COMPUTER PROGRAM

FOR PACKAGE WATER TREATMENT PLANTS DESIGN

A THESIS

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BY

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جامعــــــــــــة بابل

كليـــــــــة الهندسة

قسم الهندسة المدنية

برمجة تصميم محطات معالجة الماء المضغوطة

أطروحة

مقدمة الى قسم الهندسة المدنية

كلية الهندسة

جامعة بابل

كجزء من متطلبات نيل شهادة الماجستير

في الهندسة البيئية

من قبل

احمد سمير ناجي

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حزيران٢٠٠٧

بسم الله الرحمن الرحيم

وفوق

كل ذي علم

عليم

صدق الله العظيم

الخلاصة

تضمنت هذه الدراسة إعداد برنامج كومبيوتر بلغة (Quick Basic) لتصميم مشاريع ماء مضغوطة (صغيرة) لتنقية المياه السطحية (مياه الأنهار وتفرعاتها)، حيث يعمل البرنامج بطاقات تصميمية تتراوح بين (٥٠ الى ٢٠٠ م٣/سا) ليعطي نتائج تفصيلية لجميع مراحل المشروع ابتداء من أنبوب السحب الرئيسي (المآخذ) وصولاً الى مضخات الرفع العالي المرتبطة بالشبكة.

يتكون مشروع الماء المضغوط المصمم بواسطة برنامج هذه الدراسة من المراحل التالية :ـ محطة الضخ ذات الرفع الواطئ مع ملحقاتها من أنبوب السحب الرئيسي وأنابيب الارتباط، والوحدة المضغوطة التي تتكون من حوض الخلط السريع، وحوض الاندماج (الترويب)، وحوض الترسيب الذي يحتوي على ألواح الترسيب، ومرشحات الرمل السريعة مزدوجة الوسط، بعدها تأتي أحواض الخزن والغسل العكسي، ومحطة الضخ ذات الرفع العالي، بالإضافة الى قنوات نقل الأطيان والماء الزائد, أحواض محلول الشب، و كميات الكلور المضافة الى التعقيم.

قورنت النتائج التي تضمنت هذه الدراسة مع أمثلة نظرية ومواصفات مذكورة في المصادر حيث أثبتت دقتها. ولقد أسردت في جداول النتائج الرئيسية بطاقتين تصميميتين (٥٠ و ٢٠٠ م٣/ سا) لمشاريع الماء المضغوطة تحت نفس الظروف من ضغط ودرجة حرارة وإبعاد مقطع لها والمدخلات الأخرى التي يتطلبها البرنامج لتوضيحها ومناقشتها.

البرنامج المعد في هذه الدراسة سهل الاستخدام، ومرن من حيث الخيرات التي يضعها، ودقيق النتائج، مما يجعل منه وسيلة سهلة وسريعة للوصول الى النتائج المطلوبة لتصميم وحدات التنقية المضغوطة والضخ والأحواض، وإفادة المهندسين والباحثين في مجال الهندسة البيئية (الهندسة الصحية) بالنتائج المتعددة للارتقاء والتقدم في مجال البحث العلمي في سبيل خدمة الإنسان والبيئة.

We certify that this thesis titled **"COMPUTER PROGRAM FOR PACKAGE WATER TREATMENT PLANTS DESIGN "** was prepared by **Ahmed Sameer Najee** under our supervision at the University of Babylon in fulfillment of partial requirements for the degree of Master of Science in civil Engineering (Environmental Engineering).

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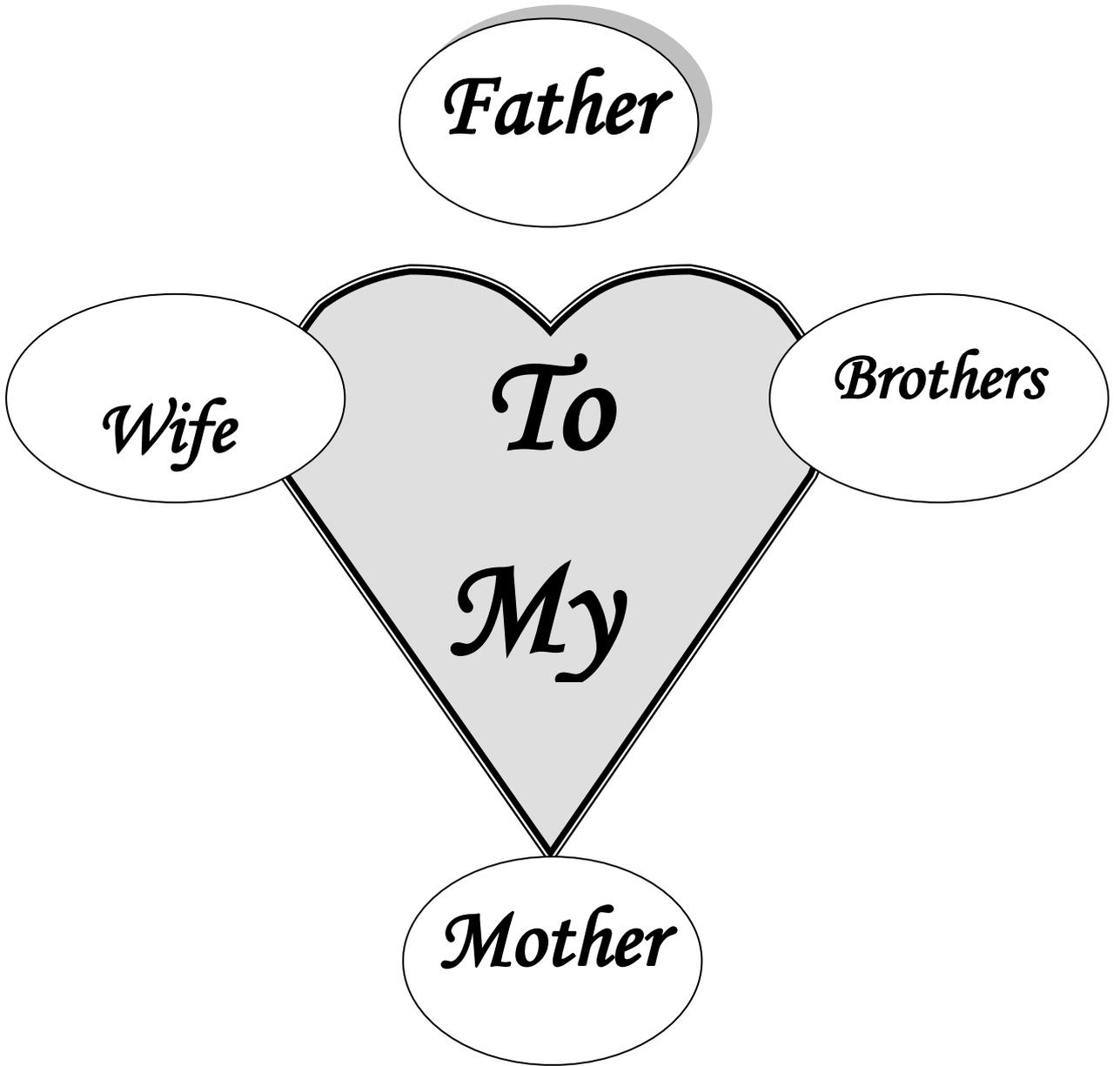**(Supervisor)**

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Father

Wife

To
My

Brothers

Mother

APPENDIX

AKNOWLEDGMENT

Firstly, all the thank and praise be to God in enabling me to achieve this research.

I would like to express my deepest gratitude and gratefulness to Assis. Proff. Dr. Riyad Al-Anbary and to Assis. Proff. Dr. Jabbar Hmoad Al-Baidhani the supervisors of this study for their valuable guidance, encouragement, and constructive suggestions.

Furthermore, thanks are devoted to my family for their sacrifices, care, encouragement, and the disturbance caused to them by my study.

Finally, deepest thanks to my friends, specially my friend "Hussein Ali Mahdi", for their help to accomplish this study.

Ahmed

٢٠٠٦

ABSTRACT

This study presents a computer program for the comprehensive design of a package water treatment plant with a capacity ranging from ٥٠ to ٢٠٠ m^3/h .

The main program, which was written in "Quick Basic", contains a number of sub-programs that deal with the design of individual treatment units.

The designed package water treatment plant is envisaged to be of the conventional plant which is usually used in the treatment of surface water (rivers, and branches). The plant consists of the following train of processes:-
Low lift pumping station, rapid mixing chamber, flocculation basin, settling

basin, rapid filter with dual media, storage tank, sludge-overflow channels, alum solution tank, chlorine feeders, and ,finally, high lift pumping station.

The output of the computer program was compared with solved design examples and acceptable limits from available text-books to confirm the algorithm of the programs. The results include two different cases of package water treatment plants design by using (٥٠, and ٢٠٠) m^3/h as a capacities where the input data are constant in these cases.

The program is easy and simple in the selection of the number of basins, the number of pipes, and solving all the problems that may be obtained with running of the program such as closed loops, frequency, and divergence of the objective. It is envisaged to be of great help to environmental engineers.

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SYMBOLS DESCRIPTION   UNITS

CHAPTER THREE : THEORETICAL BACKGROUND

A   Area of blades. L^2

C_c Chezy coefficient. $L^{0.5}/T$

C_D Drag coefficient.

D_e Degree of mixing.

d_m Diameter of mixer. L

d   Diameter of particles. L

d_e	Effective size.	L
F_D	Drag force.	F
g	Gravitational acceleration.	L/T^2
l	Filter media depth.	L
l_e, l_s	Anthracite and sand layers depth.	L
k	Constant depending on blade shape.	
N	Revolution per minute of mixer.	
N_g	Number of grains.	
n_b	Number of mixer blades.	
n	Expansion coefficient of filter media.	
P	Input Power per unit volume of fluid	$F.L/T$
P	Power dissipation in liquid	F
p	Input Power of fluid.	$F.L/T$
Q	Design capacity of plant.	L^3/T
R	Hydraulic radius.	L
Re	Reynold number.	
r	Radius of mixer.	L
S	Slope of channel.	L/L
S_o	Apparent surface overflow rate.	L/T
S_o'	Actual surface overflow rate.	L/T

V	Volume of basin.	L^{r}
v_s	Settling velocity.	L/T
v_P	Velocity of blades.	L/T
w	Width of blade element.	L
ρ	Mass density of water.	M/L^{r}
π	Circle constant ratio.	
τ	Shear stress.	F/L^{r}
ε	Porosity of filter media.	
γ	Weight density of water.	F/L^{r}
μ	Absolute viscosity.	$F.T/L^{r}$
η	Kinematic viscosity.	$L^{r}/F.T$
ψ	Grains shape factor.	
$\dfrac{\overline{dv}}{dy}$	Velocity gradient.	$T^{\,'}$

CHAPTER FOUR : DESIGN STEPS

A_{IPS}	Area of screen.	L^{r}
A_{TP}	Total area of ports.	L^{r}
A_{FO}	Area of orifice and control orifice.	L^{r}
A_{P}	Area of port.	L^{r}

station and the package unit. L

DS_{SP}　　Distance between the last package unit and

　　　　　　sludge pit. L

DP_1, DP_n　Deliver joint pipes.

$DPPU_1$　First deliver pipe connected with the first

　　　　　　package unit.

$DPBPU_1$　First deliver pipe between the package units.

d_{10}　　　　Effective size. L

d_P　　　　Diameter of port. L

EL_{PP}　　Elevation of project above the sea water level. L

EL_P　　　Elevation of project from minimum expected

　　　　　　river water level. L

EL_{NT}　　Elevation of the net-work. L

F　　　　Ratio of lamella height to the depth of

　　　　　　settling chamber.

FB　　　　Free board. L

FR　　　　Filtration rate. L/T

$FLOC.T$　Flocculation basin.

G　　　　Velocity gradient. T^{-1}

HL_{IPS}　　Head loss through the screen. L

H_{PS} Height of lamella plate.   *L*

H_{LLP} Pressure head of low lift pump.   *L*

HL_{VW} Head losses of V-Notch weir.   *L*

H_{NT} Net-work serve head.   *L*

k   Constant depending on blade shape.

K   Ratio of the length to the width of chamber.

L   Length of basins and channels.   *L*

LI   Length of inlet.   *L*

LCH   Length of effluent channel.   *L*

L.L.P   Low lift pumping station.

NU_{LLPDDP} Number of deliver pipes between the

      package units (distribution pipes).

NU   Number of basins.

NU_{LLP} Number of low lift pump in service.

NUO_{LLP} Number of low lift pump out of service.

$NU_{PAC.U}$ Number of package unit.

NUT_{LLP} Total number of low lift pump.

NUP_{LLPS} Number of suction joint pipes.

N_P Number of port.

NUP   Number of pipes.

NUOP   Number of pipes out of service.

N_{PS} Number of lamella plate.

NCH   Number of effluent channel.

NU_{RMC} Number of rapid mixing chamber.

P   Required power of mixer. $F.L/T$

PL_{LLS} Length of main suction pipe for low lift pump. L

PQ_{LLS} Discharge of main suction pipe for low lift pump. L^r/T

PQ_{LLD} Discharge of main deliver pipe for low lift pump. L^r/T

PDM_{LLPS} Diameter of main suction pipe for low lift pump. L

P_{LLP} Required power of low lift pump. $F.L/T$

PA   Cross sectional Area of pipe. L^r

PHL   Pipe head losses. L

PL_{LLD} Length of main deliver pipe for low lift pump L

PL_{LLPDPU} Length of deliver pipe connected with the

    package unit. L

PQ_{LLPDPU} Discharge of deliver pipe connected with the

    package unit. L^r/T

Q_{cap} Capacity of plant. L^r/T

Q_{PUMP} Discharge of pump. L^r/T

QPAC.U   Discharge of package unit. L^r/T

Q_{LLP} Discharge of low lift pump. L^r/T

Q_{VW} Discharge of V-Notch weir. L^r/T

$QPUMP_{LL}$ Discharge of low lift pump. L^r/T

R   Hydraulic radius. L

$R_{L/W}$ Length to width ratio of filter. L

Re_M Minimum Reynold number.

Re_O Optimum Reynold number.

RT_{RMC} Retention time of rapid mixing chamber. T

RPM   Revolution per minute of mixer.

R.M.C   Rapid mixing chamber.

R_{BW} Expansion ratio through the backwashing process.

RT   Retention time. T

S   Slope of channel. L/L

SR   Spacing between ports. L

S.T   Storage tank.

SP_1, SP_n Suction joint pipes.

SOR   Surface overflow rate. L/T

T   Thickness of lamella plate. L

TD_{RMC} Total depth of rapid mixing chamber. L

T_{max} Maximum expected temperature. C°

T_{min} Minimum expected temperature. C°

TH_{LLP} Total head losses of low lift pump. L

U.L.P   Up lift pumping station.

VO_{FCBW} Water consumption for filter during the

        backwashing process. L^{r}

VH   Velocity head. L

VOL_{RMC} Volume of rapid mixing chamber. L^{r}

V_{mf} Minimum fluidized velocity for particles media. L/T

VOL   Volume of basins. L^{r}

W   Width of basins and channels. L

WL   Weir load. $L^{r}/L.T$

W_{O} Width of opening. L

WPAC.U   Width of package unit. L

W_{RMC} Width of rapid mixing chamber. L

WI   Width of inlet. L

W_{R} Width of river water. L

W_{RB} Width of river water bottom. L

X   Angle of lamella plates.   *degree*

μ_{max} Maximum dynamic viscosity of water. $F.T/L^{r}$

μ_{min} Minimum dynamic viscosity of water. $F.T/L^{r}$

ρ_{max} Maximum density of water. M/L^r

ρ_{min} Minimum density of water. M/L^r

α   Porosity of filter media during the

            backwashing process

CHAPTER FIVE : RESULTS AND DISCUSSION

AA   Changing number of the pipe cross sectional area.

A_{PR} Provided area of settling chamber. L^r

A_{RE} Required area of settling chamber. L^r

BV   Butterfly valves number of the pipe.

BWR   Backwashing rate of filter media. L/T

BWV   Fluidized velocity of media grains. L/T

CV   Check valves number of the pipe.

DOI   Depth of inlet opining of rapid mixing chamber. L

DOO   Depth of outlet opining of rapid mixing chamber. L

D_{SMC} Depth of slow mixing chamber. L

D_{FT} Depth of flocculation basin.. L

DI_{SMC1} Diameter of first slow mixer. L

DI_{SMC2} Diameter of second slow mixer. L

D_{SC} Depth of settling chamber. L

D_{ECH} Depth of effluent channel of settling chamber. L

D_{HOPPER} Depth of hopper. L

DM_P Diameter of pipe. L

D_{CT} Depth of collection basin. L

DM_O Diameter of orifice of under drain system. L

DM_{CO} Diameter of control orifice of under drain system. L

D_B Depth of block under drain system (Leopold type). L

D_T Depth of backwashing trough in filter. L

D_{CBW} Depth of clear-backwashing storage tank. L

D_{GT} Depth of coagulation solution tank. L

DIM_{GT} Diameter of coagulation solution tank. L

D_C Depth of channels of sludge and over flow water. L

$DD_١$ Deliver distribution pipes system one of low lift

pumping station.

$DD_٢$ Deliver distribution pipes system two of low lift

pumping station.

ET   Entrance number of pipe.

$E^٩$ Elbow ٩٠ number of pipe.

$E^٦$ Elbow ٦٠ number of pipe.

FHL_{ECH} Slope of influent channel of settling chamber. L/L

F	Friction factor of pipe.	
FR_{FL}	Filtration rate through filter operation.	L/T
G	Velocity gradient of rapid mixing.	L/T
G_{SMC1}	Velocity gradient of first slow mixing.	T'
G_{SMC2}	Velocity gradient of second slow mixing.	T'
GV	Gate valves number of pipe.	
H_{LAM}	Height of lamella plates of settling chamber.	L
H_W	Height of V- Notch weir.	L
HL_P	Head losses of pipe.	L
HL_{SM}	Head losses through the sand media.	L
HL_{TSM}	Head losses through the anthracite media.	L
HL_{GM}	Head losses through the gravel support media.	L
HL_O	Head losses through the orifices of under drain system.	L
HL_{CO}	Head losses through the control orifices of under drain system.	L
HL_{UDS}	Head losses of under drain system.	L
HL_{PC}	Head losses of primary feeder channels for backwashing water.	L
H_{PUMP}	Head losses of pumps.	L

l_E	Total expansion depth of dual media.	L
l_{ES}	Expansion depth of sand media.	L
l_{ETS}	Expansion depth of anthracite media.	L
L_{SMC}	Length of slow mixing chamber.	L
L_{FT}	Length of flocculation basin.	L
L_{B1}	Length of blades for the first slow mixer.	L
L_{B2}	Length of blades for the second slow mixer.	L
L_{SC}	Length of settling chamber.	L
L_{LAM}	Length of lamella plates.	L
L_{ECH}	Length of effluent channel for settling chamber.	L
L_{HOPPER}	Length of hopper.	L
L_P	Length of pipe.	L
L_{CT}	Length of collection basin.	L
L_{FL}	Length of filter.	L
L_B	Length of block for under drain system.	L
$L_{PAC.U}$	Length of package unit.	L
L_C	Length of sludge-over flow channels.	L
L_{CBW}	Length of clear-backwashing storage tank.	L
MD	Main deliver pipe.	
MS	Main suction pipe.	

NU_{BP} Number of blades for rapid mixer.

NU_C Number of sludge-over flow channels.

NU_{CT} Number of collection basin.

NU_{CBW} Number of clear-backwashing storage tank..

NU_{GT} Number of coagulation solution tank.

NUO_{GT} Number of coagulation solution tank

out of service.

NU_{SMC} Number of slow mixing chamber.

NU_{SC} Number of settling chamber.

NU_{ECH} Number of effluent channels for settling chamber.

NU_{HOPPER} Number of hopper.

NU_P Number of pipe.

NU_{FL} Number of filter.

NU_O Number of orifices of under drain system.

NU_{FT} Number of flocculation basin.

NU_{MIXER} Number of rapid mixer.

NU_{BS1} Number of blades for the first mixer.

NU_{BS2} Number of blades for the second mixer.

NUI_{PAIR1} Number of dual impeller blades for

the first mixer.

NUI$_{PAIR2}$ Number of dual impeller blades for

the second mixer.

NU$_{CO}$ Number of control orifices of under

drain system.

NU$_T$ Number of trough for filter.

NU$_{PUMP}$ Number of pump in service.

NUO$_{PUMP}$ Number of pump out of service.

OU   Outlet number of pipe.

P   Required power of rapid mixer. $F.L/T$

P$_{SMC1}$ Required power of the first slow mixer. $F.L/T$

P$_{SMC2}$ Required power of the second slow mixer. $F.L/T$

Pb   Pressure balance between primary feeder

channels and control orifices.

PD   Propeller diameter of rapid mixer. L

P$_{PUMP}$ Required power of pump. $F.L/T$

P$_1$ Diameter of the first connection pipe. L

P$_2$ Diameter of the second connection pipe. L

PHI   Height of propeller from the bottom

of rapid mixing chamber. L

Q$_{RMC}$ Discharge of rapid mixing chamber. L^3/T

Q_{FT} Discharge of flocculation basin. L^r/T

Q_{SC} Discharge of settling chamber. L^r/T

$Q_{PAC.U}$ Discharge of package unit. L^r/T

Q_P Discharge of pipe. L^r/T

Q_O Discharge of orifices of under drain system. L^r/T

Q_{CO} Discharge of control orifices of under

drain system. L^r/T

Q_{PC} Discharge of primary feeder channel. L^r/T

Q_T Discharge of trough for filter. L^r/T

Q_{PUMP} Discharge of pump. L^r/T

Q_{BW} Discharge of filter backwashing. L^r/T

Q_{CBW} Discharge of clear-backwashing storage tank. L^r/T

Q_{GT} Discharge of coagulation solution tank. L^r/T

Q_C Discharge of sludge-over flow channels. L^r/T

Q_{LLPDP} Discharge of main devoir pipe for low lift pump. L^r/T

Q_{ULPSP} Discharge of main suction pipe for up lift pump. L^r/T

R   Total expansion ratio of dual media.

Re_{MIN} Minimum Reynold number.

Re_{OPT} Optimum Reynold number.

R_S Expansion ratio of sand media.

R_{TS}	Expansion ratio of anthracite media.	
RPM	Revolution per minute of rapid and coagulation solution mixers.	
RPM_{SMC1}	Revolution per minute of the first slow mixer.	
RPM_{SMC2}	Revolution per minute of the second slow mixer.	
RT_{SMC}	Retention time of the slow mixing chamber.	T
RT_{FT}	Retention time of flocculation basin.	T
RT_{SC}	Retention time of settling chamber.	T
RT_{CT}	Retention time of collection basin.	L^{3}/T
SD	Shift diameter of rapid mixer.	L
S_{LAM}	Spacing between lamella plates.	L
SOR_{AP}	Apparent surface over flow rate.	L/T
SOR_{AC}	Actual surface over flow rate.	L/T
S_{PC}	Slope of primary feeder channel.	L/L
SP_{T}	Spacing between troughs.	L
S_{T}	Slope of trough for filter.	L/L
SS_{1}	Suction pipe system (1).	
SS_{2}	Suction pipe system (2).	
T	Temperature.	C°
TD_{FT}	Total depth of flocculation basin.	L

TD_{SC} Total depth of settling chamber. L

TL_{SC} Total length of settling chamber. L

TD_{ECH} Total depth of effluent channel for

              settling chamber. L

TD_{CT} Total depth of collection basin. L

TD_{FL} Total depth of filter. L

THL Total head losses of filter. L

TH Total pressure head losses at filter backwashing. L

TSH Total static head of filter. L

TH_P Total required pressure head of pump. L

T_{BW} Period of filter backwashing. T

T_W Time of filter washing. T

TD_{CBW} Total depth of clear-backwashing storage tank. L

TD_C Total depth of sludge-over flow channels. L

$T٩T$ Distributor ٩٠ number of pipe.

V_P Velocity of pipe. L/T

W_{SMC} Width of the slow mixing chamber. L

WOI Width of opening inlet. L

WOO Width of opening outlet. L

W_{BP} Width of blades for rapid and coagulation

	solution mixers.	L
W_{CT}	Width of collection basin.	L
W_{SC}	Width of settling chamber.	L
W_{FT}	Width of flocculation basin.	L
W_{FL}	Width of filter.	L
W_{ECH}	Width of effluent channel for	
	settling chamber.	L
W_W	Width of V-Notch weir.	L
W_{HOPPER}	Width of hopper.	L
$W_{PAC.U}$	Width of package unit.	L
W_B	Width of block for underdrain system.	L
W_T	Width of trough for filter.	L
W_{CBW}	Width of clear-backwashing storage tank..	L
W_C	Width of sludge-overflow channels.	L

CERTIFICATE

We certify that we have read the thesis titled **"COMPUTER PROGRAM FOR PACKAGE WATER TREATMENT PLANTS DESIGN**",was prepared by **"Ahmed Sameer Najee"** in its content and in what is connected with it, and that our opining it meets the standard of thesis for the degree of Master of Science in Civil Engineering (**Environment**).

