legend:
new Pipes
modified Pipes
Reservoir
Pressure Reducing Valve
Booster Station
Well, Pumping Station
Inflow Point DMA
WSS Erbil
Design
Status 06 2012
SETEC Engineering

Measurement Points Ifraz I + II Intake



Measurement Points BS Maroda

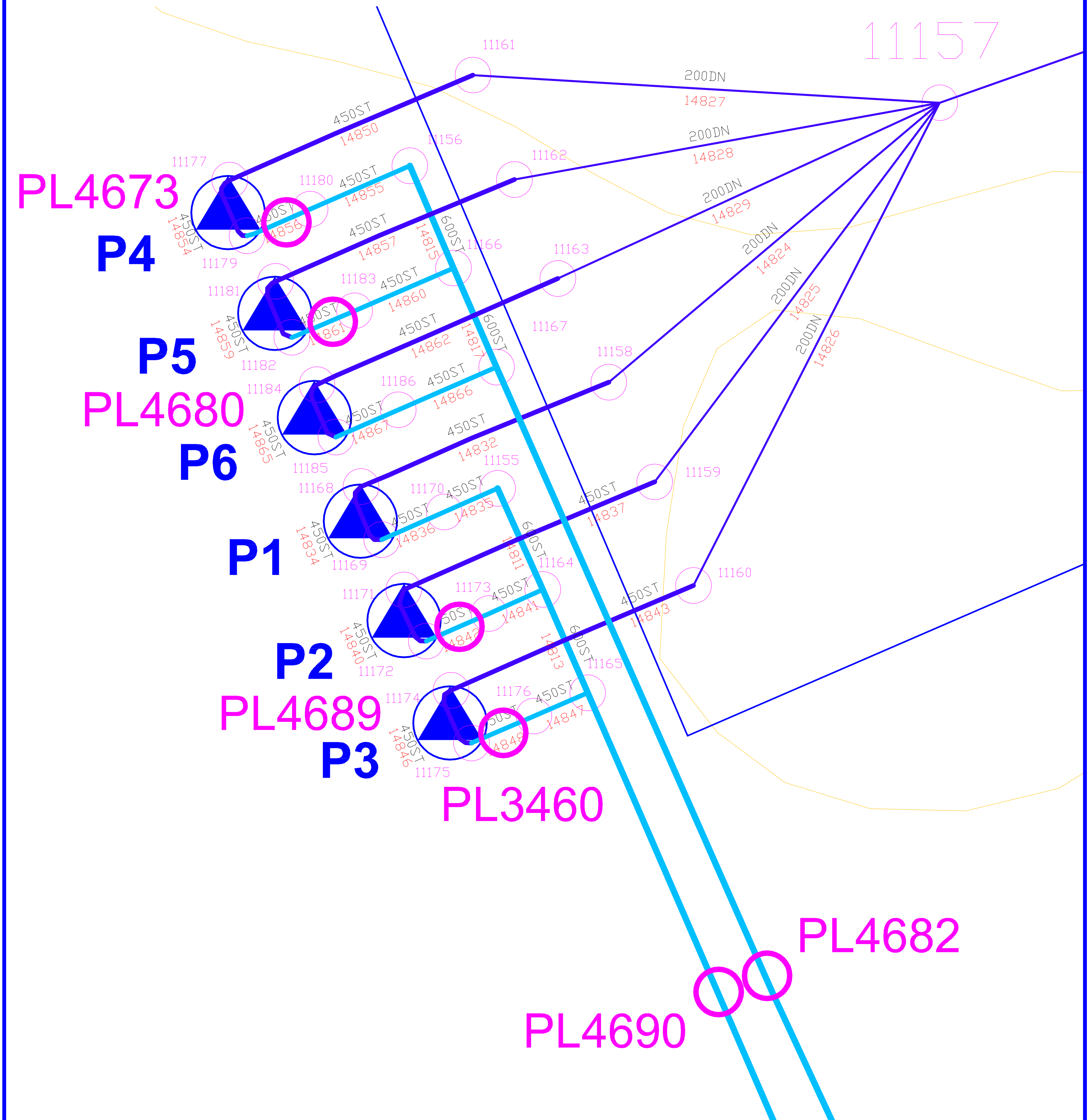


BS Maroda Ifraz III

Measurement
Status 11 2011

SETEC Engineering

Measurement Points BS Ainkawa



BS Ainkawa

Measurement
Status 11 2011

SETEC Engineering

Measurement Points Inside Sarbasty Quarter