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CHAPTER ONE
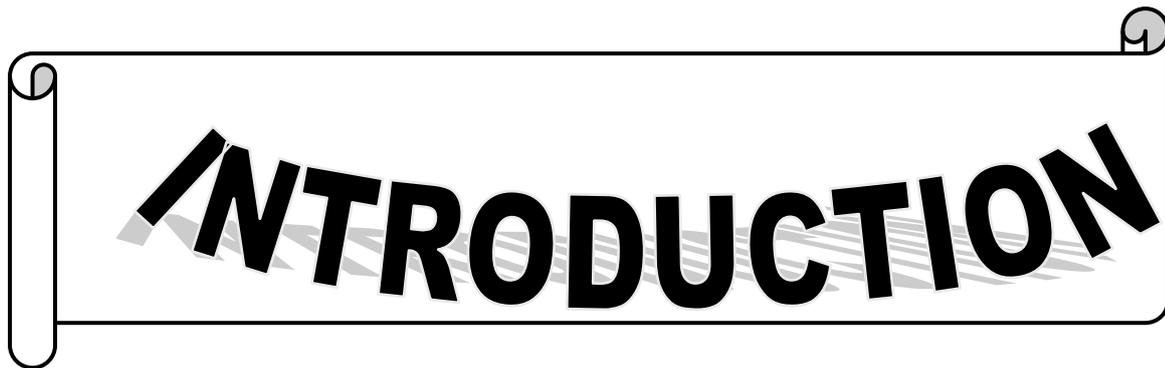
INTRODUCTION

CHAPTER ONE

INTRODUCTION

١.١ Introduction

The basic concept for the design criteria for water treatment plant leads to a water quality service with economic sides and technical conditions for application in developed country.

To select the capacity of water treatment plant, it should be taken

the number of population served by the plant, the design period using for the plant, the application of storage in the plant, the distance between the source of water and the plant, and the last point where the plant is able to serve. Selection of the design period for the plant is not easy, it depends on many considerations such as the rate of population growth, the rate of advantages for the plant, the technical development that used in the plant, and the design period for the structures and the equipments used in the plant.

Recently, the using of a package plant is increased in many countries especially in Iraq. Package water treatment plant has the same steps of conventional water treatment systems (coagulation, flocculation, sedimentation, and filtration) but they are combined in one unit with a small capacity.

١.٢ The Type of Package Plants According to The Process

The are three type of package plants according to the process:

١. Conventional package plants: as the name suggests, contain the conventional steps of coagulation, flocculation, sedimentation, and filtration.

٢. Tube-plate settler type clarification package plants: in this type, manufactures have used a relatively new technology including tube or plate settlers and high rate dual or mixed media filters to reduce the size of a plant and extend the capacity of a single factory-assembled units (used in the present study).

٣. Adsorption clarifier package plants: in this type, features on up-flow filter with low density plastic bed media (called the adsorption clarifier),

followed by a mixed media filter to complete the water treatment. The flocculation and sedimentation basins have been replaced by the adsorption clarifier bed, thus combining the two steps in to one.

١.٣ System Description and Design Considerations

Package water treatment plant used in the present study is of the second type to treat all the rivers water in Iraq .

Treatment processes includes:

١. Chemical pretreatment unit: the chemical pretreatment is achieved by using a rapid mixing unit with propeller mixer(include ٤ blades) where the rational speed and the velocity gradient for this mixer range from (٦٠٠ to ١٦٠٠) *rpm*, (٣٠٠-١٠٠٠) s^{-1}, respectively with short retention time ١ *min* (AL-Majid Co.,٢٠٠٢).

٢. Gentle stirring unit: it is obtained by using two turbine mixers (paddle impellers) in the centre of flocculation basins where the rational speed and the velocity gradient for these mixers range from (٢ to ١٥) *rpm*, (٢٠-٧٠) s^{-1}, respectively with the retention time range from (١٠-٣٠) *min* (Qasim et al.,٢٠٠٠) .

٣. Sedimentation unit: this unit contains lamella plates technique with a surface overflow rate from (٢٠-٦٠) *m/h* and short startup time about ١٥ *min* (VEOLIA water Inc., ٢٠٠٦)

٤. Filtration unit: it is obtained by using a rapid sand filter with dual media, the filtration rate range from (٧-١٥) *m/h* . The under drain system is Leopold type where the water is used only during the backwash of the filter (Nishihara Inc., ٢٠٠١).

In addition to these processes, package water treatment plant used in the present study contains low and high lift pumping stations, storage tank, alum solution tank, pipes, trenches, and chlorine feeders for disinfection.

١.٤ The Objectives of The Present Study

The main aims of the present study are:

١. Construction of a computer program by using a quick basic language to design different sizes of package water treatment plants in range of (٥٠-٢٠٠)m^3/h.

٢. To Construct a national units of package water treatment plants suitable for Iraqi water sources at a set of different range of capacity as simple and practical as possible.

١.٥ Contents of The Study

Chapter two gives a literature review about the main processes of the package water treatment plant.

Chapter three describes the theoretical background for the design of package units and the facilities used to carry the water.

Chapter four gives a design steps for the designed computer program.

Chapter five deals with the results of the designed computer program for two capacities (٥٠-٢٠٠)m^3/h *and* the discussion

Finally, chapter six is intended for conclusions and recommendations for further studies

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO
LITERATURE REVIEW

٢.١ Introduction

The main process in packaged water treatment plants includes the conventional steps as coagulation by rapid mixing the chemical coagulants with raw water, flocculation by gentle stirring to promote the growth of floc (a colloidal suspension), sedimentation to remove suspended solid particles, filtration for further removal of colloidal matter , and disinfection by chlorine. These steps are often combined in a complete pre-assembled unit.

the laboratory-scale and pilot-scale optimization studies culminated in the conceptual design and development of a high-rate packaged water treatment plant, the process has a number of advantages over the conventional treatment:

١. A more compact in size where the construction is quickly.

٢. Lower capital costs because it is eliminate sedimentation tanks in the treatment process.

٣. Longer filter runs because a high percentage of the suspended matter is removed in the steeply inclined settling tubes or plates.

٤. Lower running costs.

٥. High filtration whilst meeting quality requirements for water in supply.

٢.٢ The Rapid Mixing

Rapid mixing chamber consists of a mechanical mixer with an impeller or propeller to create turbulence in this chamber, the axis of rotation for mixer is vertical or horizontal on the direction of flow. There are two main conditions

that has effect on the rapid mixing and flocculation process (Amirtharajah et al.,١٩٩٠):

1. The intensity of agitation is called velocity gradient.

2. Agitation time is defined as the ratio of the volume chamber to the flow entering through this chamber .

In the design of rapid mixer, the retention time is less than the retention time in the design of the slow mixer for flocculation.

ASCE, AWWA, and CSSE, (l٩٦٩) suggested to use velocity gradient (G) and the retention time as listed in Table (٢.١) in the design of rapid mixing chamber and they show that the typical retention time is between (٢٠ -٦٠)s.

Table (٢.١) : Velocity gradient and Retention time for rapid mixing chamber (Sank, ١٩٨٠)

Velocity gradient (s⁻¹)	٧٠٠	٨٠٠	٩٠٠	١٠٠٠
Retention Time (s)	> ٤٠	٤٠	٣٠	٢٠

ESMIL Inc., (١٩٧٨) suggested that the rotational speed for the motor of the rapid mixer is between (٧٠٠-١٥٠٠) *rpm* .

Sank, (l٩٨٠) showed that mechanical mixers usage is better than the hydraulic mixers due to the easy change of rotation in operation and easy of control at a low velocity gradient, these features are important in the change of water quality.

Reynold, (١٩٨٢) showed that the diameter of propeller for rapid mixer is (٣٠٪ to ٥٠٪) of the width of this chamber and the small baffles are used to reduce short circuiting. Rotational speed for the blades ranging from (٦٠٠ to ١٢٠٠) *rpm* with retention time and velocity gradient ranging from (٣٠ – ٦٠)*s*, (٣٠٠ to ١٠٠٠) s^{-1} respectively.

Peavy and Rowe, (١٩٨٦) mentioned that the best range of velocity gradient for rapid mixing chamber is (٧٠٠–١٠٠٠) s^{-1} with detention time ٢ *min* .

Amirtharajah et al., (l٩٩٠) in their study about the design of the rapid mixing chamber , mentioned that the typical velocity gradient range from ٣٠٠ to ٥٠٠ s^{1} with the retention time (١٠-٥٠) *s*.

Infilco Degremont Inc., (٢٠٠٢) showed that a coagulant is injected to raw water upstream of the package unit. The water then enters a rapid mixing chamber to destabilize colloidal matter by the mixer where it is the rotational speed is between (٧٥٠-١٥٠٠) *rpm*.

AL-Magid Co., (٢٠٠٢) indicated that alum is used as a coagulant and added as a solution to the raw water in the rapid mixing chamber of package unit. The raw water is mixed with alum solution by the rapid mixer where the rotational speed of it is ١٠٠٠ *rpm* for the package plant with capacity of ٢٠٠ $m^{٣}/h$.

٢.٣ Gentle Stirring

The coagulation process chemically modifies the colloidal particles so that the stabilizing forces are reduced. To insure that a maximum amount of turbidity is removed, mixing condition and energy input must be properly provided after rapid mixing to allow the aggregation of destabilized particles. The coagulated water must be gently stirred to promote the growth of the floc. This process is known as flocculation. In the flocculation process, the mixture is gently stirred to promote the growth of the floc to a size that can be removed by sedimentation and filtration. The typical floc size ranges from ٠.١ to٢.٠ μm (Qasim et al. ,٢٠٠٠).

Ives and Bhole, (1973) showed that the value of G*t range between (10^{4}-10^{5}) with the retention time (١٠-٣٠) *min*. The large values for velocity gradient and retention time will produce dense and small floc which are difficult

to settle from water and the low value of velocity gradient and retention time are produced large size and light weight for flocs which are difficult to settle too. To produce dense and large flocs which are easy to settle in the water ,velocity gradient along the flocculation chamber should be reduced by dividing it on factors   equal to 2 .

Sank, (١٩٨٠) in his study have shown that the flocculation chamber usually found in upward flow clarifiers, sometimes the number of mixers is more than one in the flocculation basin which is rotated with a variable speed to create rotation in motion of water if paddle mixers are used, the rotational speed for this mixers should be (٢-١٥) *rpm* to prevent the high disturbance flow which effects on the setting of flocs in the sedimentation stage .

Wilson and Barnes, (1983) mentioned that the typical value for the velocity gradient G is (30–70)s^{-1}.

Quaye and Isaias, (l٩٨٥) in their study about packaged water treatment plant have shown that the range of the mean velocity gradient for the design flocculation criteria ,G, value are ١٠-٧٥s^{-1}.

Rowe and Peavy, (١٩٨٦) in their study have shown that the total area of blades should be not more than ٢٠٪of the cross sectional area for the chamber. The speed of the end of blades relative to the speed of liquid equals to ٧٥% of the actual speed of blades, this speed is not more than $1\frac{m}{s}$. Minimum distance between the end of blades and any structure is ٠.٣m to reduce the high velocity gradient in small areas.

Smethurst, (l٩٨٨) showed that the total area of blades for mixer is (٢٠٪) from the cross sectional area of chamber with dimension (٠.١٥, and ٠.٦) m. The limit of the velocity for it is (٠.١٥-٠.٥) *m/s* with retention time (١٠-٤٠) *min*.

Goodrich et a١., (١٩٩٥) showed that the retention time of flocculation tank in conventional package plant is between (٢٠-٣٠)*min* but in plate or tube-

type settler package plant then water enters the flocculation chamber, the gentle mixing needs from ١٠to٢٠ *min* depending on the flow.

Qasim et al., (٢٠٠٠) showed that the degree of agitation employed in flocculates is much less than that used for rapid mixing. The purpose of flocculation is to cause a particle contact, while not creating sufficient turbulence to break up the floc particles. The typical velocity gradients (G) for flocculators range from 15 to $75s^{-١}$. Flocculation basins are normally designed with multiple mixing compartments in a series, with a velocity gradient successively lower in each compartment . This type of design is called (tapered flocculation) and has been found to produce a uniform and tough floc that will settle readily. The higher (G) value in the first compartment causes a rapid transformations of the primary particles into higher-density floc. The lower G value in subsequent compartments cause the build up of progressively Larger-size floc, for better settling .

The typical velocity criteria used in flocculation unit are as follows:

- Typical velocity in conduits or flume from the rapid- mixing unit to flocculation chamber is from ٠.٤٥ to $٠.٩\dfrac{m}{s}$. Tapered shape, either in width or depth is sometimes used to achieve constant velocity in the flocculation basin influent-distribution channel.

- The flocculation chamber should be designed to have a velocity through the basin between ٠.١٥ and$٠.٤٥\dfrac{m}{\min}$. Velocities greater than $٠.٥\dfrac{m}{\min}$ may result in shearing of the floc across the cross-section , to ensure that no dead spots exist in the basin .

- The baffles are typically designed to have a velocity of ٠.٣ to $٠.٤٥\dfrac{m}{s}$.The baffle-wall opening ratio is usually ٣ to ٦ percent. Staggered slots (typically ٠.١-٠.١٥m high and ٠.٤-٠.٦m long) are also provided in the bottom for cleaning.

- When a diffusion wall (or end baffle) is provided between the flocculation and sedimentation basins, a velocity of $0.15 \frac{m}{s}$ is typically used to determine the orifice's opening area. A small part at the bottom and a small submerged section at the top of the diffusion wall are often provided to allow sludge and scum to pass to the sedimentation basin.

٢.٤ Sedimentation

There are three limits in the design of sedimentation basin:

١. Quantity of water that can be treated (Q) .

٢. Retention time (t_o).

٣. Surface Loading rate (v_o) .

High-rate settlers can be purpose designed but prefabricated units can be inserted in to existing conventional settling chambers to improve their performance. Inclined tube or plate settlers provide a greatly increased surface area for settlement within the area of containing chambers. The critical settling velocity for discrete particles in a tube or a plate settler, as shown diagrammatically in Fig.(٢.١) is given by (Tebbutt, ١٩٩٨)

$$V_0 = \frac{KV}{(Sin\alpha + Lcos\alpha)} \qquad \qquad …(٢.١)$$

Where

K : ١.٣٣ for circular tubes and ١.٠٠ for flat plates.

V : Velocity of flow through settler elements (*m/h*).

α : Angle of inclination of elements (*degree*) with horizontal, and

L : Length of element / diameter of tube or distance between plates(*m*).
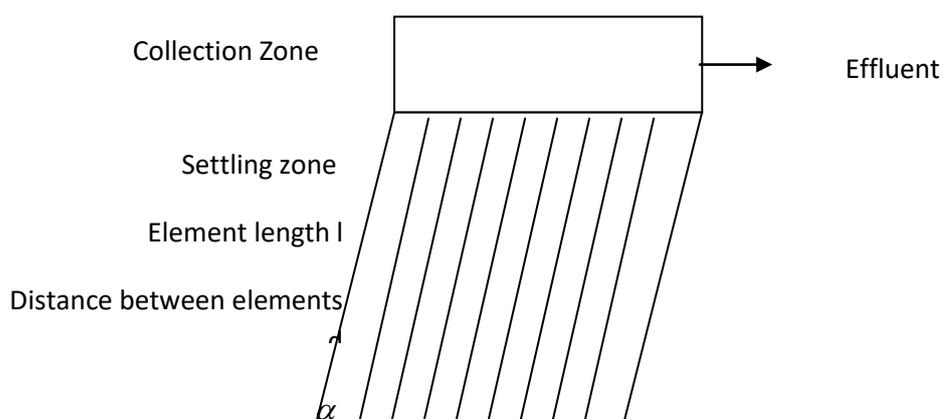
Fig (٢.١) : High-rate settler (Tebbutt, l٩٩٨)

Surface loading rate in some references is called setting velocity in (Smethurst,١٩٨٨) and is called surface over flow rate (SOR) in (Steel and McGee, ١٩٧٩ ; Tchobanoglous and Schroeder,١٩٨٥).

Hofkes et al., (l٩٨٣) in their study have shown that the tube or plate settlers can be added to the sedimentation chamber. These are steeply inclined that allow the suspended matter to settle in a shallow depth as the water passes through them and frequently installed in package treatment plants .A maximum loading rate is ٢ *gpm/ft* ٢ of cross sectional area for tube setters and ٠.٥ *gpm/ ft* ٢for plate settlers, based on ٨٠ percent of the projected horizontal plate area .

Quaye and Isaias, (١٩٨٥) in their study about package water treatment plant after the laboratory and pilot-scale optimization studies, a square ٤٥ pyramidal up flow clarifier model was designed for a throughput of ١.٧٦ *m*٣*/h*, but this was up rated to ٦.٧ *m*٣*/h* by installing a steeply inclined settling plate or tubes module in the clarification zone with short detention time (٢.٥ *min*).

Huisman, (١٩٨٦) in his study has shown that if use plate settlers in the sedimentation chamber, the clear opening (w) not less than ٤*cm* and for upward flow, the slope a larger than ٥٠. For the same clarification efficiency, the cost of

construction including land purchase is about ٢٠-٣٠ % less than for horizontal flow settling chamber .

Goodrich et al., (١٩٩٥) in their study have shown that retention time for settling chamber in convention package plant is ٢*hr* but in tube or plate-type clarifier package plant is less than ٢٥ *min* with surface over flow rate less than ٦.٥ *m* ٢*/day /m*

Qasim et al.,(٢٠٠٠) in their text have shown that the design of sedimentation basin is dependent upon the concentration, size, and behavior of the solid suspension. The variations in a basic sedimentation basin design have been employed to enhance the performance of the sedimentation process. The common variations include:

١. Laminar-flow devices that enhance performance by creating more nearly ideal flow conditions, one well known modification of conventional sedimentation chambers used in water treatment , these devices consist of banks of small square- shaped tubes (commonly called tubes settlers) or plates (commonly called plate setters) , inclined at ٤٥° -٦٠° angles from horizontal. The devices are installed near the outlet of the basin and are positional so that the water must pass through the tubes or channels, these devices provide enhanced solid removal because:

a. The settling distance that a particle fall to enter the sludge zone is reduced (SOR reduced).

b. Laminar flow is a achieved through the tubes or plates .

c. Density currents, temperature currents, and wave action do not hinder the sedimentation process as they do in a conventional chamber. The design details of laminar–flow settlers are provided in Fig.(٢.٢).

(i)   (ii))

Fig.(٢.٢): Laminar-flow settlers (i) Flow regime in circular basin
(ii) Flow regime in rectangular basin (Qasim et al.,٢٠٠٠)

٣. Number of available proprietary systems   that claim to enhance sedimentation are on the market. These system are mostly of the modifications of the solids-contact clarifier to prevent the formation channels in the sludge blanket that generally reduce the settling effectiveness of a sedimentation chamber. For example on these systems and more recent development in enhanced sedimentation is " Actiflo clarification" which is a combination of the micro-sand ballasted flocculation and the high-rate settling. The technique consists of mixing the flocs (suspended solids) on micro-sand with the help of a polymer. The micro-sand is (٥٠-١٠٠) μm in size, and the polymer is a flocculation aid. Reported benefits of the process in water treatment are increased removals of turbidity, color, TOC, and algae, with a reduction in mixing, flocculation ,and sedimentation time. The hardware, supplied by Kruger, Inc., utilizes an integral unit with a rapid mixing zone , a gentle mixing zone, and lamella modules. The hydrocyclone is used for micro-sand recovery. The system configuration is shown in Fig. (٢.٣).

Generally,٨٠ to ٩٥ percent of the total solids are removed in the sedimentation process. This mass of solids must be removed from the sedimentation chamber before accumulation becomes excessive. Although some package plant drain chambers and remove sludge manually. In some times mechanical sludge collection equipment (scraper) is used to move the sludge to a hopper for removal. The mechanical equipment employed in this process in generally used circular type shown in Fig.(٢.٣)
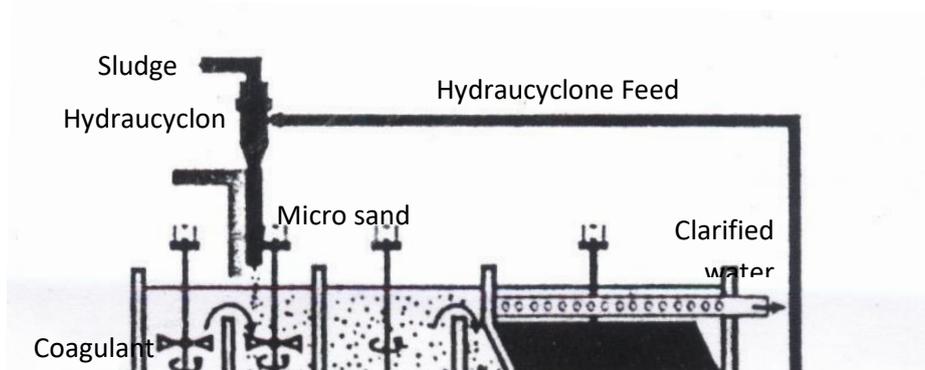
Fig.(٢.٣) : Actiflo micro - sand ballasted flocculation system

(Qasim et al., ٢٠٠٠)

John Meunier Inc., (٢٠٠٠) in their project of packaged water treatment plant have shown that heavy flocs ballasted settle quickly in lamella plate or tube settler with settling rates ranging from ٢٠ to ٦٠ *m/h* down to the thickening hopper and short retention time (not more than ١٥ min).

Nishihara Inc., (٢٠٠١) in its research has fixed the surface over flow rates for the sedimentation chamber in conventional water treatment plant is ٢ *m/h* while for package water treatment plant with lamella plate is (٢٠- ٦٠) *m/h*. The high settling rates reduce the foot print size to (١/١٠ to١/ ٢٠) of the conventional water treatment plant as shown in Fig.(٢.٤).
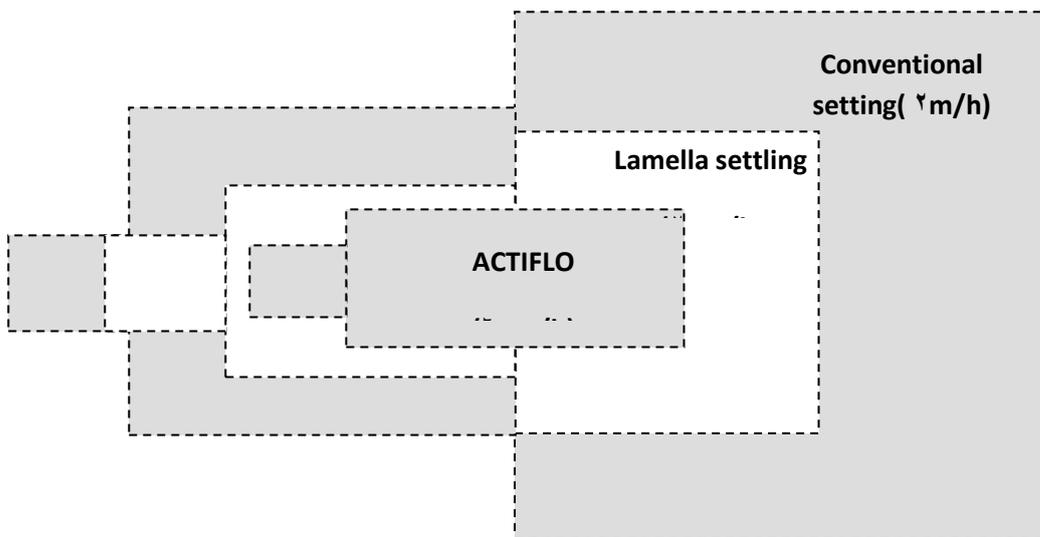
*where ACTIFLO is package plant with lamella plate.

Fig.(٢.٤) : Plan of footprint size for package water treatment

plant with lamella plate(Nishihara Inc., ٢٠٠١)

Infilco Degremont Inc., (٢٠٠٢) showed that the over flow rate of lamella settling chamber in the package unit ranging from (١٠-٦٠)*m/h* with the short retention time of (٢٠) *min*.

VEOLIA water Inc., (٢٠٠٦) in its paper about the package water treatment have shown that the over flow rate in the settling chamber with lamella plate is between $(20-80)$ *m/h* where the footprint size for the package unit is reduced.

٢.٥ Filtration

Sank, (١٩٨٠)in his text book state that the typical design for filter depend on:

١. Depth and particle size for filter media.

٢. Filtration rate.

٣. Driving force for water.

٤.Method of filter work.

According to his experiment in the dual media filter, he said that particle size for anthracite which is the top layer is between (١ to ١.٢) *mm* and sand which is the bottom layer is between (٠.٤ to ٠.٥) *mm*.

Morris et al., (١٩٨٠) in their study have shown that packaged gravity filter with dual media used anthracite material as the top layer with particle size is ranging from (١.٠٠ to ١.٤) *mm* and the depth for this layer is between (٠.٣ to ٠.٥) *m*. The bottom layer used sand material with particle size and depth ranging from (٠.٤ to ٠.٧) *mm* ,(٠.١٥ to٠.٣) *m*, respectively. Dual media filter bed is supported by gravel layer with particle size (٢ to ٥٤) *mm* and depth from (٠.١ to٠.٢٥)*m*.

Zajic, (١٩٨٢) has shown that the small rapid sand filter may come in one of two types open or pressurized. There is also another variant related to the in-depth filter. Normally, these units have four layers of sand which , starting from the top , increase in size as liquids pass down to the gravel bed. The principle of

operation of the in-depth filter is that of using a depth first smaller particles. Operation characteristics for open filter single or in–depth listed in Table (٢.٢).

Quaye and Isaias, (١٩٨٥) have shown that flocculation in steeply-inclined tube or plate settler followed by a single or dual media filtration can produce water of a good quality to meet the WHO recommendations at three times the conventional filtration velocity. A very high quality water of turbidity as low as ٠.١ *NTU* and very levels of iron ٠.٠٥ *mg/l*, manganese ٠.٠٣ *mg/l*, aluminum ٠.٠٨ *mg/ l*, and color was achieved at filtration velocity of ١٥ *m/h* which is treble the conventional filtration velocity. Some package units used pressure filter with filtration velocities ranging from ١٢.٧ to ١٩.١ *m/h* (١٠ to ١٥ *m³/h* through put) for filter run times ranging from ٥ to ٢٤ *h* during the on-site testing of packaged water treatment plant.

Goodrich et al., (1٩٩٥) in their study have shown that clarifier water then enters a gravity flow mixed media (a filter with a coarse to fine gradation of filter media or several type of filter media) . Packaged filter usually rapid rate-mixed media filter with filtration rate of ٥ to ١٥ *m/h*.

Adams et al., (٢٠٠٠) in their study about packaged drinking water treatment systems have shown that packaged filter is simply all of the features of filtration-chemical addition, flocculation, sedimentation, and filtration mounted as a unit on a frame for simple hook up of pipes and services . It is most color and coliform organisms removed with filtration process. Packaged filtration is often used to treat small community water supplies as well as supplies in recreational areas, state parks, construction site, ski areas, and military installation, among others.

John Meunier Inc., (٢٠٠٠) has shown that the filtration bed in a gravity packaged filter can either consist of a single layer of sand or multiple layers of sand and anthracite with filtration rate range from ١٠ to ١٥ *m/h*.

Qasim et al., (٢٠٠٠) in their research about filters, developed a relationship between the depth of filter media (I) and the effective size of the

media (de) from many filter design in operation. This relationship is summarized in Table (٢.٣).

Table (٢.٢): Design parameters for rapid sand filter (single and in-depth) (Zajic, l٩٨٢)

Parameters	Rapid sand filter	
	Single	In-depth
Through put rate $GPM / ft^{٢}$	٢-٤ (٦-١٠) up flow	١٢-١٦
Depths of bed Materials (*inches*)	(١٨-٣O) Sand (٨-٢٠) Gravel	(١٨-٢٢) Anthracite ١٠ sand or garnet (٨-٢٠) gravel
Bed area ($ft^{٢}$)	(٢٠-٤٥)	(٢٠-٤٠)
Grain size (*mm*)	٠.٤ Top ٢.٥ (Max) bottom Gravel ٢.٥+	٠.٩ Anthracite ٠.٤ Sand ٢.٥ + Gravel
Typical tank depth(ft)	١٠ open	Varies
Back wash rate ($gal/min/ft^{٢}$)	(١٥-٣٠)	(١٥-٣٠)
Backwash frequency	٢٤ hr	٢٤ hr

Table (٢.٣) : The ratio of the media depth (I) to the effective size of media (de) (Qasim et al.,٢٠٠٠)

Filter type	Material	Effective size (de)mm	Media depth (I) cm	Uniformity Coefficient	I/de
Small dual media	Anthracite, & Sand	١.٠٠ ٠.٥	٥٠ ٢٥	١.٥ ١.٣	١٠١٦
Intermediate dual media	Anthracite, & Sand	١.٩٨ ٠.٧٥	٧٦.٢ ٣٨.١	١.٥ ١.٢	١٠٢٣
Large dual media	Anthracite, & Sand	٢.٠٠ ١.٠٠	١٠١.٦ ٥٠.٨	١.٥ ١.٣	١٠١٦
Mixed media	Anthracite, Sand, & Granet	١.٠٠ ٠.٤٢	٤٥.٧ ٢٢.٩	١.٥ ١.٥	١٣٠٦

		٠.٢٥	٧.٦	١.٣	
Mono media	Anthracite	١.٠٠	١٠١.٦	١.٤	١٠١٦

CHAPTER THREE

THEORETICAL BACKGROUND

CHAPTER FOUR
DESIGN STEPS

٤.١ Introduction

The package water treatment plant used in this search include multi–units for mechanical, physical and chemical processes starting from:

١. Low lift pumps.

٢. Package unit which include rapid mixing connecting with alum solution tank, flocculation, sedimentation, collection, and filtration.

٣. Clear and back wash water storage tank .

٤. High lift pumps connecting with chlorine feeders.

These units are shown in Fig.(٤.١).
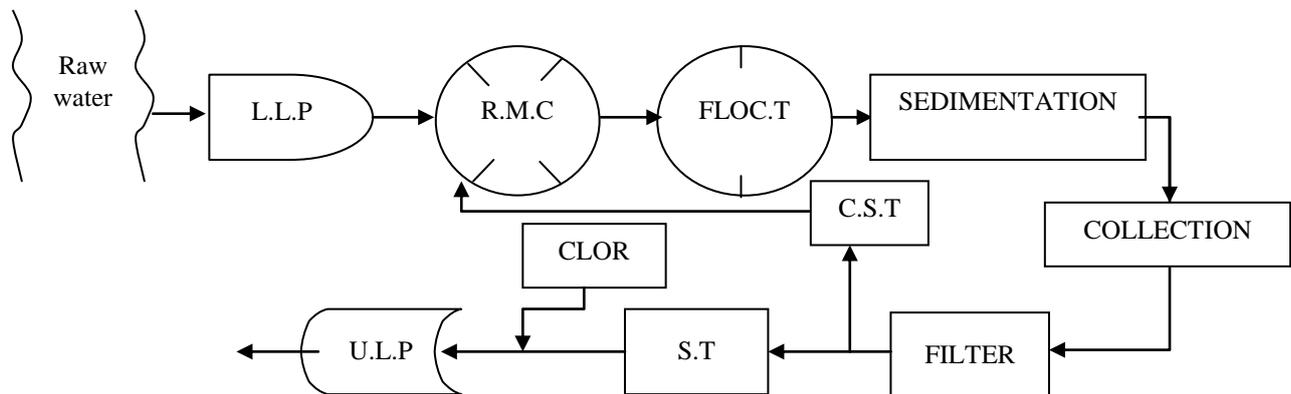
Fig. (٤.١) : Design plan of package water treatment.

٤.٢ Flow Chart for The Computer Program

The steps of the computer program are:

١. Input the maximum demand capacity for the plant in m^3/h ($Q_{CAPPWTP}$).

٢. Input the maximum and minimum estimated temperature values for the water in the river (C°) (T_{max}, $T_{min.}$), respectively According to these

values, the computer program will calculate the water density (ρ) and

water viscosity (μ) from the following equations:

ρ_{max} = Input from file at T_{max} $\qquad$ if $T_{max} \leq ٣٠C°$ $\qquad$ ...(٤.١)

ρ_{av} = Input from file at T_{av}

μ_{min} = Input from file at T_{min} $\qquad$ if $T_{min} \geq ٠C°$ $\qquad$ ...(٤.٢)

μ_{av} = Input from file at T_{av}

$$\rho_{max} = 0.000466 + \frac{\rho_{max} - 0.00466}{30 \times \Delta T} \qquad \text{if } T_{max} > ٣٠C° \qquad ...(٤.٣)$$

$$\mu_{max} = 983.2 + \frac{\mu_{max} - 983.2}{30 \times \Delta T} \qquad \text{if } T_{max} > ٣٠C°$$

...(٤.٤)

٣. Input maximum, minimum, and natural depths for the river water (DX_R, DM_R, and D_R), respectively as shown in fig.(٤.٢).

٤. Input top and bottom widths of the river water as variables (W_R, and W_{RB}), respectively.

٥. Input the raw–water pump station distance from the river bank (DS_{LLPS}).

٦. Input the project distance between the package units (DSPAC.U).

٧. Input the elevation of project (plant) above the sea water level (EL_{PP}).

٨. Input the vertical distance between the low lift pump and the package units (DS_{LLPP}) in whish this value is entered by the user according to the natural of a project and not less than ١.٥*m*.

٩. Input the spacing between the package units and the clear-backwash water storage tank (DS_{PCBW}).

١٠. Input the vertical distance between the clear-back wash water storage tank and the high lift pump (DS_{ULPDT}) in whish this value is entered by the user according to the natural of a project and not less than ١.٥*m*.

١١. Input the elevation of project (plant) from the minimum expected level river water (EL_P).

١٢. Input the net–work serve head (H_{NT}).

١٣. Input the net–work elevation (EL_{NT}).

١٤. Call the subroutine to design the rapid mixing chamber (R.M.C).

١٥. Call the subroutine to design the flocculation basin (F.T).

١٦. Call the subroutine to design the settling chamber (S.T).

١٧. Call the subroutine to design the collection basin (COLL.T).

١٨. Call the subroutine to design the filter (filter)

١٩. Call the subroutine to design the sludge and overflow channel (Trench).

٢٠. Call the subroutine to design the plant hydraulics profile (H.G).

٢١. Call the subroutine to design the low lift pumping station (L.L.P.S).

٢٢. Call the subroutine to design the high lift pumping station (H.L.P.S).

٢٣. Call the subroutine to design coagulation solution tank (C.T).

٢٤. End the program.

٤.٣ Low Lift Pumping Station

It is the first stage in the package water treatment plant which locates on the river water. This station is responsible on the suction of raw water from the river to the package units. Low lift pumping station include main suction pipe, low lift pump, delivery and distribution pipes to the package units as shown in Fig.(٤.٣).

Assume the number of service pumps is equal to the number of package units (NU_{LLP} = NUPAC.U) and the number of out of service pump (NUO_{LLP} = ١), thus the total number of pumps can be calculated from the following equation:

$$NUT_{LLP} = NU_{LLP} + NUO_{LLP} \qquad\qquad …(٤.٥)$$

Main program

Start

$Q_{CAP},T_{MAX},T_{MIN},DX_R,DM_R,D_R,W_R,W_{RB},DS_{LLPS},DS_{SP},$
$DSPAC.U,DS_{PCBW}, DS_{LLPP}, DS_{ULPDT},EL_{PP},EL_P, H_{NT}, EL_{NT}$

Open File For Input
ρ, μ

$T_{MAX١}=T_{MAX}$
$T_{AVR}=(T_{MAX} + T_{MIN})/٢$

IF
$T_{MAX} > ٣٠$

$T_{MAX١} = ٣٠$

$\mu_{MAX} = 0, \rho_{MAX} = 0$

FOR I=١ TO $T_{MAX١}$

μ_{MAX}, ρ_{MAX}

IF
$I = T_{MIN}$

$\mu_{MIN} = \mu_{MAX}(I)$
$\rho_{MIN} = \rho_{MIN}(I)$

IF
$I = INT(T_{AVR})$

$\mu_{AVR} = \mu_{MAX}(I)$
$\rho_{AVR} = \rho_{MIN}(I)$

NEXT I

Main program

$$\mu_{MAX} = \mu_{MAX}(T_{MAXl})$$

$$\rho_{MAX} = \mu_{MAX}(T_{MAXl})$$

I

$$\rho_{MAX} = 0.000466 + \frac{\rho_{MAX} - 0.000466}{30 * \Delta T}$$

$$\mu_{MAX} = 983.2 + \frac{\rho_{MAX} - 983.2}{30 * \Delta T}$$

IF
$$T_{MAX} - T_{MAXl} > 0$$

R.M.C

F.T

S.T

Coll.T

Fillter

I

Main program

Fig. (٤.٢) : Computer flow chart
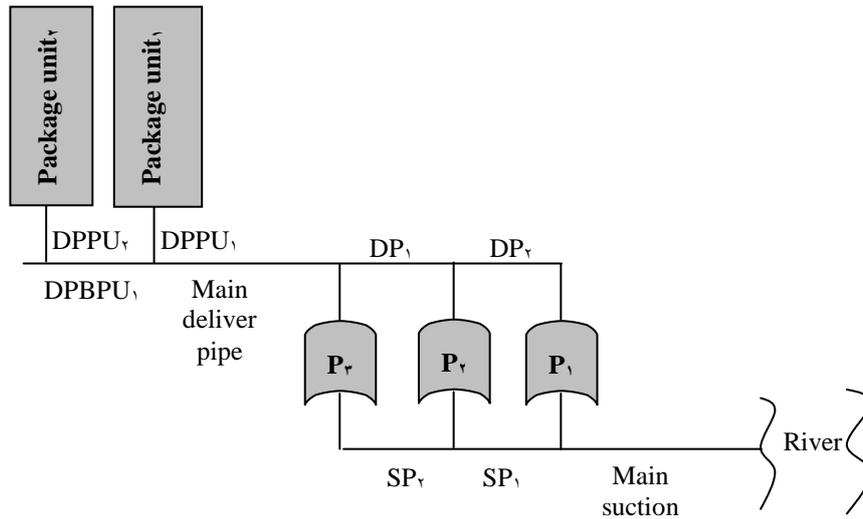
Fig. (٤.٣) : Plan of low lift pumping station for design capacities (١٤٠-٠٠) $m^{٣}/h$

٤.٣.١ Raw Water Suction Pipe

Raw water or main suction pipe as shown in Fig.(٤.٤) is extended to the horizontal distance equal to one fifth of the river bottom width to protect the pipe from the large dirt and suspend which are always grouped at the river shoulders. This pipe rises lm above the bottom of river to prevent suction the sludge from the bottom and damping ٠.٥m from the minimum expected water depth in river where the NPSH value is high and positive always, and continue after the horizontal distance (DS_{LLPS}) which is entered according to the natural of a project (AL-Nakeeb, ٢٠٠٠). The length of main suction pipe can be calculated from the following equation:

$$PL_{LLS} = DS_{LLPS} + \frac{WR_B}{5} + \frac{WR - WR_B}{2} + DMR - 1.5 \qquad \ldots(٤.٦)$$

The discharge of this pipe is equal to the capacity of package plant ($m^{٣}/s$):

$$PQ_{LLS} = \frac{Qcap}{3600} \qquad \ldots(٤.٧) \text{ The}$$

program of pipe design is used to find the diameter of the pipe

and the head loss is calculated according to the number of:

١. Entrance from the river, ET = ١.

٢. Gate valve, GV = ١.

٣. Check valve, CV = ١.

٤. Run to branch, TR = ١.

٥. Out to the pump, OU = ١.
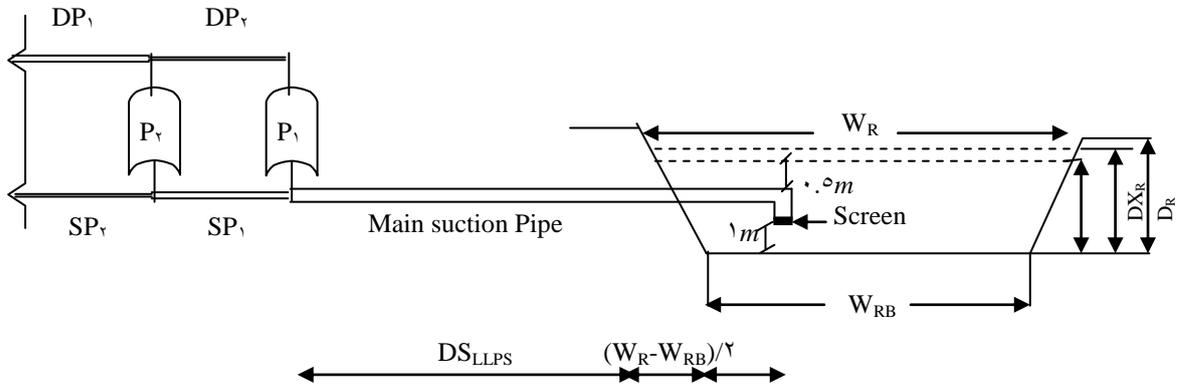
Fig. (٤.٤) : Main suction pipe and it's joints

The head loss of the pipe is added to the total head loss of the plant to calculate the power of low lift pumps.

The main suction pipe contains screen that has the same diameter to prevent the entering of the large dirt and fish to the pumps.

The diameter of screen opening is ٢٥*mm.* The total area of opening is calculated according to the following equation(ESMIL Inc.,١٩٧٨):

$$A_{IPS} = \frac{\lambda PDM_{LLPS}^{2}}{4} \times 0.75 \qquad \ldots(٤.٨)$$

Where PDM$_{LLPS}$ is the main suction pipe diameter.

Discharge of the screen in equal to the discharge of the pipe (PQ$_{LLPS}$), then the head loss through this screen is calculated from the following equation(AL-Nakeeb,٢٠٠٠):

$$HL_{IPS} = \frac{1}{2g}\left(\frac{PQ_{LLPS}}{0.6A_{IPS}}\right)^{2} \qquad \ldots(٤.٩)$$

The main suction pipe is connected with horizontal joint pipes which are differed in their diameters and are equalized in their length (L$_{LLPS}$ = ٣*m*) where each pipe is to feed one pump. The number of these

pipes is equal to the number of pumps (NUP$_{LLPS}$=NU$_{LLP}$) The discharge of the main suction pipe differs from the discharge of the first joint pipe because the first pump receives discharge equal to the discharge of the second pump and then for other joint pipes. Discharge that passing through the pump (m^3/s) can be calculated from the following equation:

$$QPUMP_{LL} = \frac{PQ_{LLS}}{NUPUMP_{LL}} \qquad \qquad ...(٤.١٠)$$

Discharge of joint pipes between the pumps is calculated from the following equation:

$$PQ_{LLS\,(i)} = PQ_{LLS\,(i-1)} - QPump_{LL} \qquad \qquad ...(٤.١١)$$

The design of joint pipes is calculated from the program of pipe design to find the diameter and the head loss is calculated according to the number of the following fitting:

١. Gate valve, GV = ١.

٢. Reverser ,T٩T = ١.

٣. Out to the pump, OU = ١.

The head loss due to the change in pipes diameters is added to the head loss of joint pipes and is calculated from the following equation:

$$PA\% = \frac{PA_{LL(i-1)}}{PA_{LL(i)}} \qquad \qquad ...(٤١٢a)$$

$$PHL_{LL(i)} = PHL_{LL(i-1)} + PA\%_{(i)} \times \frac{PV_{LL(i)}}{2g} \qquad \qquad ...(٤-١٢b)$$

Where PA is the cross–section area of pipe (m^2), and PH is the pipe head loss (*m*).

The head loss in the main suction pipe is added to the head loss in joint pipes to find the total head loss in suction pipes.

٤.٣.٢ Raw Water Delivery Pipe

Raw water (main) delivery pipe is extended from low lift pumps to the point of branch to feed the package units as shown in Fig.(٤.٣).

The main delivery pipe is connected with the horizontal joint pipes which are differed in diameters according to the change of discharge that passing from the pumps and the design procedure of these pipes is similar to the design procedure of suction joint pipes.

The main delivery pipe length is calculated from the following equation where the distance between the last pump and the wall of pumping station is equal to $3m$.

$$PL_{LLD} = L_{RMC} + \frac{WI}{2} + 3 \qquad \qquad ...(4.13)$$

The discharge of this pipe is equal to the capacity of plant in (m^3/s):

$$PQ_{LLD} = \frac{Q_{cap}}{3600} \qquad \qquad ...(4.14)$$

The pipe is designed from the program of pipe design to find the diameter and the head loss can be calculated according to the number of the following fitting:

1. Check valve, CV = 2.
2. Run to branch, TR = 1.
3. Gate valve, GV = 1.

٤.٣.٢.١ Delivery Pipes to The Package Units

The first pipe is extended from the main delivery pipe to the first package unit but the other pipes are extended from the delivery pipes between the package units (distribution pipes) to the package units according to the number of package units as shown in Fig.(٤.٣). The number of pipes is equal to the number of package units (NU_{DPPU} = NUPAC.U).

The length of each pipe is calculated from the following equation:

$$PL_{LLPDPU} = DS_{PL} + D_{RMC} + EL_P + 0.5 \qquad \qquad ...(4.15)$$

Where DS$_{PL}$ is the vertical distance between the low lift pumping station and the package units which is entered the according to the natural of a project. In all cases, not less than $1.5m$. The discharge passes through these pipes is equal to the discharge of package units in (m^3/s) and is calculated as:

$$PQ_{LLPDPU} = \frac{QPAC.U}{3600} \qquad \qquad ...(4.16)$$

These pipes are designed from the program of pipe design to find the diameter and the head loss of each pipe can be calculated according to the number of the following fitting:

1. Out to the package units, OU = 1.
2. Gate valve , GV = 1.
3. Elbow 90, E9 = 1.
4. Run to run, TR = 1.

4.3.2.2 Delivery pipes between Package Units (Distribution pipes)

The work of delivery pipes between package units is to distribute the raw water to the delivery pipes of package units as shown in Fig (4.3).

The number of these pipes depends on the number of package units (NU$_{LLPDDP}$ = NUPAC.U -1).

The length of each pipe is calculated from the following equation:

$$PL_{LLPDD} = SP + L_{RMC} + WI \qquad \qquad ... (4.17)$$

The discharge of the delivery pipes between the package units can be calculated from the following equation:

$$PQ_{LLPDD(i)} = PQ_{LLPDD(i-1)} - QPAC.U \qquad \qquad ...(4.18)$$

Design of pipe is attempt from the program of pipe design to find the diameter and the head loss is calculated according to the number of the following fitting:

1. Gate valve, GV = 1.
2. Reverser,T9T = 1.

The head loss due to change in pipes diameters is added to the head loss of pipes which calculated from Eq.(٤.١٢a) and Eq.(٤.١٢b).

After the head loss calculation in all pipes of low lift pumping station, the total head loss is calculated from the following equation:

$$TH_{LLP} = PHL_{LLD} + \sum PHL_{LLD\,(i)} + \sum PHL_{LLD\,(1)} + \sum PHL_{LLD\,(2)} + PHL_{LLs} + \sum PHL_{LLS\,(i)}$$

$$+ \left(EL_{RMC} - EL_{pp}\right) + EL_{P} \qquad \qquad …(٤.١٩)$$

The total head loss in each pump is calculated from the following equation:

$$H_{LLP} = TH_{LLP} \qquad \qquad … (٤.٢٠)$$

The discharge for each pump in ($m^{٣}/s$) can be calculated from the following equation:

$$Q_{LLP} = \frac{PQ_{LLD}}{NU_{LLP}} \qquad \qquad … (٤.٢١)$$

When the pump efficiency is $٨٠٪$, the power of each pump in (*kw*) is calculated from the following equation:

$$P_{LLP} = \frac{0.163 \times 60 \times Q_{LLP} \times H_{LLP}}{0.8} \qquad \qquad … (٤.٢٢)$$

And the total power for all pumps is :

$$TP_{LLP} = P_{LLP} \times NU_{LLP} \qquad \qquad … (٤.٢٣)$$

٤.٤ The Rapid-Mixing Chambers

It is the first stage of package units where the coagulant solution is added after mixing the coagulant with water in chemical basin. Coagulant solution is mixed in rapid mixing chamber with raw water that entered from inlet to this chamber by using "rapid mixers ". The work of rapid mixers is to give the homogeity of mixture by the water currents that generated in mixing chamber. The method of mixing that used in the

computer program is done by the central mixer locates in the rectangular chamber where the water is raised from the low lift pump station . The rapid mixing chamber is located in all lines of production for raw water treatment. The number of production lines depend on the number of rapid mixing chamber, therefore a method to find the number of this chamber should be taken. Water treatment plant is not work with its full production of its first operation. The designed capacity of production is calculated according to the design period of the plant (after passing the time period that must be taken change in the size of population for the region or the volume that the plant is feed). There are different methods to operate the plant, one of these methods is the operation of the one line of production for all times of day to meet the maximum actual water demand.

This method is used to design the rapid mixing chamber but it is not favorable because the maximum actual water demand is less than the designed capacity of the plant, so it is necessary to constructed multi-line of production, and then the size work and the total cost of plant are increased. In this method, the time period to operate the line of production is less than the demand period for the designed capacity of plant. Other method is usually used that must be taken the hours of operation for plant or the line of production which designed multi - lines of production with capacity large than the maximum actual water demand but does not work in all time of the day (distribution the hours of work for the lines of production to safe the maximum actual water demand). To safe positivist first method with this method and to prevent the problems that occur due to construct one line of production, the package plant is designed with multi-lines of water production. The work of these lines does not depend on the actual water demand (large than the actual water demand) at the suggested limits from the designer. In the designed

computer program, design factor is used to find the number of lines production (package units) by dividing the maximum demand capacity on this design factor. The number of production lines is not more than ١٠ and the value of designed capacity of plants:

١. Design capacity from (١٠٠ to ٢٠٠) $\dfrac{m^3}{hr}$ DF=٧٠

٢. Design capacity from (٥٠ to ٩٩) $\dfrac{m^3}{hr}$ $NU_{RMC}=١$

Where the designed computer program is not work with capacity less than ٥٠ $\dfrac{m^3}{hr}$ or more than ٢٠٠ $\dfrac{m^3}{hr}$.

The number of rapid mixing chamber is calculated from the following equation:

$$NU_{RMC} = INT(\frac{Q\max}{DF})$$ ...

(٤.٢١)

Then the number of package units is equal to the number of rapid mixing chamber (NUPAC.U= NU_{RMC}).The retention time range for the rapid mixing chamber in the package plant is (٠.٥-١.٥)min, then the retention time in the designed computer program is assumed one minute ($RT_{RMC} = ١$ min) as a first assumption.

The discharge of rapid mixing chamber is calculated from the following equation:

$$QPAC.U = \frac{Q_{\max}}{NU_{RMC}}$$ ... (٤.٢٢)

The volume of rapid mixing chamber is calculated from the following equation:

$$VOL_{RMC} = QPAC.U \times \frac{RT_{RMC}}{60}$$ ...

(٤.٢٣)

In the designed computer program, the length of rapid mixing chamber is assumed to be equal ($L_{RMC} = 2W_{RMC}$) and the depth is assumed of ($D_{RMC} = 1.5 \ W_{RMC}$), therefore the width of rapid mixing chamber is calculated from the following equation:

$$W_{RMC} = \sqrt{\frac{VOL_{RMC}}{3}} \qquad \qquad ...(4.24)$$

So, the total depth is:

$$TD_{RMC} = D_{RMC} + FB \qquad \qquad ...(4.25)$$

Where FB is the free board and is equal to $0.25 m$.

The design of rapid mixing chamber in the computer program contains an inlet basin to reduce the dead current and to improve the mixing performance where the width of inlet basin is equal to three quarter of the width of rapid mixing chamber ($W_I = 0.75 W_{RMC}$) and its length is equal to the width of inlet ($L_I = W_I$) as shown in Fig.(4.5).

The width of one package unit is calculated from the following equation:

$$WPAC.U = L_{RMC} + L_I \qquad \qquad ...(4.26)$$

4.4.1 The Rapid Mixer

Rapid mixing chamber contains the mixer (marine type) where the dimensions of this mixer is depended on the dimensions of the chamber. The following design criteria are adopted (AL-Majid Co.,2002) :

1. Propeller mixer diameter (*m*) : $PD = \dfrac{1}{3}W_{RMC}$

2. Number of propeller mixer per chamber : $NUPD = 1$

3. Number of blades per mixer : $NUB = 4$

4. Height of propeller mixer from the bottom of chamber (*m*):

   $H_p = 3PD$

5. Width of blades per mixer : $W_B = 0.2 \ PD$

٦. Shaft diameter : $SD = \dfrac{1}{8}PD$

a. Side view

b. Top view
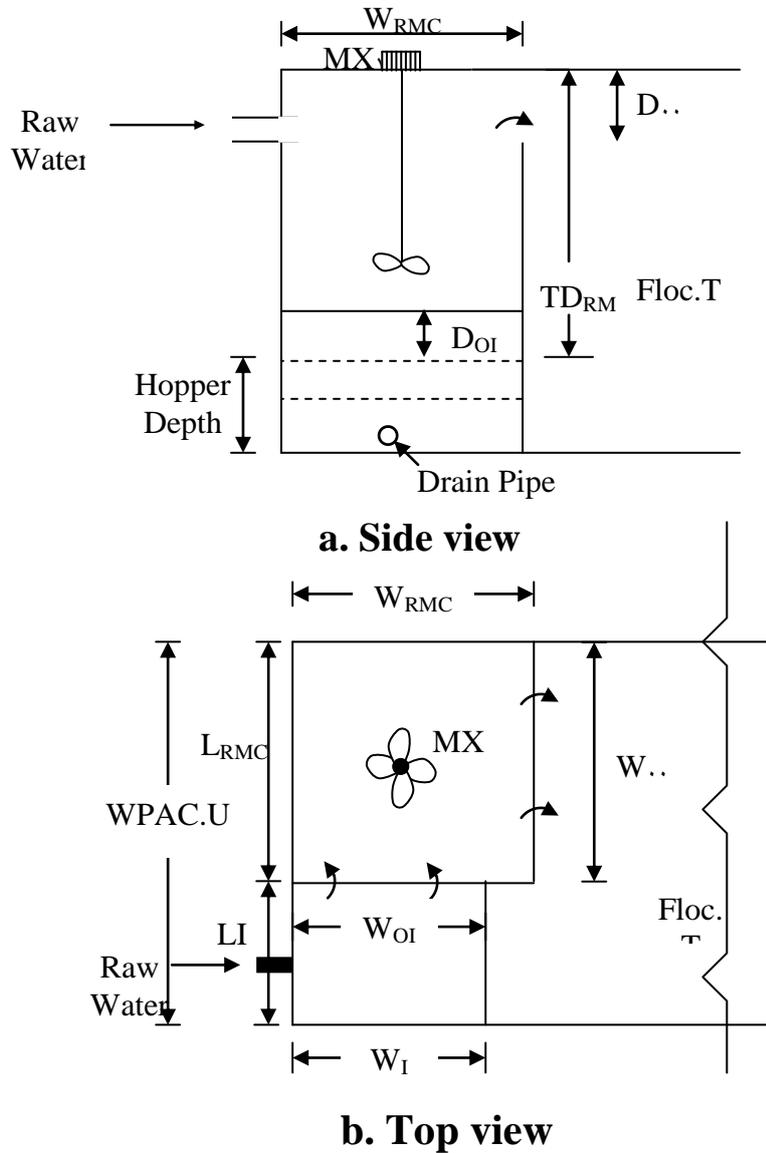
Fig. (٤.٥) : Plan of rapid mixing chamber designed

in the package unit

٤.٤.٢ The Power of Mixing

To calculate the power of mixer, it should be assumed that the value of revolution per minute for mixer (RPM_{RMC}) is between (٦٠٠-١٦٠٠).

The first assumption for The revolution per minute is (RPM_{RMC}=١٠٠٠). By substituting the value of (RPM_{RMC}) in Eq.(٤.٢٧), we get the required power for mixer as follows:

$$P_{RMC} = \frac{k * \rho * (\frac{RPM_{RMC}}{60})^3 * PD^5}{g} \qquad ...(٤.٢٧)$$

Where *k* is the constant of marine type propeller blades which is equal to ١.٩٤, as shown in Table (٣.١).

After calculation the required power of the mixer, the velocity gradient is calculated from the following equation:

$$G_{RMC} = \sqrt{\frac{P_{RMC}}{\mu * VOL_{RMC}}} \qquad ...(٤.٢٨)$$

The G_{RMC} value is compared with the maximum and minimum limits (٣٠٠-١٠٠٠/s), respectively. If this value is more or less than the design limits, the Eq.(٤.٢٩) is applicated and re-calculated of G_{RMC} value from Eq.(٤.٢٨) at new value of RPM_{RMC}.

$$RPM_{RMC} = RPM_{RMC} \pm ٥ \qquad ٣٠٠ < G_{RMC} < ١٠٠٠ \qquad ...(٤.٢٩)$$

If the RPM_{RMC} value is out the design limits then Eq.(٤.٣٠) is applicated and the chamber is re-designed at new RT_{RMC} value.

$$RT_{RMC} = RT_{RMC} \pm ٠.١ \qquad ٦٠٠ < RPM_{RMC} < ١٦٠٠ \qquad ...(٤.٣٠)$$

If the RT_{RMC} value is out the design limits then Eq.(٤.٣١) is applicated and the chamber is re-designed at new RT_{RMC} value.

$$NU_{RMC} = NU_{RMC} \pm ١ \qquad ٠.٥ < RT_{RMC} < ١.٥ \qquad ...(٤.٣١)$$

If the Eq.(٤.٣١) is applicated then the number of package unit is re-calculated according to the following equation:

$$NUPAC.U = NU_{RMC} \qquad ...(٤.٣٢)$$

The width of inlet opening at the bottom of rapid mixing chamber is calculated from the following equation:

$$W_{OI} = W_{RMC} \qquad ...(٤.٣٣)$$

And the depth is:

$$D_{OI} = 0.5\ W_{RMC} \qquad\qquad …(4.34)$$

The width of outlet opening at the top of rapid mixing chamber is calculate from the following equation as shown in Fig (4.5).

$$W_{OO} = L_{RMC} \qquad\qquad …(4.35)$$

And the depth is :

$$D_{OO} = 0.25\ W_{RMC} \qquad\qquad …(4.36)$$

4.5 The Flocculation Basin

Flocculation Basin is the second stage after the rapid mixing chamber. In this basin, The mixing process is conducted by the mixer with gentle or slow speed to promote the growth of floc to a size that can be removed by the settling chamber. In the designed computer program, tapered flocculation type is used to design the flocculation basin where its location is after the rapid mixing chamber directly as shown in Fig.(4.6).

In one package unit, the following assumptions are used:

- The number of flocculation basin per package unit is ($NU_{FT} = 1$)

- The width of flocculation basin is ($W_{FT} = WPAC.U$)

- The depth of flocculation basin is ($D_{FT} = D_{RMC}$)

- The number of slow mix chamber (compartment) per flocculation basin is ($NU_{SMC} = 2$) but not less than 1 and not more than 3 according to available retention time ($1 \le NU_{SMC} = 2 \le 3$).

- The width of slow mixing chamber is equal to width of the flocculation basin ($W_{SMC} = W_{FT}$), the length ($L_{SMC} = 1.5\ W_{SMC}$) and the depth ($D_{SMC} = D_{FT}$), then the volume of slow mixing chamber ($VOL_{SMC} = W_{SMC}*L_{SMS}*D_{SMC}$).

The volume of flocculation basin is calculated from the following equation:

$$VOL_{FT} = D_{FT} * W_{FT} * L_{SMC} * NU_{SMS} \qquad … (4.37)$$

The retention time limit is between ($١٠-٣٠$) *min* and can be calculated from the following equation:

$$RT_{FT} = \frac{VOL_{FT}}{Q_{FT}} \qquad \ldots (٤.٣٨)$$

If RT_{FT} value is more or less than the limits then Eq.(٤.٣٩) is applicated and VOL_{FT} will determined from Eq.(٤.٣٧) at new (NU_{SMC})value.

$$NU_{SMC} = NU_{SMC} \pm ١ \qquad \ldots (٤.٣٩)$$

Free board is added to the depth of flocculation basin according to the following equation:

$$TD_{FT} = D_{FT} + ٠.٢٥ \qquad \ldots (٤.٤٠)$$

٤.٥.١ Gentle Mixers

The slow mixing chamber (compartment) in the flocculation basin contains one gentle mixer, the gentle mixer is designed according to the standards as shown in Fig.(٤.٧).
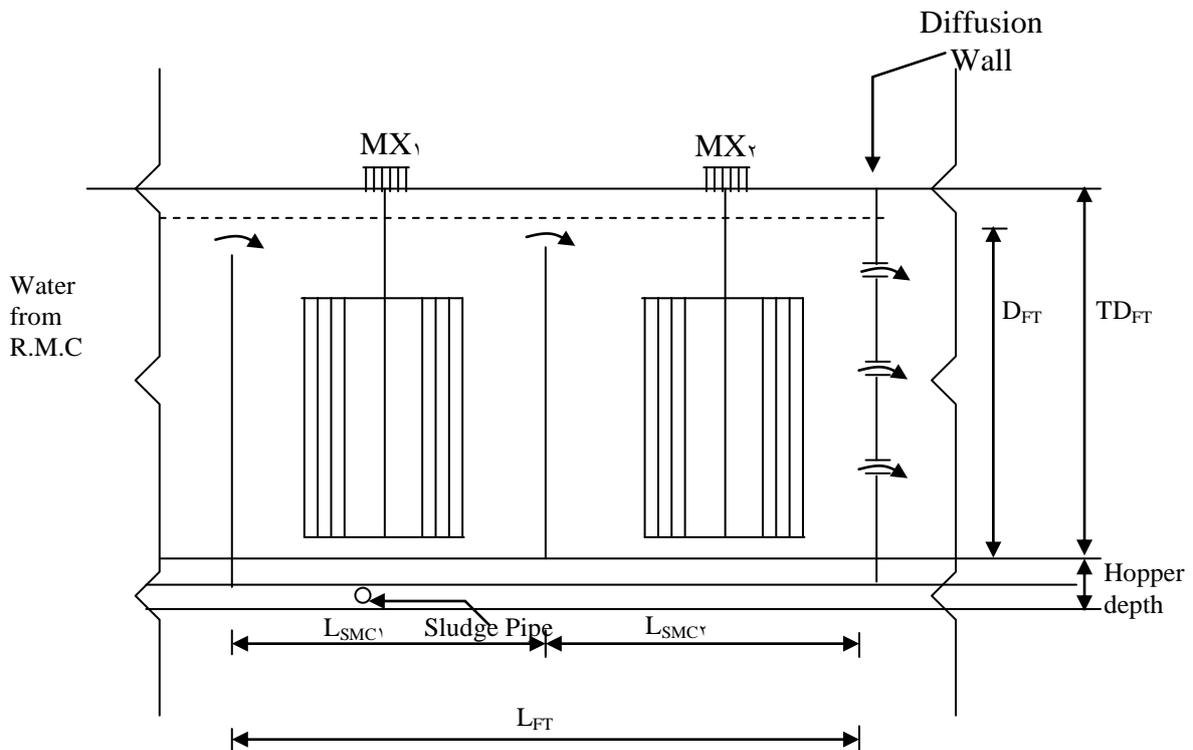
Fig. (٤.٦) : Plan of flocculation tank design with two slow mixing chambers (compartments) according to available retention time ($1 \le NU_{SMC} \le 3$)

- The diameter of mixer (*m*): $DM_{SMCI} = \cdot.\vee\circ\ W_{SMC}$.
- The radius of mixer (*m*): $R_{SMCI} = \cdot.\circ\ DM_{SMCI}$.
- The height of mixer from the bottom of chamber (*m*): $H_I = \cdot.\Upsilon\circ$.
- The blade mixer width (*m*): $W_{BI} = \cdot.\Upsilon$.
- The blade mixer length (*m*): $L_{BI} = D_{SMC} - \cdot.\circ$.
- The number of dual blade bar in all axis: $NU_{SMCIP} = \Upsilon$.
- The number of blades in each bar: $NU_{SMCBI} = \xi$.
- The length of rod for each blade from the major axis:

  $R_{SMCBI} = R_{SMCI} - \cdot.\circ\ *W_{BI}$.

  $R_{SMCBI(i)} = R_{SMCB(i-\backslash)} - (\cdot.\cdot\daleth + W_{BI})$.

- The summation of blade rod in each bar:

$$SR_{SMCI} = \sum_{i=2}^{NU_{SMCBI}} (R_{SMCI}^{\ 4} - R_{SMCI(i)}^{\ 4})$$

- The designed computer program selects the typical value of drag coefficient according to the relation length to width of blades from Table ($\xi.\backslash$):
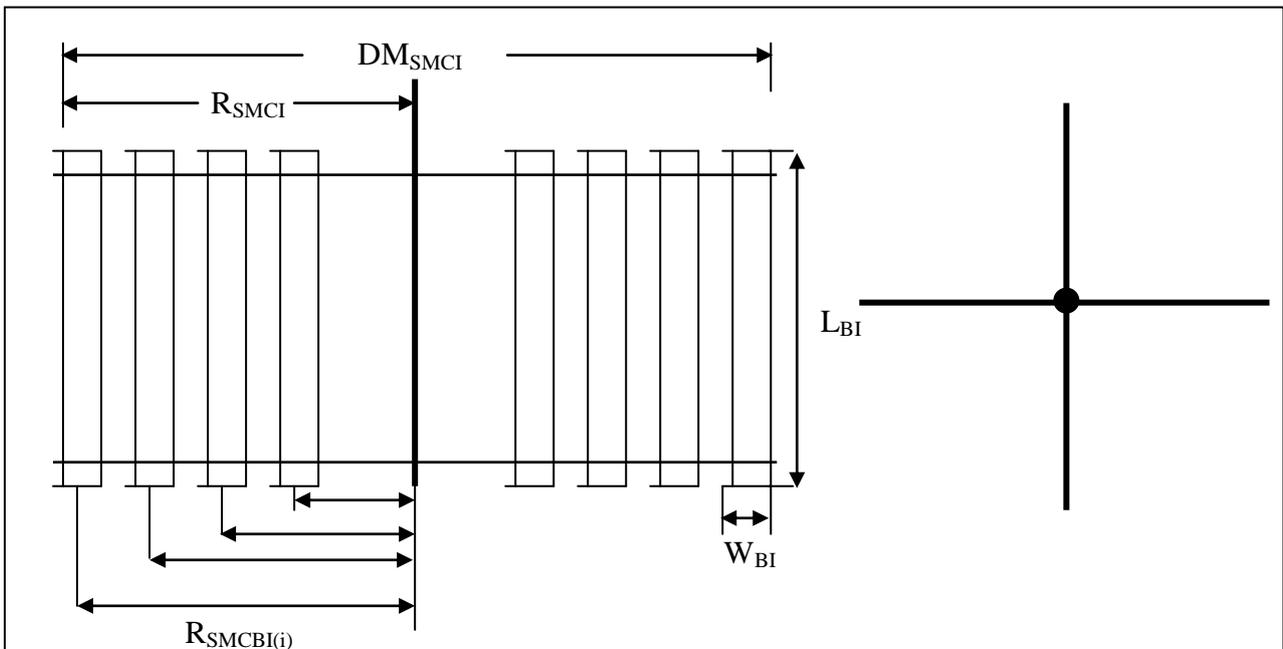
Fig.($\xi.\vee$) : Gentle mixer configuration

Table (٤.١) : Drag coefficients of flat blades

Ratio L_{BI}/W_{BI}	C_D
< ١	١.١٦
١ to ٥	١.١٦+(L_{BI}/W_{BI} -١)*٠.٠١
٥ to ٢٠	١.٢+(L_{BI}/W_{BI} -٥)*٠.٠٢
>٢٠	١.٥+(L_{BI}/W_{BI} -٢٠)*٠.٠٤

٤.٥.٢ The Power of Mixing

The power of mixing is depended on the revolution per minute for mixers. The limit of revolution per minute is between (٢ to ١٠). The first assumption of revolution per minute is ($RPM_{SMC(٠)} = ٦.٥$) and the revolution per minute for each mixer in the flocculation basin is calculated from the following equation:

$$RPM_{SMC(٠)} = ٦.٥$$

$$RPM_{SMC(i=١ \text{ to } NU_{SMC})} = RPM_{SMC(i-١)} - ٠.٥ \qquad \qquad ...(٤.٤١)$$

The power of each mixer is calculated by substitution the $RPM_{SMC(i)}$ value for each mixer and as shown in the following equation:

$$P_{SMC(i=1 \text{to} NU_{SMC})} = \frac{NU_{SMCBI} * NU_{SMCIP}}{8} * C_D * \rho * W_{BI} * (1-k)^3 * (\frac{\pi}{60} * RPM_{SMC(i)})^3 * SR_{SMCI}$$

$$...(٤.٤٢)$$

The range of velocity gradient limits is between (١٥-٧٥/*s*). The velocity gradient for each mixer is calculated from the following equation:

$$G_{SMC(i)} = \sqrt{\frac{P_{SMC(i)}}{\mu * VOL_{SMC}}} \qquad \qquad ...(٤.٤٣)$$

The velocity gradient value is compared with the limits, If this value is more or less than the limit then the following equation is applicated:

$$\text{RPM}_{\text{SMC(i)}} = \text{RPM}_{\text{SMC(i)}} \pm \cdot.\circ \qquad \text{\textbf{١}}\circ < G_{SMC(i)} < \text{\textbf{٧}}\circ \qquad ...(٤.٤٤)$$

Re–calculation of $G_{SMC(i)}$ value is made at new $\text{RPM}_{\text{SMC(i)}}$ value calculated from Eq.(٤.٤٣). If the $\text{RPM}_{\text{SMC(i)}}$ value is more or less than the limits then Eq.(٤.٤٥) is applicated and re-designed the mixer at new DM_{SMCI} value

$$\text{DM}_{\text{SMCI}} = \text{DM}_{\text{SMCI}} \pm \cdot.\cdot\circ \qquad\qquad ...(٤.٤٥)$$

After calculation of the retention time for flocculation basin, the retention time of one slow mixing chamber is calculated from the following equation:

$$\text{RT}_{\text{SMC(i)}} = \frac{RT_{FT}}{NU_{SMC}} \qquad\qquad ...(٤.٤٦)$$

The value of $(\text{G}_{\text{SMC(i)}}*\text{RT}_{\text{SMC(i)}}*٦٠)$ is compared with the limit values, the limit value is between ($٩٥٠٠ - ١٠\circ$). If the value of $(\text{G}_{\text{SMC(i)}}*\text{RT}_{\text{SMC(i)}}*٦٠)$ is more than the design limits, the following equation is applicated:

$$\text{NU}_{\text{SMCB١}} = \text{NU}_{\text{SMCB١}} - ١ \qquad\qquad ...(٤.٤٧)$$

If the value of $(\text{G}_{\text{SMC(i)}}*\text{RT}_{\text{SMC(i)}}*٦٠)$ is less than the limit then the following equation is applicated:

$$\text{NU}_{\text{SMCIP}} = \text{NU}_{\text{SMCIP}} + ١ \qquad\qquad ...(٤.٤٨)$$

In each case, the computer program is redesigned the mixer according to the to the new values of $\text{NU}_{\text{SMCB١}}$ and NU_{SMCIP}.

٤.٥.٣ Diffusion Wall with Ports as Outlet of Flocculation Basin

The diffusion wall separates the flocculation tank and settling chamber by circular ports as shown in Fig.(٤.٦). The important design consideration of diffusion wall is to distribute the flow evenly into the settling chamber.

In the designed computer program, the basic design requirements are:

- The ports should be uniformly distributed through out the baffle wall.

- In order to minimize the length of the jets and the dead zones between ports, a maximum number of ports should be provided.

- The maximum flow velocity through the ports should be approximately VP = ١٥٠ *mm/s*, in order to prevent floc break up.

- The most effective type of diffusion wall should have uniformly distributed ports where ports diameter is (dp = ١٢٥*mm*) with an opening ratio of ٦ to ٨ percent.

- The optimum head loss through the ports should be (٢-٣)*mm*. This value is small and assumed zero.

  The total area port is calculated from the following equation:

$$A_{TP} = \frac{Q_{FT}}{V_P} \qquad\qquad ...\ (٤.٤٩)$$

And the port area is calculated from the following equation:

$$A_P = \frac{\pi}{4} d_P{}^2 \qquad\qquad ...(٤.٥٠)$$

The total number of ports can be calculated from the following equation:

$$N_P = INT(\frac{A_{TP}}{A_P}) \qquad\qquad ...(٤.٥١)$$

Then the number of ports per one row is calculated from the following equation:

$$N_{PPR} = INT\left(\frac{NP}{W_{SMC}}\right) \qquad\qquad ...$$

$$(٤.٥٢)$$

And the number of ports per one column is calculated from the following equation:

$$N_{PPC} = INT\left(\frac{NP}{N_{PPR}}\right) + ١ \qquad \ldots (٤.٥٣)$$

The port spacing per row and per column are calculated from the following equations, respectively:

$$SR = \frac{W_{SMC} - (N_{PPR} * dp)}{N_{PPR}} \qquad \ldots(٤.٥٤)$$

$$SC = \frac{D_{SMC} - (N_{PPC} * dp)}{N_{PPC}} \qquad \ldots(٤.٥٥)$$

٤.٦ Settling Chamber with Lamella Plate

Settling Chamber is the third stage in the design of package unit where it is located after the flocculation basin directly. In this chamber, the floc that forming in the flocculation basin is settling by gravity according to surface area of settling basin with available retention time, and settling velocity.

In the designed computer program, the lamella plate is used in the settling chamber to increase the settling efficiency by increasing the surface area of settling as shown in Fig.(٤.٨) with the following assumptions:

- The width of settling chamber : W_{SC} = WPAC.U
- The depth of settling chamber : D_{SC} = D_{FT}
- The length of settling chamber : L_{SC} = K*W_{SC} (k=١)

    The features of Lamella Plate are:

- The height of Lamella plate (*m*) : H_{PS} = F*D_{SC} (F=٠.٧)
- The angle slope of lamella plate (*degree*) : X = $50°$
- The spacing between lamella plates (*m*) : W = ٠.٠٦
- The width at lamella plate (*m*) : W_{PS} = W_{SC}

- The thickness of lamella plate (*m*) : $T = 0.004$

The number of Lamella plates is calculated from the following equation:

$$N_{PS} = INT\left(\frac{L_{SC}}{W}\right) + 1 \qquad \qquad \dots (4.56)$$

Then, the discharge(m^3/h) is:

$$Q_{PS} = \frac{QPAC.U}{N_{PS}} \qquad \qquad \dots (4.57)$$

The length of Lamella plate (*m*) is calculated from the following equation:

$$L_{PS} = \frac{H_{PS}}{Sin\left(X * \dfrac{\pi}{180}\right)} \qquad \qquad \dots (4.58)$$

The apparent surface overflow rate can be calculated from the following equation where the limit values are between ($10-60$) *m/h*.

$$S_{ap} = \frac{QPAC.U * Sin\left(X * \dfrac{\pi}{180}\right)}{W + T} \qquad \qquad \dots (4.59)$$

If the S_{ap} value is more or less then the limit then the following equation is applicated and re-designed the lamella plates according to new X value.

$$X = X \pm 5 \qquad \qquad 10 < S_{ap} < 60 \qquad \qquad \dots (4.60)$$

The limit value of angle slope X is ($40-75$).If the X value is more or less than the limit then the following equation is applicated and re-designed the lamella plate according to the new W value.

$$W = W \pm 0.01 \qquad \qquad 40 < X < 75$$
$$\dots (4.61)$$

The limit value of spacing between lamella plates is ($0.04-0.09$)*m*. If the W value is more or less than the limit then the following equation is

applicated and re-designed the lamella plates according to the new K value where K is the ratio of length to width of settling chamber.

$$K = K \pm ٠.١ \qquad\qquad ٠.٠٤ < W < ٠.٠٩$$

$$...(٤.٦٢)$$

The actual surface overflow rate can be calculated from the following equation:

$$SOR = Sap * \frac{W + T}{H_{PS} * Cos\left(X * \frac{\pi}{180}\right)} \qquad ... (٤.٦٣)$$

The flow velocity is calculated from the following equation:

$$V_0 = SOR * \frac{H_{PS} * Cos(X * \frac{\pi}{180}) + W}{W * Sin(X * \frac{\pi}{180})} \qquad ...(٤.٦٤)$$

The limit value of the retention time for settling chamber with lamella plate is not more than ١٥ *min*. The retention time can be calculated from the following equation:

$$RT_{SC} = \frac{H_{PS}}{Sin\left(X * \frac{\pi}{180}\right) \Big/ V_0} * 60 \qquad ...(٤.٦٥)$$

If the RT$_{SC}$ value is more than the limit then Eq.(٤.٦٠) is applicated and re-designed the lamella plate according to the new X value.

If X value is more than the limit then Eq. (٤.٦٦) is applicated and re-designed the lamella plates according to the new F value where F is the ratio of lamella height to the depth settling chamber.

$$F = F - ٠.٠٥ \qquad\qquad ...(٤.٦٦)$$

The required area becomes

$$A_{rq} = \frac{QPAC.U}{S_{ap}} \qquad\qquad ...(٤.٦٧)$$

The provided area is calculated from the following equation and then compared with the required area.

$$A_{pr} = W_{SC} * L_{SC} \qquad \qquad ...(٤.٦٨)$$

If the required area is more than the provided area then Eq.(٤.٦٠) and eq (٤.٦١) are applicated and re-designed the lamella plates according to the new values.

Inlet length for settling chamber can be calculated from Eq. (٤.٦٩)

$$L_{ISC} = 0.2 * L_{SC} \qquad \qquad ...(٤.٦٩)$$

Then, the total length of settling chamber is

$$TL_{SC} = L_{ISC} + L_{SC} \qquad \qquad ...(٤.٧٠)$$

Free board is added to the depth of settling chamber to calculate the total depth of settling chamber:

$$TD_{SC} = D_{SC} + ٠.٢٥ \qquad \qquad ...(٤.٧١)$$
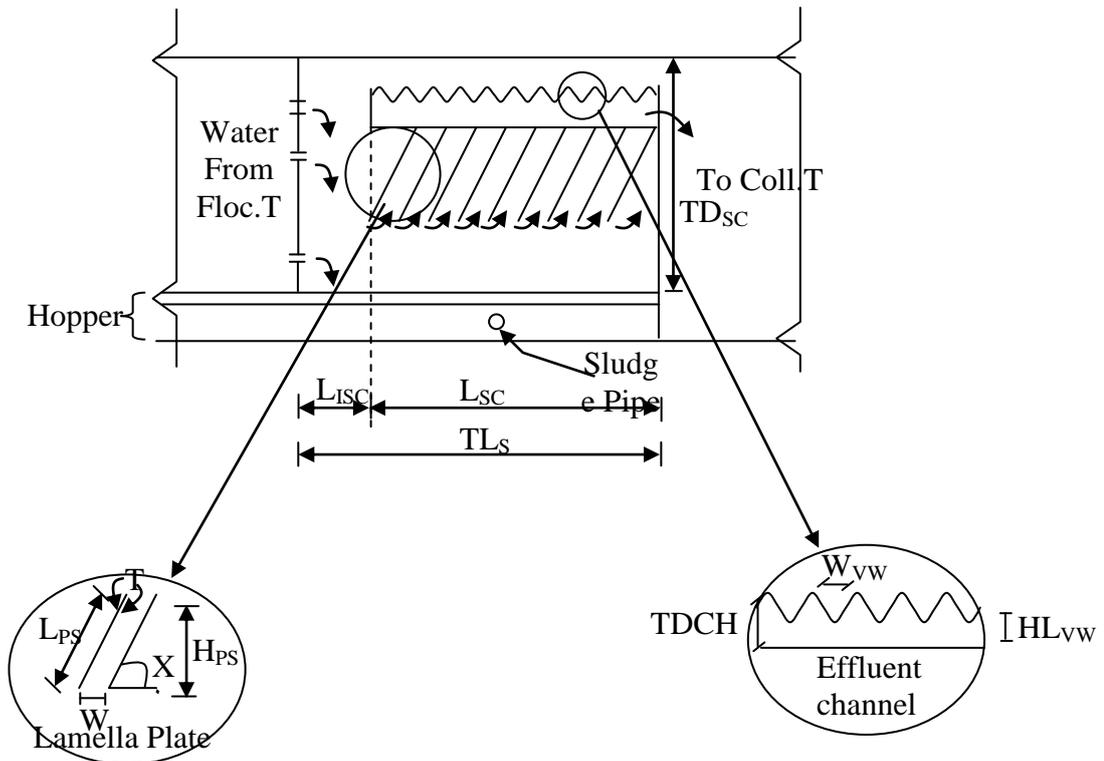
Fig. (٤.٨) : Plan of setting chamber design with lamella plate and effluent channel with V– Notch weir as outlet to collection tank

٤.٦.١ Effluent Channel (Launder) and V-Notch Weirs as Outlet of The Settling Chamber

Effluent channel is used to carry the water from the settling chamber to the collection tank. V-Notch weirs are found at the top of effluent channel, where these weirs are uniformed the water flow from the settling chamber (lamella plate) to the effluent channel as shown in Fig.(٤.٨).

In the designed computer program, the following assumptions are used:

- The number of effluent channel : NCH = ٢

- The length of effluent channel (*m*) : LCH = L$_{SC}$

- The width of V-Notch weir (*m*) : W$_{VW}$ = ٠.١

The number of V-Notch weirs per one effluent channel is calculated from the following equation:

$$NU_{vw} = INT(\frac{2*LCH}{Wvw})$$ ...(٤.٧٢)

The discharge of each V-Notch weir per one effluent channel is calculated from the following equation:

$$Qvw = \frac{QPAC.U \Big/ NCH}{Wvw*3600}$$ ...(٤.٧٣)

The head loss of V-Notch weir is calculated from the following equation:

$$HLvw = \left(\frac{Qvw}{2.5}\right)^{\frac{2}{5}}$$ ...(٤.٧٤)

The limit value of weir loading is between $(١٢٠\text{-}٣٨٠)\frac{M^3}{m.d}$, and it is calculated from the following equation:

$$WL = \frac{(\frac{QPAC.U*24}{2*NCH})}{LCH}$$ ...(٤.٧٥)

If weir loading is more or less than the limit then the following equation is applicated and re-designed the V-Notch weir according to the new NCH value.

$$NCH = NCH \pm 1 \qquad\qquad\qquad ...(٤.٧٦)$$

The width of effluent channel (*m*) is calculated from the following equation:

$$WCH = \left(\frac{0.2}{NCH}\right) * Wsc \qquad\qquad ...(٤.٧٧)$$

The critical depth of effluent channel (*m*) is calculated from the following equation:

$$DCCH = \sqrt[3]{\left(\frac{QPAC.U}{3600}\right)^2 \Big/ \left(WCH^2 * g\right)} \qquad ...(٤.٧٨)$$

Then, the depth at the upper end (*m*) is calculated from the following equation:

$$DCH = \sqrt{DCCH^2 + \left(\frac{2*(\frac{QPAC.U}{2*LCH*3600})^2 * LCH^2}{g*WCH^2*DCH}\right)} \qquad ...(٤.٧٩)$$

If the depth at the upper end is less than the width of channel (DCH<WCH) then the following equation is applicated and re-calculated the depth at new WCH value.

$$WCH = WCH \pm 0.01 \qquad\qquad\qquad ...(٤.٨٠)$$

The head loss at critical depth (m/m) is calculated from the following equation:

$$SL = \sqrt{\frac{0.013 * \frac{QPAC.U}{3600}}{2 * ACH * R^{\frac{2}{3}}}} \qquad\qquad ...(٤.٨١)$$

The head loss in effluent channel (*m*) is:

$$HLCH = LCH * SL \qquad\qquad\qquad ...(٤.٨٢)$$

If the head loss of effluent channel is more than half the depth of channel (HLCH> $\dfrac{DCH}{2}$), then Eq.(٤.٨٠) is applicated and re-designed the effluent channel at new WCH value.

The total depth of the effluent channel is calculated from the following equation:

$$TDCH=DCH+ HLCH + HLvw \qquad …(٤.٨٣)$$

If the total depth of effluent channel is more than twice the width of channel (TDCH>٢*WCH) Then Eq.(٤.٨٠) is applicated and re-designed the effluent channel at new WCH value .

$٤.٦.٢$ Sludge Hopper of Clarifier

Sludge hopper is extended along the rapid mixing chamber, flocculation basin, and the settling chamber as shown in Fig.(٤.٩), where the sludge is settling and collecting in hopper by gravity force.

For one package unit, the following consideration are adopted:

- The bottom slope of the chamber (rapid mix, flocculation, and settling) according the width of package unit:

$$BCcf = \frac{WPAC.U}{1} \qquad ١<WPAC.U<٢$$

$$BCcf = \frac{WPAC.U}{2} \qquad WPAC.U>٢$$

- Depth of sludge hopper (m) : $D_{CFS} = ٠.٤$

The discharge of hopper($m^٣/h$) is calculated from the following equation:

$$Q_{CFS}=٠.٢*QPAC.U \qquad …(٤.٨٤)$$

The length of hopper(m) can be calculated from the following equation:

$$L_{CFS}=W_{RMC} +L_{FT} +TL_{SC} \qquad …(٤.٨٥)$$

The retention time for sludge thickening (*min*) in hopper is:

$$RT_{CFS} = RT_{RMC} + RT_{FT} + RT_{SC} \qquad \qquad ...(٤.٨٦)$$

Then, the width of sludge hopper (*m*)is calculated from the following equation :

$$W_{CFS} = \frac{Q_{CFS} * RT_{CFS}}{D_{CFS} * L_{CFS}} \qquad \qquad ...(٤.٨٧)$$

٤.٦.٣ Sludge Pipes

Sludge pipes are found at the bottom of the rapid mixing chamber, flocculation basin, and setting chamber where this pipe is connected with sludge hopper to carry the sludge from the hopper to the channel of sludge and overflow as shown in Fig.(٤.٩).

In the designed computer program, one sludge pipe is assumed in each chamber then the number of pipe is ($NUP_{CFS} = ٣$).

The discharge of each pipe is calculated from the following equation:

$$PQ_{CFS} = \frac{Q_{CFS}}{NUP_{CFS} * 3600} \qquad \qquad ...(٤.٨٨)$$

The Length of pipe(*m*) is calculated from the following equation:

$$PL_{CFS} = \frac{WPAC.U - W_{CFS}}{2} + \frac{DSPAC.U}{3} \qquad \qquad ...(٤.٨٩)$$

The sludge pipe is designed from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: ET = ١, GV = ١, and OU = ١.

٣
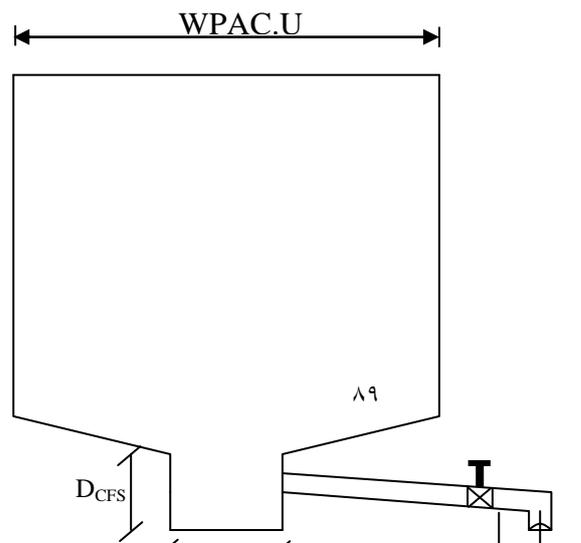
Fig. (٤.٩) : Plan of sludge hopper and sludge pipe

٤.٧ The Collection Basin

Collection basin is located between the setting chamber and the filter. It is used to collect the entering water of the setting chamber as shown in Fig.(٤.١٠). In this basin, the overflow water of package unit is discharged via inner vertical pipe of the collection basin.

In the designed computer program, the following assumptions are used :

- The number of collection basin per package unit : $NU_{CT} = ١$

- The width of basin (*m*) : $W_{CT} = WPAC.U$

- The retention time (min): $RT_{CT} = 2.5$

The depth of collection basin is calculated from the following equation:

$$D_{CT} = D_{SC} + D_{CFS} + \frac{WPAC.U - W_{CFS}}{2} \times Tan(\phi) - TDCH$$

$$...(٤.٨٩)$$

Thus, the length of collection basin is:

$$L_{CT} = \frac{QPAC.U \times RT_{CT}}{D_{CT} \times W_{CT}} \qquad ...(٤.٩٠)$$

Free board is added to find the total depth of collection basin:

$$TD_{CT} = D_{CT} + 0.25 \qquad\qquad ...(٤.٩١)$$

٤.٧.١ The Overflow Pipe in Collection Basin

Overflow pipe is located in the collection basin to discharge the overflow water of package unit from the collection basin to the channel of

overflow and sludge. In each package unit is found one overflow pipe as shown in Fig.($\xi.١٠$).

The discharge of this pipe (m^3/s) is calculated from the following equation:

$$PQ_{OVCT} = \frac{QPAC.U}{3600} \qquad ...(\xi.٩٢)$$

Thus , the pipe length is calculated from the following equation:

$$PL_{OVCT} = TD_{CT} + \frac{DSPAC.U}{3} \qquad ...(\xi.٩٣)$$

The overflow pipe is designed from the program of pipe design to find the diameter according to the number of fitting: OU = ١, ET = ١, GV = ١, and E٩ = ٢.

٤.٨ The Filter

After sedimentation process, some small suspend particles are not settled through the time period of setting chamber, to remove these particles, the settled water should be passed through a bed of granular media, the tank that contains this media is called "Filter". Many types of filters are found which are differed in the type of media, the type of flow water through media, and the hydraulic type. The rapid sand filter type is used in the designed computer program with dual media from sand and anthracite. This dual media is supported by gravel bed. Water is carried from the collection basin to the filter and filtrated through the media by the pressure head of water above this media.
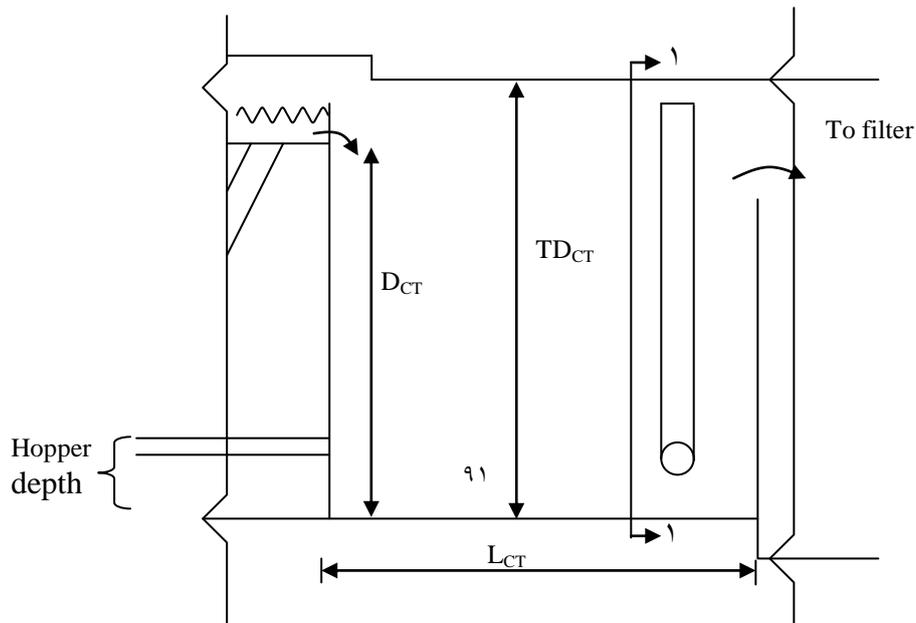
Fig. (٤.١٠) : Plan of collection basin and overflow pipe

After passing the water through the media the water is penetrated through the small orifice that distribute on hollow block uniformed a long the length of filter, and carried to the clear and back wash water tank by the effluent pipe of filter as shown in Fig.(٤.١١).
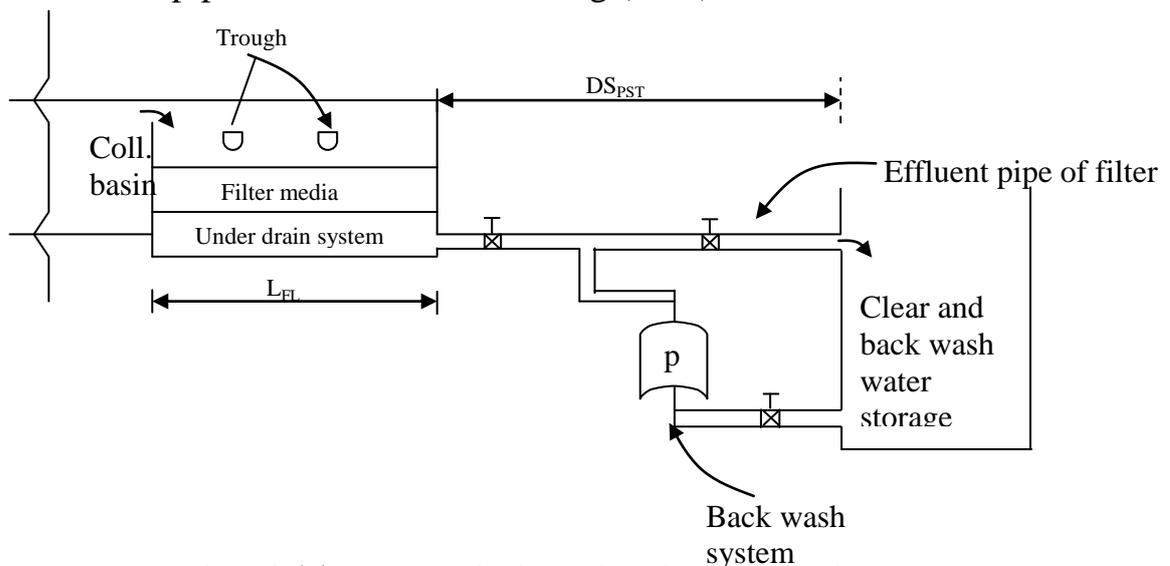
Fig. (٤.١١) :Plan of Filtration System design

٤.٨.١ Design of Filter Media

The characteristic of the media is designed by computer program is presented in Table (٤.٢), and shown in Fig.(٣.١٧):

Table (٤.٢) : Characteristic of filter media

Type of media	No. of Layers	Depth of Layers (*m*)	Size of Particles (*mm*)		α
			d١	**d٢**	
Gravel	١	٠.٠٥	٢.٨	٥.٦	٠.٤٥
	٢	٠.٠٥	٥.٦	١١.٠	
	٣	٠.٠٧٥	١١.٠	١٩.٠	
	٤	٠.٠٧٥	١٩.٠	٣٢.٠	
Sand	١	٠.٠٥	٠.٨٤	١.١٩	٠.٥
	٢	٠.١٥	٠.٥٩	٠.٨٤	
	٣	٠.٠٥	٠.٤٢	٠.٥٩	
Anthracite	١	٠.١	١.٤٥	١.٨٦	٠.٤٥
	٢	٠.٢	١.٤٥	١.١٩	
	٣	٠.٢	١.١٩	١.٠٠	

Where α is the porosity of the media.

Calculations of the geometric mean for the sizes of each anthracite (d_{MAL}) and sand (d_{MSL}) is made from the summation of multiplying the root of $d_١$ and $d_٢$.

Calculation ($d_{٦٠}$) of each sand and anthracite layer from the following equations after calculation the average particles size for each layer:

$$d_{60SM} = \frac{\sum d_{MSL}}{NU_{SL}} \qquad \qquad ...(٤.٩٦)$$

$$d_{60AM} = \frac{\sum d_{MAL}}{NU_{AL}} \qquad \qquad ...(٤.٩٧)$$

Where NU_{SL} is the number of sand layers, and NU_{AL} is the number of anthracite layers.

The depth of filter media (sand, anthracite, and gravel) is calculated from the following equation:

$$D_{FM} = D_{FSM} + D_{FAM} + \sum D_{FGM} \qquad \qquad ...(٤.٩٨)$$

٤.٨.٢ Filter Dimensions

The depth of underdrain system (Leopold type) is equal to ($D_{FUDS} = ٠.٢٥m$) and the total depth of water above the media is assumed equal to ($D_{FW} = ١.٢٥m$). Then the depth of filler basin is calculated from the following equation:

$$D_F = D_{FM} + D_{FUDS} + D_{FW} + FB \qquad\qquad …(٤.٩٩)$$

For rapid sand filter, minimum and maximum acceptable limits of filtration rate are (٥-١٥) $\dfrac{m}{h}$, respectively, then the following assumptions are used:

- The width of filter (*m*) : $W_{FL} = WPAC.U$
- The number of filter per package unit : $NU_{FL} = ١$
- The relation length to width of filter : $R_{L/W} = ٢$

The length of filter (*m*) is calculated from the following equation:

$$L_{FL} = R_{L/W} \times W_{FL} \qquad\qquad …(٤.١٠٠)$$

Then the filtration rate (*m/h*) is:

$$FR = \frac{QPAC.U}{L_{FL} \times W_{FL}} \qquad\qquad …(٤.١٠١)$$

If the filtration rate is more or less than the acceptable limit, then the following equation is applicated and re-calculation of filtration rate is conducted with new $R_{L/W}$ value :

$$R_{L/W} = R_{L/W} \pm 0.5 \qquad\qquad …(٤.١٠٢)$$

٤.٨.٣ Underdrain System Design

Underdrain system that is used in the designed filter is Leopold type which contains blocks with standard dimensions extend along the length of filter to discharge the filtered water as shown in Fig.(٤.١٢).

The dimensions of block is constant as follows:

- The depth of block (*m*) : $D_{FUDSB} = \dfrac{D_{FUDS}}{2}$

- The width of block (*m*) : $W_{FUDSB} = ٠.٢٧٩$

- The length of block (*m*) : $L_{FUDSB} = ١$

For each square meter, the following items are considered:

- The number of orifice at the top surface of block : $NU_{FUDSOB} = ١٩٤$

- The diameter of orifice at the top surface of block (*m*) : $DM_{FUDSOB} = ٠.٠٠٦ \ m$

- The number of control orifice at the middle web : $NU_{FUDSCOB} = ٢١.٥$

- The diameter of control orifice (*m*) : $DM_{FUDSOB} = ٠.٠١٥ \ m$

The water discharge between the channels is controlled by the control orifices. The discharge of each orifice and control orifice (m^3/s) is calculated from the following equation:

$$Q_{FO} = \dfrac{FR}{NU_{FO} \times 3600} \qquad \ldots(٤.١٠٣)$$

Thus the area (m^2) is:

$$A_{FO} = \dfrac{\pi \times DM_{FO}^{\,2}}{4} \qquad \ldots(٤.١٠٤)$$
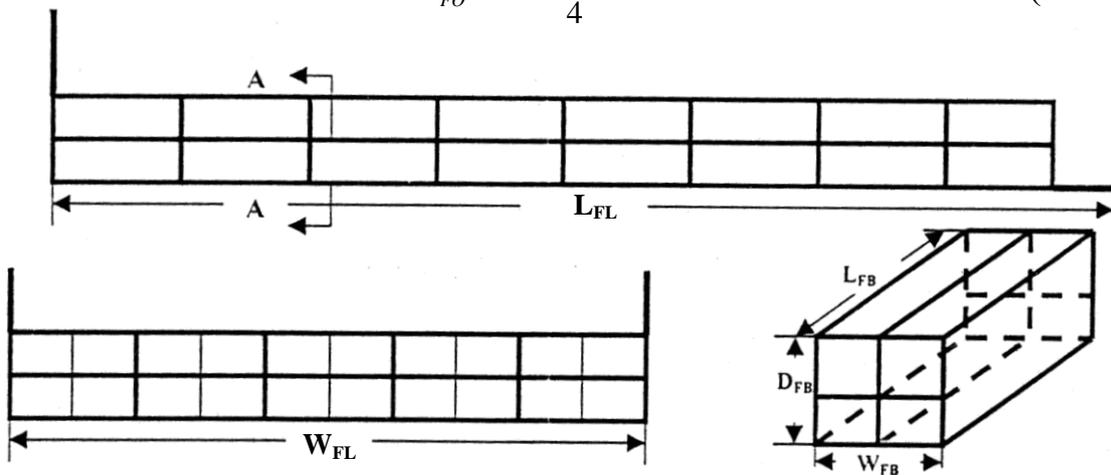
Fig. (٤.١٢) : Underdrain system of filter

٤.٨.٤ The Head Loss at Filter Run

The head loss of each sand anthracite, and gravel layer can be calculated from the following equation:

$$HL_{FM} = 5 \times \frac{\eta}{g} \times FR \times \frac{(1-\alpha)^2}{\alpha^3} \times (\frac{6}{\phi})^2 \times \sum \frac{1}{d_{FM}^2} \times D_{FM} \qquad ...(٤.١٠٥)$$

Thus, the head loss due to the orifice and control orifice for underdrain system is calculated from the following equation:

$$HL_{FUDSO} = \frac{(\dfrac{Q_{FO}}{0.6 \times A_{FO}})^2}{2 \times g} \qquad ...(٤.١٠٦)$$

Then, the total loss due to filtration is:

$$HL_{FL} = HL_{FSM} + HL_{FAM} + HL_{FGM} + HL_{FUDSO} \qquad ...(٤.١٠٧)$$

Where HL_{FSM}, HL_{FAM}, and HL_{FGM} are the head loss (*m*) for sand, anthracite, and gravel, respectively.

٤.٨.٥ Design of Filter Backwashing System

During the operation of filter with a period time not more than ٤٨ hr (according to the turbidity of water), the suspension particles which is not settled in the settling chamber is suspended in the filter media, the volume of particles removed equals the reduction in pore volume of the media where the filtration rate is reduced and the head loss during the filtration process is increased by increase of the water depth above the filter media. A filter cell must be cleaned by back washing process. This process involves pumping water upward through the filter media by using pump called backwashing pump.

Backwashing velocity must be limited to suit with the characteristic of water, the specific gravity ,and size particles of sand and anthracite beds.

The minimum fluidization velocity for sand grains is calculated the following equation:

$$V_{Mf} = d_{60SM}^{1.82} \times \frac{(\rho \times (SG_{SM} - \rho))^{0.94}}{\mu^{0.88}} \qquad \ldots(٤.١٠٨)$$

Where SG_{SM} is Specific gravity for sand which is equal to ٢.٦٥

The Reynold number due to the minimum fluidization velocity is calculated from the following equation:

$$\text{Re}_m = \frac{\rho \times V_{mf} \times d_{60SM}}{\mu} \qquad \ldots(٤.١٠٩)$$

If the Reynold number (Re_m) is more than ١٠ then it must be corrected by the correction factor is calculated from the following equation and then multiply with the minimum fluidization velocity:

$$K_{\text{Re}} = 1.775 \times R_e^{-0.272} \qquad \ldots(١.١١٠)$$

$$V_{mf} = K_{\text{Re}} \times V_{mf} \qquad \ldots(١.١١١)$$

The Reynold number of fluidized sand grains due to non-hindered setting velocity of particles is calculated from:

$$\text{Re}_o = 8.45 \times \text{Re} \qquad \ldots(٤.١١٢)$$

$$n = 4.45 \times \text{Re}^{-0.1} \qquad \ldots(٤.١١٣)$$

$$K = \frac{V_{mf}}{\alpha^n} \qquad \ldots(٤.١١٤)$$

The acceptable limits for backwash rate of sand grains are ($٠.٢٥-٤.٧$) $\frac{m}{\min}$. The backwash rate relative to $d_{٦٠sm}$ is calculated from Table (٤.٣):

Table (٤.٣) : The average backwash rate relative to the effective size of the sand bed.

$d_{٦٠SM}$ (*mm*)	BWR (*gpm*)
> ٠.٥٥	٦.٣ + ($d_{٦٠SM}$ − ٠.٥٥) * ٢٧.٠
٠.٦٥ To ٠.٧٨	٩.٠ + ($d_{٦٠SM}$ − ٠.٦٥) * ٢٧.٧

۰.۷۸ To ۰.۹۲	۱۲.٦ + (d٦۰SM − ۰.۷۸) * ۲۷.۱
۰.۹۲ To ۱.۰۹	۱٦.٤ + (d٦۰SM − ۰.۹۲) * ۲۷.۰
۱.۰۹ To ۱.۳۰	۲۱.۰ + (d٦۰SM − ۱.۰۹) * ۲۸.٦
۱.۳۰ To ۱.٥٤	۲۷.۰ + (d٦۰SM − ۱.۳۰) * ۲٥.۰
۱.٥٤ To ۱.۸٤	۳۳.۰ (d٦۰SM − ۱.٥٤) * ۲٦.۷

The average backwash rate is corrected according to the effect of temperature by using correction factor of temperature from Table (٤.٤). The average backwash rates ($m^3/m/s$) is calculated from the following equation:

$$BWR = BWR \times \frac{T_{FAC}}{1585.3} \qquad \ldots(٤.١١٥)$$

The expected void ratio during the backwash process is calculated from the following equation:

$$\alpha_{BW} = (\frac{BWR \times 60}{K})^{\frac{1}{n}} \qquad \ldots(٤.١١٦)$$

Table (٤.٤) : Temperature correction factors

$T_{MAX} (C^o)$	T_{FAC}
>= ۳۰	۱.۰۹
۲٥ To ۲۹	۱.۰۰
۲۰ To ۲٤	۰.۹۱
۱٥ To ۱۹	۰.۸۳
۱۰ To ۱٤	۰.۷٥
٥ To ۱۰	۰.٦۸
< ٥	۰.٥

The expansion of sand and anthracite bed can be calculated from the following equations:

$$L_{eSM} = D_{FSM} \times \frac{1 - \alpha_{SM}}{1 - \alpha_{BW}} \qquad \ldots(٤.١١۷a)$$

$$L_{eAM} = D_{FAM} \times \frac{1 - \alpha_{AM}}{1 - \alpha_{BW}} \qquad \ldots(٤.١١۷b)$$

The expansion ratio for sand and anthracite bed is calculated from the following equations:

$$R_{BWSM} = (\frac{L_{esm} - D_{FSM}}{D_{FSM}}) \times 100 \qquad \ldots(٤.١١٨)$$

$$R_{BWAM} = (\frac{L_{eAM} - D_{FAM}}{D_{FAM}}) \times 100 \qquad \ldots(٤.١١٩)$$

Then total expansion ratio for the media is calculated from the following equation:

$$R_{BW} = (\frac{(L_{eAM} + L_{eSM}) - (D_{FSM} + D_{FAM})}{D_{FSM} + D_{FSM}}) \times 100 \qquad \ldots(٤.١٢٠)$$

٤.٨.٦ The Head Loss During Backwashing Process

The head loss due to backwashing process is calculated for each layer of filter media, The head loss through the sand layer (*m*) is calculated from the following equation:

$$HL_{BWSM} = D_{FSM} \times (SG_{SM} - 1) \times (1 - \alpha) \qquad \ldots(٤.١٢١)$$

Where SG_{SM} is the specific gravity of sand layer and is equal to ٢.٦٥.

The head loss through the anthracite layer (*m*) is calculated from the following equation:

$$HL_{BWAM} = D_{FAM} \times (SG_{AM} - 1) \times (1 - \alpha) \qquad \ldots(٤.١٢٢)$$

Where SG_{AM} is the specific gravity of anthracite layer and is equal to ١.٥.

The head loss of gravel support is calculated from the following equation:

$$HL_{BWGM} = (150 \times \frac{\eta}{g} \times BWR \times \frac{(1-\alpha)^2}{\alpha^3} \times (\frac{1}{\phi})^2 \times \sum \frac{1}{d_{60}^2} + 1.75 \times \frac{(1-\alpha)}{\alpha^3} \times \frac{BWR^2}{g} \times (\frac{1}{\phi}) \times \sum \frac{1}{d_{60}^2}) \times D_{FGM}$$

$$\ldots(٤.١٢٣)$$

And the head loss through the orifices and control orifices of underdrain system is calculated from the following equation:

$$HL_{BWUDSO} = \frac{HL_{FUDSO}}{FR^2} \times BWR^2 + \frac{HL_{FUDSCO}}{FR^2} \times BWR^2$$

$$\ldots(٤.١٢٤)$$

In each meter width of filter basin there are ٦.٥ primary feeder channels two in each black, then the dimensions of this channel are:

- The depth of one primary feeder channel (*m*) : $D_{BPC} = ٠.١$
- The width of one primary feeder channel (*m*) : $W_{BPC} = ٠.١$
- The length of primary feeder channel (*m*) : $L_{BPC} = L_{FL}$

The cross sectional area of primary feeder channel ($m^٢$) is calculated from the following equation:

$$A_{BPC} = W_{BPC} \times D_{BPC} \qquad \ldots(٤.١٢٥)$$

Therefore the number of primary feeder channels for filter basin is:

$$NU_{BPC} = \frac{W_{FL}}{W_{FB}} \times 2 \qquad \ldots(٤.١٢٦)$$

The discharge of each primary feeder channel ($m^٣/s$) is calculated from the following equation:

$$Q_{BPC} = L_{FL} \times BWR \qquad \ldots(٤.١٢٧)$$

Thus the velocity of flow through primary feeder channel (*m/s*) is:

$$V_{BPC} = \frac{Q_{BPC}}{A_{BPC}} \qquad \ldots(٤.١٢٨)$$

The slope of this channel (*m/m*) is calculated from the following equations:

$$S_{BPC} = (\frac{V_{BPC} \times 0.013}{R^{2/3}})^2 \qquad \ldots(٤.١٢٩)$$

$$R = \frac{A_{BPC}}{2 \times (W_{BPC} + D_{BPC})}$$

$$\ldots(٤.١٣٠)$$

The head loss due to the primary feeder channel (*m*) is calculated from the following equation:

$$HL_{BPC} = \frac{1}{3} \times S_{BPC} \times L_{FL}$$

$$...(٤.١٣١)$$

The head loss of primary feeder channel is checked with velocity head (*m*) that calculated from Eq. (٤.١٣٢) and the difference between them is not more than ٠.٠١ *m* to produce the pressure balance in primary feeder channel:

$$VH_{BPC} = \frac{V^2_{BPC}}{2 \times g} \qquad ...(٤.١٣٢)$$

The total static head from the bottom of underdrain system after added the assumed trough depth (٠.٣*m*) with (٠.١٥*m*) as free board (*m*) is calculated from the following equation:

$$TSH_{BW} = D_{FM} + D_{FUDS} + 0.3 + 0.15 + L_{eSM} + L_{eAM} \qquad ...(٤.١٣٣)$$

The required pressure head above the primary feeder channels of underdrain system (*m*) is calculated from the following equation:

$$HL_{BW} = TSH_{BW} + HL_{BWGM} + HL_{BWUDS} + HL_{BWSM} + HL_{BWTSM} \qquad ...(٤.١٣٤)$$

٤.٨.٧ The Backwashing Water Trough

During the backwashing of filter, the head of water above the media is raised to a level equals to the total static head and this level is the same level of the back wash water trough as shown in Fig (٤.١٣). The trough extends along the width of filter and the spacing between the backwashing water troughs is calculated from the following equation:

$$SP_{BWT} = 2 \times TSH_{BW} \qquad ...(٤.١٣٥)$$

The number of backwashing water trough is calculated according to the trough spacing and as follows:

$$NU_{BWT} = \frac{L_{FL}}{SP_{BWT}}$$

$$...(٤.١٣٦)$$

The discharge of backwashing water for filter (m^3/s) is calculated from the following equation:

$$Q_{BW} = A_{FL} \times BWR \qquad \qquad ...(4.137)$$

Therefore, the discharge of each trough (m^3/s) is calculated from the following equation:

$$Q_{BWT} = \frac{Q_{BW}}{NUT_{BWT}} \qquad \qquad ...(4.138)$$

In the designed computer program, then the following assumption is used:

- The width of backwashing water trough (m) : $W_{BWT} = 0.2$

Backwashing water trough is designed from the program of lateral spillway channel design where discussed in the next item after calculation of the length of the end of spillway water in the trough from the following equation:

$$RL = W_{FL} \times 2 \qquad \qquad ...(4.139)$$

The height of backwashing water trough is equal to the total static head (TSH_{BW}) .

4.8.8 Backwashing Wastewater Pipe

Backwashing wastewater pipe is used to carry the backwashing wastewater from the backwashing water trough to the overflow and sludge channel as shown in Fig (4.13) where the pipe length (m) is calculated from the following equation:

$$PL_{BWE} = \frac{DSPAC.U}{3} + TSH_{BW} \qquad \qquad ...(4.140)$$

The number of pipe is equal to the number of backwashing water trough ($NUP_{BW} = NUT_{BWT}$), therefore the discharge of pipe can be calculated from the following equation:

$$PQ_{BWE} = Q_{BW} / NUP_{BWE} \qquad \qquad ...(4.141)$$

This pipe is designed from the program of pipe design to find the diameter according to the number of fitting :ET = ١,OU=١, E٩ = ١,and BV = ١
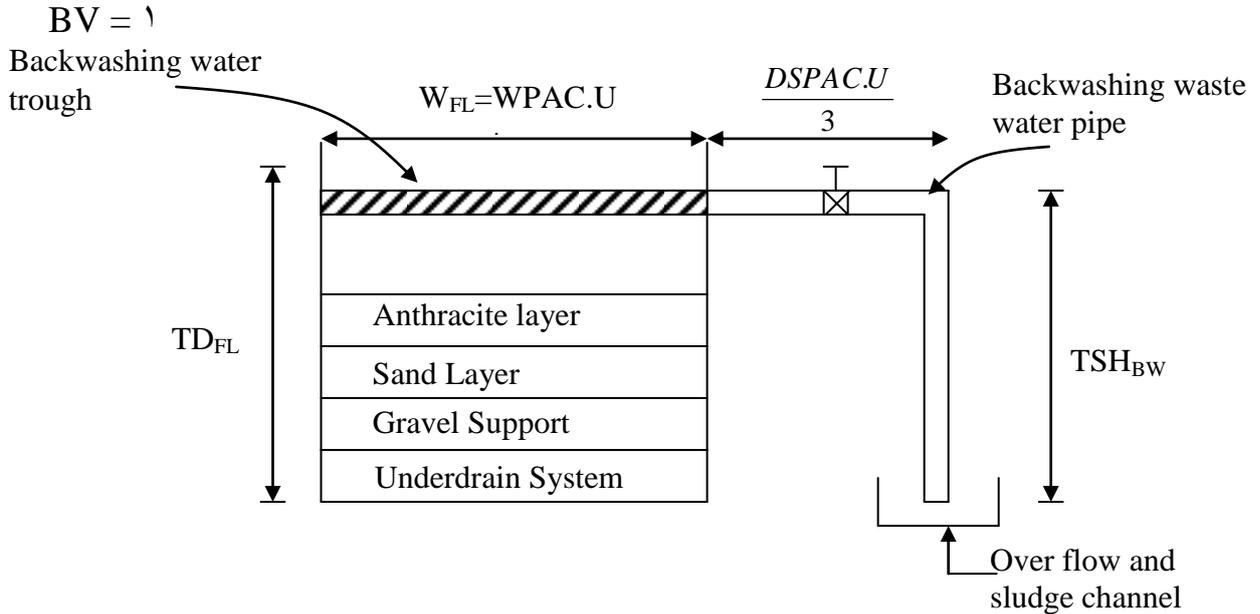
Fig. (٤.١٣) :Plan of Backwashing wastewater pipe

٤.٨.٩ Influent Weir of Filter

Influent weir of filter is rectangular weir and locates between the collection basin and the filter to uniform the influent water to filter along the filter width then the length of weir is :

$$L_{IW} = W_{FL} \qquad\qquad ...(٤.١٤٢)$$

The discharge that passed above this weir ($m^٣/s$) is calculated from the following equation:

$$Q_{IW} = \frac{QPAC.U}{3600} \qquad\qquad ...(٤.١٤٣)$$

The head loss of weir (*m*) which is equal to the height of water above this weir is calculated from the following equation:

$$HL_{IW} = (\frac{Q_{IW}}{3.33 \times L_{IW}})^{2/3} \qquad\qquad ...(٤.١٤٤)$$

٤.٨.١٠ Filter Effluent Pipe

Filter effluent pipe is used to carry the filtered water from the filter to the clear and backwashing water storage tank and also is used to carry the backwashing water from the back wash pipe system to the filter underdrain system as shown in Fig.(٤.١١). The length of the pipe is equal to the distance between the package unit and the clear and backwashing water storage tanks (DS$_{PST}$):

$$PL_{FE} = DS_{ULPDT} \qquad\qquad ...(٤.١٤٥)$$

Discharge of this pipe ($m^٣/s$) is equal to discharge of influent weir of filter (PQ$_{FE}$ = Q$_{IW}$) .

Filter effluent pipe is designed from the program of pipe design to find the diameter according to number of fitting: ET = ١, OU = ١, GV = ٢ , and TR=١ .

٤.٨.١١ Backwashing Pipes System

The backwashing pipes system include Pipes connected with the pump to carry the backwashing water from the clear and backwashing storage tank to filter as shown in Fig.(٤.١٤). For each package unit, pipes include :

١. Main suction pipe : it carries the backwashing water from the clear and backwashing water tank to the backwashing pump according to effect of this pump, the characteristics of this pipe are:

- The number of pipe : NUP$_{BWS}$ = ١
- The length of pipe (*m*) : PL$_{BWS}$ = ٢
- The discharge of pipe ($m^٣/s$) : PQ$_{BWS}$ = Q$_{BW}$
- The design of pipe from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: ET = ١, TR = ١, and GV=١.

٢. Minor suction and delivery pipe : Minor suction pipe locates between the main suction pipe and the backwashing pump, the characteristics of this pipe are:

- The number of pipe in service : $NUP_{BWMS} = ١$
- The number of pipe out of service : $NUOP_{BWMS} = ١$
- The length of pipe $(m) = PL_{BWS} = \frac{1}{2} DS_P$

Where D_{SP} is the distance between washing pump and is equal to $١.٥m$.

- The discharge of pipe $(m^٣/s) : PQ_{BWMS} = Q_{BW}$
- The design of pipe from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: $E^٩ = ١, GV = ١$, and $OU = ١$.

In the designed computer program, the characteristics of minor delivery pipe are the same of characteristics of minor suction pipe.

٣. Main delivery pipe : it connects between the backwashing pump and the effluent pipe of filter to carry the backwashing water to the underdrain system of filter, the characteristics of this pipe are:

- The number of pipe : $NUP_{BWD} = ١$
- The length of pipe (m) : $PL_{BWD} = D_{ST} – ١.٢٥$
- The discharge of pipe $(m^٣/s) : PQ_{BWD} = Q_{BW}$
- The design of pipe from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: $TR = ١$, and $GV = ١$.

Filter

Backwashing
Minor suction and deliver Pines

$P_{BW٢}$

١.٥

Backwashing
Deliver Pipe

$P_{BW١}$

C.B.W.T
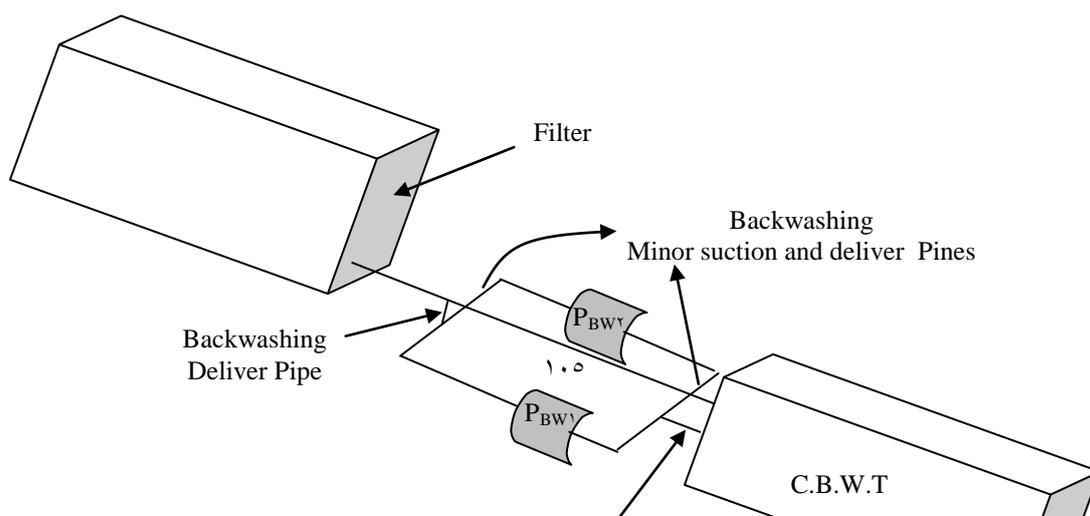
Fig. (٤.١٤) : **Plan of backwashing pipes system
for each package unit**

Then the characteristic of back washing pump is:

- The number of pump in service : NUPUMP_{BW} = ١

- The number of pump out of service : NUOPUMP_{BW} = ١

- The discharge of pump (m^3/s) : $Q_{BWP} = Q_{BW}$

The head loss of backwashing pump is equal to the total head loss of backwashing pipes ($\text{TH}_{BWP} = \text{PHL}_{BW}$), thus the required power of backwashing pump (*KW*) is calculated from the following equation:

$$P_{BWP} = \frac{0.163 \times 60 \times Q_{BWP} \times TH_{BWP}}{0.8} \qquad \ldots(٤.١٤٦)$$

٤.٨.١٢ Backwashing Procedure

In each package unit, filter is designed to work ٢٤ hr in day, then the filter must be washed through (T_{FW} = ٢٤). The maximum backwashing water usage is $(4\frac{m^3}{m^2})$, thus the backwashing time of filter is $(T_{BW} = \frac{4}{BWR} + \frac{1}{60})hr$, where added one minute to close the valve, then the water consumption for filter during the backwashing (m^3) is :

$$VO_{FCBW} = Q_{BW} \times T_{BW} \qquad \ldots(٤.١٤٧)$$

$$R_{BW} = \frac{VO_{FCBW}}{QPAC.U} \times 100 \qquad \ldots(٤.١٤٨)$$

Where R_{BW} is the percent ratio of backwashing water usage .

٤.٨.١٣ Lateral Spillway Channel

Lateral spillway channel is designed as an open channel in which it receives the water along one or two side and then discharges the accumulation water at the upstream of this channel. For example on this type where used in the designed computer program is "backwashing water trough". By neglecting channel friction and assuming the shape of the water surface approximates a parabola as shown in Fig.(٤.١٥), $(\Delta \gamma)$ is the change in water surface elevation between sections ١ and ٢, Thus $(\Delta \gamma)$ (m) is :

$$\Delta \gamma = y_2 - y_1 \qquad \qquad ...(٤.١٤٩)$$
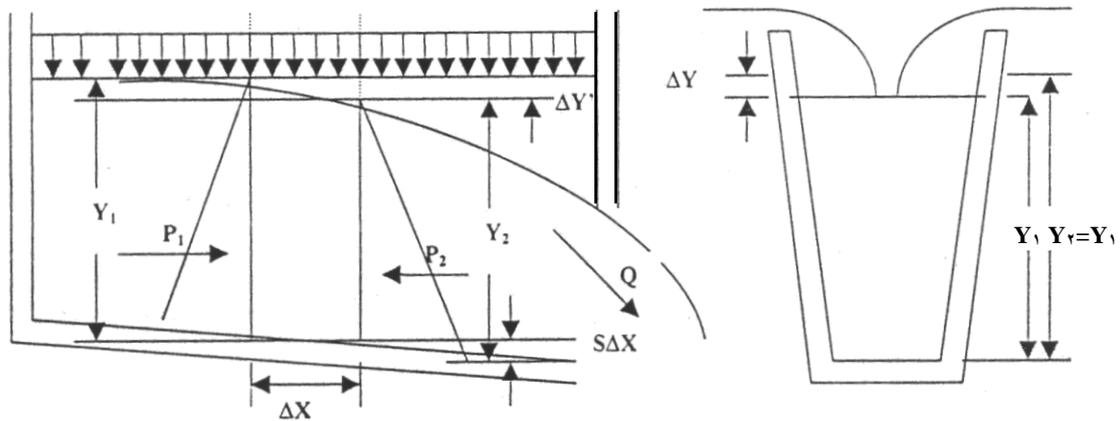
Fig. (٤.١٥) : Plan of lateral spillway channel .

Discharge in each section (m^3/s) is calculated from the following equation:

$$Q_S = \frac{Q_{BW}}{RL} \qquad \qquad ...(٤.١٥٠)$$

Where RL is the length of channel in which the water is spilled above it.

The critical depth is calculated from the following equation:

$$Y_c = \frac{Q_{BW}}{g \times W^2} \qquad \qquad ...(٤.١٥١)$$

The following assumptions are adopt :

- The depth of water in section ٢ is equal to the critical value (m):

$$Y_٢ = Y_c$$

- The distance between the upstream end of the channel and section ٢ (*m*): $X_٢ = RL$

- The charge in gradient : $DYPA = ٠.٠٠٠٥$

- The distance between section ١ and ٢ (*ft*): $\Delta X = ١.١$

The value of ($\Delta \gamma$) is calculated from the following equation:

$$\Delta Y = (S \times \Delta X) - DYPA \qquad\qquad ...(٤.١٥٢)$$

Where S is the slope of channel.

Then the depth of water in section ١ (*m*) is calculated from the following equation:

$$Y_1 = Y_2 - \Delta Y \qquad\qquad ...(٤.١٥٣)$$

The discharge ($m^٣/s$) and the velocity (*m/s*) for sections ١ and ٢ can be calculated from the following equations, respectively:

$$Q_2 = Q_S \times X_2 \qquad\qquad ...(٤.١٥٤)$$

$$Q_1 = Q_S \times (X_2 - \Delta X)$$
$$...(٤.١٥٥)$$

$$Vi = \frac{Qi}{W \times Y_i}$$
$$...(٤.١٥٦)$$

The hydraulic diameter for each section is calculated from the following equation :

$$Ri = \frac{W \times Y_i}{2 \times Y_i + W} \qquad\qquad ...(٤.١٥٧)$$

The average diameter and the average slope for two sections are calculated from the following equations, respectively :

$$R_{avr} = \frac{\sum Ri}{i} \qquad\qquad ...(٤.١٥٨a)$$

$$S_{avr} = \frac{n^2 * (V_1 * V_2)^2}{8.83 * R_{avr}^{1.33}} \qquad\qquad ...(٤.١٥٨b)$$

The change in velocity (*m/s*) and in discharge (m^{Υ}/*s*) between section ١ and section ٢ can be calculated from the following equation, respectively:

$$\Delta V = V_2 - V_1 \qquad\qquad ...(٤.١٥٩)$$

$$\Delta Q = Q_2 - Q_1 \qquad\qquad ...(٤.١٦٠)$$

The drop in surface water depth between section ١ and ٢ (*m*) is calculated from the following equation:

$$\Delta Y' = \frac{Q_1 \times (V_1 + V_2)}{g \times (Q_1 + Q_2)}\left[\Delta V + \frac{V_2}{Q_1} \times \Delta Q \right] + S_{avr} \times \Delta X \qquad ...(٤.١٦١)$$

By application the Eq.(٤.١٦٢), ($\Delta Y'$) value that calculated from Eq. (٤.١٦١) is compared with ($\Delta\gamma$) value that calculated from Eq.(٤.١٥٢) and as follows:

$$\left| \frac{\Delta Y - \Delta Y'}{\Delta Y'} \right| < ٠.١ \qquad\qquad ...(٤.١٦٢)$$

If the absolute value that calculated from Eq. (٤.١٦٢) is more then ٠.١, then the channel is re-designed from Eq.(٤.١٥١) after changing the value of ($\Delta\gamma$) to a value of ($\Delta\gamma$) + ٠.٠٠٠٠٥ .

The horizontal distance between the upstream of the channel and section ١ (*m*) is calculated from the following equation:

$$X_1 = X_2 + \Delta X \qquad\qquad ...(٤.١٦٣)$$

The increasing value for the horizontal distance between section ١ and ٢ (*m*) is calculated from the following equation:

$$XS = XS + \Delta X \qquad\qquad ...(٤.١٦٤)$$

Assume ($X_١ = X_٢$) and ($Y_١ = Y_٢$) to design the next sections at the same pre-design method.

If ($X_١ < \Delta X$) then the program is reached to the end of channel, the maximum expected depth of the channel is calculated from the following equation:

$$Y_U = \left[2 \times Y_C^2 + (Y_C - \frac{SL}{3})^2 \right]^{\frac{1}{2}} - \frac{2 \times SL}{3} \qquad \ldots(٤.١٦٥)$$

٤.٩ High Lift Pumping Station

The high lift pumping station is the last stage in the designed package water treatment plant where locates on the clear and backwashing water storage thank. The high lift pump is responsible for suction the clear water from the clear and backwashing water storage tank and delivery it to the net-work distribution system for consumers. The high lift pumping station as shown in Fig.(٤.١٦) includes:

١. The clear and backwashing water storage tank.

٢. The suction pipes.

٣. The high lift pumps.

٤. The delivery pipes with hydraulic forces preventers.

In the designed computer program, following assumptions are used:

- The number of high lift pump in service : NU_{ULP} = NPAC.U

- The number of high lift pump out of service : $NUOUT_{ULP}$ = ١

Then the total number of high lift pumps is :

$$NUT_{ULP} = NU_{ULP} + NUOUT_{ULP} \qquad \ldots(٤.١٦٦)$$

٤.٩.١ Clear and Backwashing Water Storage Tank

The clear and backwashing water storage tank locates after the package unit (filter). The number of clear and backwashing storage tank is equal to the number of package units (NU_{DT} = NUPAC.U) where the water is accumulated according to the maximum daily water demand for each package unit (line production) in the package water treatment plant (m^3/h):

$$Q_{DT} = QPAC.U + QT_{BW} \qquad \ldots(٤.١٦٧)$$

Retention time of water in this tank is limited as $(RT_{DT} = 0.5hr)$ thus the volume (m^3) is:

$$VOL_{DT} = Q_{DT} \times RT_{DT} \qquad \ldots(٤.١٦٨)$$

In the designed computer program , following assumptions are used :

- The depth of the tank (m) : $D_{DT} = ٤$
- The width of the tank (m) : $W_{DT} = $ WPAC.U

Then the length of clear and backwashing water storage tank is calculated from the following equation:

$$L_{DT} = \frac{VOL_{DT}}{W_{DT} \times D_{DT}} \qquad \ldots(٤.١٦٩)$$

Free board is added to the depth of tank:

$$TD_{DT} = D_{DT} + 0.25 \qquad \ldots(٤.١٧٠)$$

٤.٩.٢ Minor Suction Pipes (١)

Minor suction pipes (١) extended from the bottom clear and backwashing water tanks to the minor suction pipes (٢) as shown in Fig.(٤.١٦). The number of pipes is equal to the number of clear and backwash tanks $(NU_{ULPMSP١} = NU_{DT})$. The length of one pipe (m) is calculated from the following equation:

$$PL_{ULPMS1} = DSDTUP \qquad \ldots(٤.١٧١)$$

Where DSDTUP is the vertical distance between the clear and backwashing water tank and the high lift pump which is entered by the user
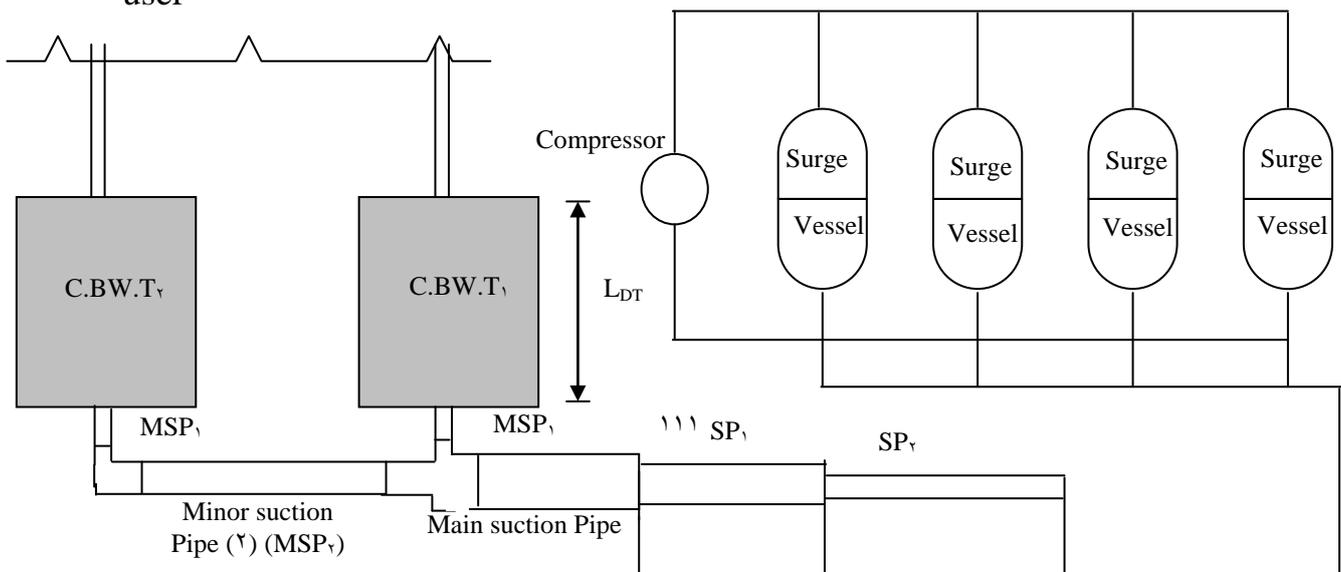
Fig. (٤.١٦) : Plan of high lift pumping station for design capacities(١٤٠-٢٠٠)*m*^{٣}

according to the available servicing area of a project, in all cases DSDTUP is not less than ١.٥*m*.

The discharge that passing through these pipes is equal to the discharge of package unit (*m*^{٣}/*s*):

$$PQ_{ULPMS1} = \frac{QPAC.U}{3600} \qquad \qquad ...(٤.١٧٢)$$

These pipes are designed from the program of pipe design to find the diameter and the head loss of one pipe can be calculated according to the number of fitting: GV = ١, ET = ١, CV=١, E٩ = ١, and OU = ١.

٤.٩.٣ Minor Suction Pipes (٢)

The minor suction pipes (٢) are located between the minor suction pipes (١) and carried the clear water from the minor suction pipes (١) to the main suction pipe as shown in Fig.(٤.١٦). The number of these pipes is depended on the number of clear and backwashing water tank $(NU_{ULPMSP2} = NU_{DT} - 1)$. The length of one pipe is calculated from the following equation:

$$PL_{ULPMS2} = DSPAC.U + W_{DT} \qquad \qquad ...(٤.١٧٣)$$

The discharge of these pipes (*m*^{٣}/*s*) can be calculated from the following equation:

$$PQ_{ULPMS\,2(i)} = PQ_{ULPMS\,2(i)} + \frac{QPAC.U}{3600} \qquad \ldots(٤.١٧٤)$$

The minor suction pipes (٢) are designed from the program of pipe design and the head loss is calculated according to the number of fitting:: OU = ١, GV = ١, and TR = ١.

The head loss due to the change in diameters which is added to the head loss of pipes and can be calculated from the following equations:

$$PA^{\%}_{(i)} = \frac{PA_{UL(i-1)}}{PA_{UL(i)}} \qquad \ldots(٤.١٧٥a)$$

$$PHL_{UL(i)} = PHL_{UL(i-1)} + PA^{\%}_{(i)} \times \frac{PV^2_{UL(i)}}{2g} \qquad \ldots(٤.١٧٥b)$$

٤.٩.٤ Main Suction Pipe

The main suction pipe is extended from the first minor suction pipe (١) to the first pump as shown in Fig.(٤.١٦), In the designed computer program, it is assumed that the length of pipe is (PL_{ULPS} = ٣m) and the discharge of this pipe ($m^٣/s$) is calculated from the following equation:

$$PQ_{ULPS} = \frac{QPAC.U \times NUPAC.U}{3600} \qquad \ldots(٤.١٧٦)$$

The main suction pipe is designed from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: GV = ١, CV = ١, TR = ١, and OU = ١.

The main suction pipe is connected with horizontal joint pipe which are differed in diameter and are equalized in their lengths (PL_{ULPS} = ٣m). One of the joint pipes feed one high lift pump, then the number of these pipes is equal to the number of pumps (NUP_{ULPS} = NU_{ULP}). The discharge of main suction pipe differs from the discharge of first joint pipe because the first pump takes discharge equal to the discharge of second pump and thus for other joint pipes.

The discharge passes through the pump ($m^٣/s$) can be calculated from the following equation:

$$QPUMP_{UL} = \frac{PQ_{ULPS}}{NU_{ULP}}$$

...(٤.١٧٧)

Thus the discharge of joint pipes between pumps can be calculated from the following equation:

$$PQ_{ULS(i)} = PQ_{ULS(i-1)} - QPUMP_{UL} \qquad\qquad ...(٤.١٧٨)$$

The joint pipes are designed as a pipe of pump from the program of pipe design to find the diameter and then the head loss is calculated according to the number of fitting: GV = ١, TR = ١, and OU = ١.

The head loss due to the change in diameter which is added to the head loss of the joint pipes and can be calculated from Eq.(٤.١٧٥a), and Eq.(٤.١٧٥b).

٤.٩.٥ Delivery Net Pipe

The delivery net pipe is extended from the high lift pumps to the main pipe of net-work distribution system as shown in Fig.(٤.١٦).

The delivery net pipe is connected with the horizontal joint pipes which are differed in diameters according to the change of discharge that passing from the pumps and the design of these pipes is the same of design of suction joint pipes.

The delivery net pipe length is (PL_{ULPD} = ٣m) and the discharge (m^3/s) is calculated from the following equation:

$$PQ_{ULPD} = PQ_{ULPS} \qquad\qquad ...(٤.١٧٩)$$

The delivery net pipe is designed as a pipe of pump from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: GV = ١, E٩ = ١, T٩T=١, BV = ١, and AA = ١ .

After calculation of the head loss for all pipes in high lift pumping station, the total head loss is calculated from the following equation:

$$TH_{ULPUMP} = PHL_{ULPD} + \sum PHL_{ULPD(i)} + PHL_{ULPS} +$$

$$\sum PHL_{ULPS(i)} + \sum PHL_{ULPMS1} + \sum PHL_{ULPMS2} \qquad \ldots(٤.١٨٠)$$

The required power for each pump (*m*) is:

$$H_{ULP} = TH_{ULPUMP} + H_{NT} \qquad \ldots(٤.١٨١)$$

With efficiency (٨٠٪), the required power for each pump (*kw*) and the total power can be calculated from Eq. (٤.١٨٢) and Eq. (٤.١٨٣), respectively:

$$P_{ULP} = \frac{0.163 \times 60 \times Q_{ULP} \times H_{ULP}}{0.8} \qquad \ldots(٤.١٨٢)$$

$$TP_{ULP} = P_{ULP} \times NU_{ULP} \qquad \ldots(٤.١٨٣)$$

٤.١٠ Sludge - Overflow Channel

For all package units, sludge - overflow channel is used to collect the sludge, overflow water, and wastewater of backwashing filter.

In the designed package plant, this channel is classified to two types:

١. Secondary sludge-overflow channel: it is used to carry the sludge, overflow water, and wastewater of backwashing filter from all package units to the main sludge-overflow channel as shown in Fig.(٤.١٧).

The number of this channel is equal to the number of package unit (NU$_{SSOC}$ = NUPAC.U) and the discharge is calculated from the following equation:

$$Q_{SSOC} = QPAC.U + Q_{BW} \qquad \ldots(٤.١٨٤)$$

The length of channel can be calculated from the following equation:

$$L_{SSOC} = LPAC.U + 1 \qquad \ldots(٤.١٨٥)$$

Secondary sludge-overflow channel is designed from the program of channel design to find its dimensions. The velocity of flow (V_{SSOC}) is checked at the minimum discharge ($Q_{SSOC} = Q_{CFS}$) .If (V_{SSOC}) value is less than $0.6\frac{m}{s}$, the slope of channel (*m/m*) is calculated from the following equation:

$$S_{SSOC} = \left[\frac{0.6 \times 0.013}{R_{SSOC}^{2/3}}\right]^2 \qquad ...(٤.١٨٦)$$

Thus, the head loss of channel can be calculated from the following equation:

$$HL_{SSOC} = S_{SSOC} \times L_{SSOC} \qquad ...(٤.١٨٧)$$

٢. Main sludge-overflow channel: it is used to carry the sludge, overflow water, and wastewater of backwashing filter from the secondary channels to the sludge pit or to the river as shown in Fig. (٤.١٧).

The number of channel is equal ($NU_{MSOC} = ١$), and the discharge is:
$$Q_{MSOC} = Q_{SSOC} \times NU_{SSOC} \qquad ...(٤.١٨٨)$$

The length of channel is calculated from the following equation:

$$L_{MSOC} = WPAC.U \times NUPAC.U + DSPAC.U \times (NUPAC.U - 1) + \frac{SP}{3} + \frac{1}{2}W_{SSOC} + DS_{SP}$$

$$...(٤.١٨٩)$$

The main sludge-overflow channel is designed from the program of channel design to find its dimensions. The velocity of flow is cheeked at the minimum discharge ($Q_{MSOC} = Q_{CFS}$). If (V_{MSOC}) value is less than $0.6\frac{m}{s}$, the slope of channel (*m/m*) is calculated from the following equation:

$$S_{MSOC} = \left[\frac{0.6 \times 0.013}{R_{MSOC}^{2/3}}\right]^2 \qquad ...(٤.١٩٠)$$

Thus, The head loss of channel can be calculated from the following equation:

$$HL_{MSOC} = S_{MSOC} \times L_{MSOC} \qquad \ldots(٤.١٩١)$$
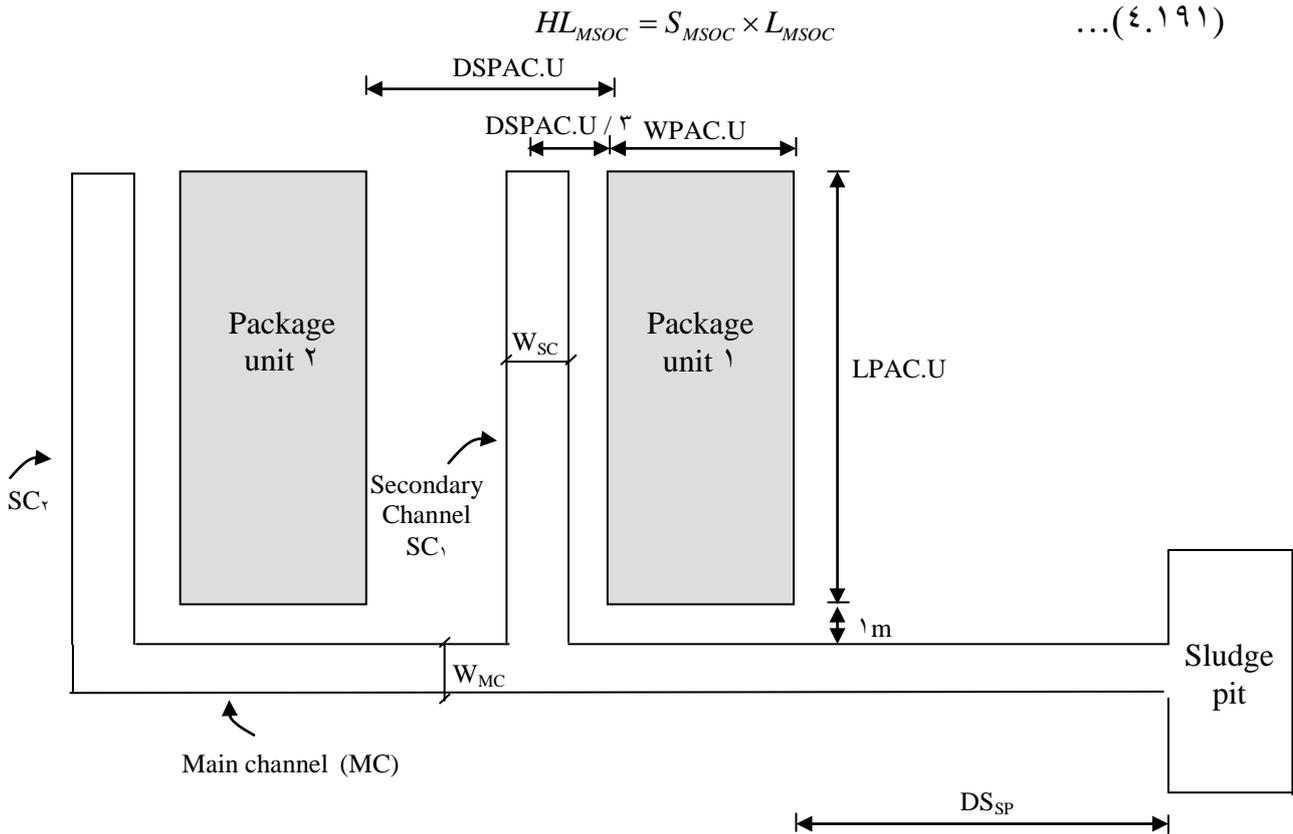
Fig.(٤.١٧): Plan of sludge-overflow channel for design capacities(١٤٠-

$$٢٠٠)m^{٣}/h$$

٤.١١ Alum Solution Tank

Alum is dissolved in cylindrical perforated basket which is located at the top of alum solution tank. Alum solution is delivered to the rapid mixing chamber by using the pumps which connect with pipes system as shown in Fig.(٤.١٨).

For one package unit (rapid mixing chamber), the following assumptions are used:

- The number of coagulation solution tank in service : $NU_{CST} = ١$
- The number of coagulation solution tank out of service: $NUO_{CST} = ١$

Thus, the total number of coagulation solution tank is calculated from the following equation:

$$NUT_{CST} = NU_{CST} + NUO_{CST} \qquad \ldots(٤.١٩٢)$$

In each $1 m^3$ of water, $10 g$ of alum is dissolved. If each $1000 m^3$ of raw water need $10 kg$ of alum solution as maximum limit, each $1 m^3$ of alum solution is sufficient to feed $1000 m^3$ of raw water. Thus, the discharge at alum solution tank (m^3/h) is calculated from the following equation:

$$Q_{CST} = \frac{QPAC.U}{1000} \qquad ...(4.193)$$

The retention time for coagulant solution tank is assumed as $(RT_{CST} = 0.5 hr)$ where alum is solid, thus the volume of alum solution tank (m^3) is :

$$VOL_{CST} = Q_{CST} \times RT_{CST} \qquad ...(4.194)$$

The depth of coagulation solution tank is assumed as $(D_{CST} = 0.8 m)$, then the area of tank is :

$$A_{CST} = \frac{VOL_{CST}}{D_{CST}} \qquad ...(4.195)$$

The coagulation solution tank used in the designed computer program is a cylindrical tank, therefore the diameter of this tank is calculated from the following equation:

$$DI_{CST} = \sqrt{\frac{4}{\pi} A} \qquad ...(4.196)$$

Coagulation solution tank contains mixer to accelerate the mixing process. This mixer is the same as the mixer used in rapid mixing chamber according to the type and design steps. The pipes system that connected with the alum solution tank include:

1. Main influent pipe: it carries water from the effluent pipe of filter to the alum solution tank. The number of this pipe for each package unit is $(NUP_{CSTI} = 1)$ and its length (m) is calculated the following equation:

$$PL_{CSTI} = \frac{WPAC.U}{2} + 0.5 + 1 + DI_{CST} \times 2 + (LPAC.U - 3 - \frac{DI_{CST}}{4}) + 0.75 \times DI_{CST} + 0.1$$

$$...(4.197)$$

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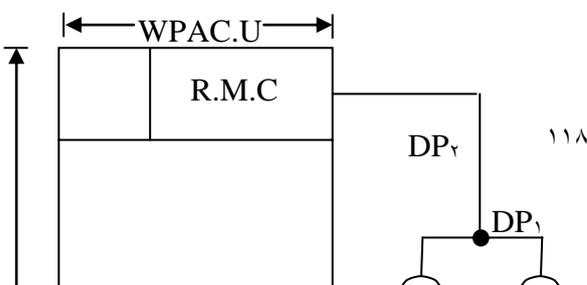
Fig.(٤.١٨) :Plan of Alum Solution System
Thus, the discharge of pipe (m^3/s) is :

$$PQ_{CSTI} = Q_{CST} / 3600 \qquad\qquad \ldots(٤.١٩٨)$$

The main influent pipe is designed from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: OU = ١, E٩ = ٢, TR = ١, and GT = ٢.

٢. Suction and delivery pipes with pumps to rise the alum solution from the tank to the rapid mix chamber which include:

A. Suction pipe (١): it carries the alum solution from the tank to the suction pipe (٢). The number of pipe in service is ($NUP_{CSTS(١)}$ = ١) and the number of pipe out of service is ($NUOP_{CSTS(١)}$ = ١) then the total number of pipe is:

$$TNUP_{CSTS\,(1)} = NUP_{CSTS\,(1)} + NUOP_{CSTS\,(1)} \qquad ...(٤.١٩٩)$$

The length of pipe (*m*) is calculated from the following equation:

$$PL_{CSTS\,(1)} = DI_{CST} + 0.5 \qquad ...(٤.٢٠٠)$$

The discharge of pipe ($m^٣/s$) can be calculated from the following equation:

$$PQ_{CSTS\,(1)} = PQ_{CSTI} \qquad ...(٤.٢٠١)$$

This pipe is designed from the program of pipe design as a pipe of pump to find the diameter and the head loss is calculated according to the number of fitting: ET = ١, E٩ = ١, and GT = ١.

B. Suction pipe (٢): it locates between the suction pipe (١) and the suction pipe (٣). The number of pipe is ($NUP_{CSTS(٢)}$ = ١) and the length to pipe (*m*) is assumed ($PL_{CSTS(٢)}$ = ٠.٥) discharge of pipe ($m^٣/s$) is calculated from the following equation:

$$PQ_{CSTS\,(2)} = PQ_{CSTS\,(1)} \qquad ...(٤.٢٠٢)$$

This pipe is designed as a pipe of pump from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: TR = ١, and GT = ١.

C. Suction pipe (٣): it connects directly with the pump after the suction pipe (٢). The number of pipe in the service is ($NUP_{CSTS(٣)}$ = ١) and

the number of pipe out of the service is ($NUOP_{CSTS(٣)} = ١$) then the total number is:

$$TNUP_{CSTS\,(3)} = NUP_{CSTS\,(3)} + NUOP_{CSTS\,(3)} \qquad …(٤.٢٠٣)$$

The length of one pipe is calculated from the following equation:

$$PL_{CSTS\,(3)} = DI_{CST} \qquad …(٤.٢٠٤)$$

The discharge of pipe can be calculated from the following equation:

$$PQ_{CSTS\,(3)} = PQ_{CST\,(2)} \qquad …(٤.٢٠٥)$$

This pipe is designed as a pipe of pump from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: $GT = ١$, and $E٩ = ١$.

D. Delivery pipe (١): it connects directly with a pump and it is the same as suction pipe (٣) in the number, the length, and the discharge. This pipe is designed as a pipe of pump from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: $GT = ١$, $E٩ = ١$, and $ET = ١$.

E. Delivery pipe (٢): it locates after the delivery pipe (١) where the alum solution is raised to the rapid mixing chamber. The number of pipe is ($NUP_{CSTD(٢)} = ١$) and its length is calculated from the following equation:

$$PL_{CSTD\,(2)} = 0.5 + (D_{CST} - 0.1) + D_{RMC} + D_{CFS} + 1.25 \qquad …(٤.٢٠٦)$$

The discharge of pipe ($m^٣/s$) is calculated from the following equation:

$$PQ_{CSTD\,(2)} = PQ_{CSTD\,(1)} \qquad …(٤.٢٠٧)$$

This pipe is designed as a pipe of pump from the program of pipe design to find the diameter and the head loss is calculated according to the number of fitting: $OU = ١$, $TR = ١$, $GT = ١$, and $E٩ = ٣$. The number of pump in the service is ($NUPUMP = ١$) and the number of pump out of the service is ($NUOPUMP = ١$) then the total number of pump is:

$$TNUPUMP = NUPUMP + NUOPMP \qquad …(٤.٢٠٨)$$

After calculation of head loss for all suction and delivery pipes of pump, the total head loss is calculated from the following equation:

$$TH_{CSTPUMP} = PHL_{CSTS\,(1)} + PHL_{CSTS\,(2)} + PHL_{CSTS\,(3)} + PHL_{CSTD\,(1)} + PHL_{CSTD\,(2)}$$

$$...(٤.٢٠٩)$$

The required power of pump (*m*) is:

$$H_{CSTP} = TH_{CSTPUMP} + TDRMC \qquad\qquad ...(٤.٢١٠)$$

With the efficiency ٨٠٪, the required power and the total power can be calculated from Eq. (٤.٢١١) and Eq. (٤.٢١٢), respectively:

$$P_{CSTP} = \frac{0.163 \times 60 \times Q_{CSTP} \times H_{CSTP}}{0.8} \qquad ...(٤.٢١١)$$

$$TP_{CSTP} = P_{CSTP} \times NUPUMP \qquad\qquad ...(٤.٢١٢)$$

٤.١٢ Additional Chlorine Dosage

Packed chlorine gas in special containers is used to add through the main suction pipe of high lift pump as a chlorination process. The chlorine injection dosage through this pipe is assumed ٦ *ppm*, then the additional chlorine dose (*kg/hr*) is:

$$CDS = \frac{Q_{LLP} \times 3}{1000} \qquad\qquad ...(٤.٢١٣)$$

In the designed computer program, the following assumptions are adopt :

- The number of chlorine feeder in the service : NUC = ٢
- The number of chlorine feeder out of the service : NUOC = ١

The total number of chlorine feeder in a pre-chlorination system is:

$$NUTC = NUC + NUOC \qquad\qquad ...(٤.٢١٤)$$

The size of chlorine feeder is calculated from the following equation:

$$QC = \frac{NUTC}{2} \qquad\qquad ...(٤.٢١٥)$$

CHAPTER FIVE

RISULTS AND DISCUSSION

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER FIVE
RESULTS AND DISCUSSION

٥.١ Input Data

The results of this chapter include two different cases of package water treatment plants design by using (٥٠, and ٢٠٠) m^3/h as a capacities with the following design criterias:

1. Maximum temperature occur in (C°) is equal to ٤٥° .
2. Minimum temperature occur in (C°) is equal to ٥° .
3. River water depth in (*m*) is equal to ٧ .
4. Minimum river water depth in (*m*) is equal to ٥ .
5. River width in (*m*) is equal to ٢٠ .
6. River bottom width in (m) is equal to ١٠ .
7. Low lift pump station distance from the river shoulder in (*m*) is equal to ١٢ .
8. Spacing between package unit in (*m*) is equal to ٣ .
9. Distance from the last package unit to the sludge pit in (*m*) is equal to ١٠ .
10. Vertical distance between package units and low lift pump station in (*m*) is equal ١.٥ .
11. Spacing between package units and clear-back wash storage tank in (*m*) is equal to ٧ .
12. Vertical distance between clear-back wash storage tank and high lift pump station in (*m*) is equal to ١.٥ .
13. Elevation of project from river in (*m*) is equal to ٣ .
14. Elevation of project in (*m*) is equal to ١٠٠ .
15. Net-work serve head in (*m*) is equal to ٢٠ .
16. Net-work elevation in (*m*) is equal to ٩٥ .

٥.٢ **Results and Discussion**

The results of the present study that shown in Tables below will not list all informations in details as the output data of designed computer program. The results give important informations to show the variation in units size with the variation of package plant capacity. To show all design informations in details, the designed computer program as presented in the appendix can be applied.

٥.٢.١ **Desgin Results of Rapid Mixing Unit**

Table (٥.١) lists the design data results of rapid mixing chamber according to the designed capacities as shown in column (٢). Column (٣) represents the passing discharge through the rapid mixing chamber in which the passing discharge equal to the discharge of one package unit. It is necessary to note that the number of rapid mixing chamber increases with increasing the designed capacities. The number of rapid mixing chamber is equal to the number of package unit as shown in column (٤). Column (٥) represents the retention time of the rapid mixing chamber where this time is remained constant for these cases and stayed in the acceptable limits (٠.٥-١.٥) *min*. Columns (٦,٧,٨, and ٩) represent the dimensions of the rapid mixing chamber where they are differed according to the designed capacities. Columns (١٢,١٣) represent the dimensions of inlet of the package unit where these dimensions depend on the dimensions of rapid mixing chamber. Columns (١٤,١٥, and ١٧) represent the dimensions of inlet and outlet opening of rapid mixing chamber .

Table (٥.٢) lists the design data results of rapid mixer where the rapid mixing chamber contains one mixer as shown in column (٤). Columns (٥,٦, and ٧) represent the propeller diameter, the height of propeller from bottom of rapid mixing chamber, and the shaft diameter respectively where these parameters depend on the dimensions of the

rapid mixing chamber. Columns (٨) represents the number of blades of one mixer which is constant for all cases. Columns (٩) represents the width of blades which depends on the diameter of propeller. Column (١٠) represents the required power of mixer which depends on the dimensions of propeller and the rotational speed of mixer as shown in column (١١). Column (١٢) represents the velocity gradient of mixing where it is in acceptable limits (٣٠٠-١٠٠٠).

٥.٢.٢ Design Results of Flocculation Unit

Table (٥.٣) lists the results of flocculation basin design. Column (٣) represents the passing discharge of package unit through the flocculation basin. Column(٤) represents the number of flocculation basin in package plant which is equal to the number of package unit. Column (٥) represents the number of slow mixing chamber of flocculation tank in one package unit which depends on the designed capacities and the retention time of flocculation basin. Columns (٦,٧ ,and ٨) represent the dimensions of one slow mixing chamber of flocculation basin which depend on the design capacities and the dimensions of one package unit. Column (٩) represents retention time of one slow mixing chamber which is equalized for all slow mixing chambers in flocculation basin and in acceptable limits (٥-٢٠) *min*. Columns (١٠,١١,١٢, and ١٣) represent the dimensions of flocculation tank per one package unit which depend on the design capacities and the dimensions of slow mixing chamber. Column (١٤) represents the retention time of flocculation basin which equals to the summations of the retention times for all slow mixing chamber in flocculation basin per package unit and depends on the designed capacities and the retention time of slow mixing chambers. This time is in acceptable limits (٥-٢٠) *min* .

Table (٥.٤) lists the design data results of the tapered slow mixer. Columns (٤, and ٥) represent the diameter of the first slow mixer which depend on the width of slow mixing chamber (width of package unit),

and the length of blades for this mixer respectively. Columns (٦, and ٧) represent the number of dual impeller blades and the number of blades for the first mixer which remain constant in these cases because the area of mixer is in the acceptable limit (٢٠% of the slow mix chamber area). Column (٨) represents the required power for the first mixer. Column (١٠) represents the velocity gradient of the first slow mixing where it is in the acceptable limits (٢٠-٧٥)s^{-1}. Columns (١١, and ١٢) represent the diameter of the second slow mixer and the length of blade for this mixer respectively. These values are same of the values of first slow mixing chamber (columns (٤, and ٥)) because the two mixing chambers have the same dimensions. Columns (١٣, and ١٤) represent the number of dual impeller blade and the number of blades for the second slow mixer. These values are same of the values of the first slow mixer because the two mixing chambers have the same dimensions. Columns (١٥,١٦, and ١٧) represent the required power, revolution per minute, and the velocity gradient respectively. For the second slow mixer, these values are in the acceptable limits and they are smaller than the values of the first slow mixer columns (٨,٩, and ١٠) to increase the floc size .

٥.٢.٣ Design Results of Settling Unit

Table (٥.٥) lists the results of settling chamber with lamella plates where the discharge and the number of this chamber are equal to the discharge and the number of package unit as shown in the columns (٣, and ٤). Columns (٥, and ٦) represent the apparent surface over flow rate (designed surface over flow rate for this chamber with lamella plates) where it is in the acceptable limits (٢٠-٦٠) *m/h* and the actual surface over flow rate for the particles where is in the acceptable limits (٢-٥) *m/h* respectively. Column (٧) represents the retention time for this chamber with lamella plates where it is in acceptable limit (< ١٥ *min*) for two cases. Columns (٨,٩,١٠,١١, and ١٢) represent the dimensions of settling chamber where the width and length (columns (٨, and ٩)) for this

chamber are equal to the width of package unit. Columns (١٣,١٤ and ١٥) represent the dimensions of lamella plates in this chamber. Column (١٦) represents the number at lamella plates of the settling chamber. Column (١٧) represents the spacing between the lamella plates where it is constant in these cases and in the acceptable limits ($٠.٠٤ < S_{LAM} < ٠.١$). Column (١٨) represent the angle of inclination for the lamella plates where it is constant in these cases and in the acceptable limits ($> ٤٠°$). Columns (١٩, and ٢٠) represent the required and provided area for this chamber respectively. In these cases, the provided area larger than the required area.

Table (٥.٦) lists the results data for the effluent channel (effluent launder) of setting chamber with V-notch weir. Column (٣) represents the discharge that passed through this channel where is equal to the discharge of one package unit. Column (٤) represents the number of effluent channel which depends on the loading weir of setting chamber. In these cases, the number of effluent channel is constant. Columns (٥,٦,٧, and ٨) represent the dimensions of the effluent channel. Column (٩) represents the slope of the channel. Column (١٠) represents the number of weir per one channel where it is depended on the design capacities and the length of effluent channel. Column (١١) represents the width of weir where it is constant for all cases. Column (١٢) represents the height of V-Notch weir. Column (١٣) represents the loading weir where it is in the acceptable limits $(120 – 380)\dfrac{m3}{m.day}$ for these cases.

٥.٢.٤ Design Results of Sludge Hopper

Table (٥.٧) lists the results data of the sludge hopper. Column (٤) represents the discharge of the sludge hopper where it is depended on the discharge of one package unit. Column (٥) represents the number of the sludge hopper of one package unit where it is constant for all cases. Column (٦) represents the width of the sludge hopper where it is depended on the discharge of one package unit (column (٣)). Column (٧)

represents the depth of the sludge hopper where it is constant for all cases. Column (٨) represents the length of hopper where it changes according to the dimensions of rapid mixing chamber, flocculation basin, and the settling chamber of one package unit.

٥.٢.٥ Design Results of Sludge Pipes

Table (٥.٨) lists the design data results for the sludge pipes. Column (٤) represent the number of the sludge pipes per one package unit where they distributed in the rapid mixing chamber flocculation basin, and the settling chamber. Column (٥) represents the diameter of this pipe where it depends on the water discharge (column (٦)), friction factor (column (٧)), velocity through this pipe (column (٨)), and the head loss of this pipe (column (٩)). Column (١٠) represents the length of sludge pipe where it depends on the discharge of one package unit, the width of package unit, and the spacing available between the package units. Columns (١١,١٢,…, and ١٩) represent the appurtenances of sludge pipe.

٥.٢.٦ Design Results of Collection Unit

Table (٥.٩) lists the design data results for the collection basin. Column (٤) represents the number of collection basin of package plant where it depends on the design capacities. Columns (٥,٦,٧, and ٨) represent the dimensions of collection basin where they depend on the discharge of one package unit. Column (٩) represents the retention time of this basin and this time is assumed to be constant for all cases .

Table (٥.١٠) lists the design data results for vertical over flow pipe. Column (٤) represents the number of pipe of collection basin. Column (٥) represents the diameter of this pipe where it depends on the discharge that passed through this pipe (column (٦)), the friction factor of this pipe (column (٧)), the velocity through this pipe (column (٨)) and the

head loss of this pipe (column (٩)). Column (١٠) represents the length of this pipe where it depends on the depth of collection basin and the spacing between package unit. Columns (١١, ١٢,…, and ١٩) represent the appurtenances of this pipe .

٥.٢.٧ Design Results of filtration Unit

Table (٥.١١) lists the design data results of filter basin. Column (٤) represents the number of filter basin of package plant where it depends on the design capacities. Column (٥) represents the filtration rate of filter where it is in acceptable limit of rapid sand fitter $(7-15)\dfrac{m^2}{m}/h$. Columns (٦,٧, and ٨) represent the width of filter where it is equal to the width of the package unit, the length of filter, and the total depth of filter respectively .

Table (٥.١٢) lists the design data results for the dimensions of underdrain system. Columns (٥,٦, and ٧) represent the length, the width, and the block depth of underdrain system (Leopold type). These are constant in all cases. Columns (٨ and ٩) represent the number of orifices and the diameter of orifices of the block of Leopold type respectively. In all cases, these dimensions are constant. Columns (١٠, and ١١) represent the number and the diameter of control orifice of the block of Leopold type respectively .These are constant in all cases. Columns (١٢, and ١٣) represent the discharge of orifice and control orifice of the block of Leopold type during the filtration process.

Table (٥.١٣) lists design data results of the head loss that occurs with filter run. Columns (٥,٦, and ٧) represent the head loss of the sand media, the anthracite media, and the gravel media respectively. The columns (٨, and ٩) represent the head loss of orifices and the control orifices of the underdrain system. Column (١٠) represents the total head loss where it represents the height of water above the filter media.

Table (٥.١٤) lists the design data results of values of backwashing rate as shown in column (٨). The backwashing rate is same in all cases because the filter media used is same in all cases. In all cases, the backwashing rate value increases while the temperature (column (٤)) increases, therefore the expansion ratio also increases. In the design equations, the relationships between the kinematics viscosity and the fluidized velocity (column (٥) where it is depended to calculate the backwashing rate) is contrary then the relationship between the viscosity and the temperature is contrary too and the fluidized velocity increases when the temperature increases, therefore the backwashing rate increases. Columns (٦, and ٧) represent the Reynold numbers. Column (٩) represents the value of void ratio during the backwashing process ,it is the nearest to a value of (٠.٧) where the water is used for backwashing process only (used in the present study). Columns (١٠,١١,١٢, and ١٣) represent the expansion depth and the expansion ratio that occur through the sand and anthracite medias respectively. Columns (١٤, and ١٥) represent the total expansion depth and the total expansion ratio for the dual media during the backwashing process respectively. The total expansion ratio is in acceptable limits (١٠-٢٠)% to produce good backwashing where the water is used only.

Table (٥.١٥) lists the design data results for the head losses which occur with filter backwashing run. Column (٣) represents the maximum and minimum temperatures that should be taken as a base for comparison purpose between the design data results because the backwashing rate (column ٥) is constant for all cases. Columns (٦,٧, and ٨) represent the head losses of sand layer, anthracite layer, and the gravel support during the backwashing process respectively. The sand and anthracite medias are not effected with the variation of temperature because the parameters of the design equations are not depended on the temperature while the head loss during the gravel support is effected by the variation of temperature because the changing that occur in the value of kinematics viscosity.

Column (٩) represents the total head losses during the orifices and control orifices of the underdrain system .The head loss of underdrain system effects by the variation of temperature because this value depends on the value of the backwashing rate. Columns (١٠,١١, and ١٢) represent the discharge, the head loss, and the slope of the primary feeder channel for backwashing water. These values effect with the different of backwashing rate. Column (١٣) represents the pressure balance value between primary feeder channel and the control orifices. These values are in acceptable limit (<٠.٠١) to produce the required balancing. Column (١٤) represents total static head of water above the bottom of filter basin where it represents the height of wash water trough. Column (١٥) represents the total pressure head that occur with filter backwashing run where it is in acceptable limit (> ٣*m*) to produce good backwashing of filter media.

Table (٥.١٦) lists the design data results for wash water trough. Column (٥) represents the spacing between troughs. Column (٦) represents the number of trough per one filter. In the first case, there is one trough in filter because the spacing between the troughs is larger than the length of filter. Column (٧) represents the discharge of one trough where it depends on the discharge of backwashing water. Columns (٨,٩, and ١٠) represent the width, depth, and the slope of the trough respectively .

Table (٥.١٧) lists the design data results for backwashing pipes system. Pipes system (١) represents the main suction pipe where it connects with the storage tank. Pipes system (٢) represents the secondary suction-delivery pipes. Pipes system (٣) represents the main delivery pipe where it connects with the effluent pipe of filter. Column (٤) represents the number of pipes in each pipes systems. Column (٥) represents the diameter of pipe where it depends on the discharge that passed through this pipe (column (٦)), the friction factor (column (٧)), the velocity through this pipe (column (٨)), and the head losses (column (٩)) for each

pipes system. Column (١٠) represents the length of pipe where it depends on the available spacing between package units and the storage tanks

Table (٥.١٨) lists the design data results for backwashing pump. Column (٤ and ٥) represent the number of backwashing pumps are in service, and the pumps are out of service respectively. Column (٦) represents the discharge of each pump where it depends on the discharge of backwashing water. Column (٧) represents the total required pressure head where it equals to the total head losses of backwashing pipes system. Column (٨) represents the required power of each pump

Table (٥.١٩) lists the design data results for backwashing waste waster pipe where it connects with the backwashing trough. Column (٤) represents the number of pipe where it depends on the number of backwashing trough per one filter of package unit. Column (٥) represents the diameter of pipe where it depends on the discharge of pipe (column (٦)), the friction factor (column (٧)), the velocity of flow through this pipe (column (٨)), and the head losses of pipe (column (٩)). Column (١٠) represents the length of pipe where it depends on the total static head that occurs above the bottom of filter basin and the spacing between the package units.

Table (٥.٢٠) lists the design data results of backwash procedure. Column (٤) represents the discharge of backwashing water for each filter. Column (٥) represents the period of backwashing for each filter. Column (٦) represents the time of washing for the filter.

٥.٢.٨ Design Results of Package Units

Table (٥.٢١) lists the design data results of the package units. Column (٤) represents the number of package units in plant where it is depended on the designed capacities. Column (٥) represents the width of package unit. Column (٦) represents the length of package unit where it is equal to the summation of the width of rapid mixing chamber, the length

of flocculation basin, the length settling chamber, the length of collection basin, and the length of filter.

٥.٢.٩ Design Results of Low Lift Pumping Station

Table (٥.٢٢) lists the suction and delivery pipes for low lift pump. Columns (١١, and ١٢) represent the diameter of connection pipes between the pumps where it depends on the discharge that passed through these pipes. Columns (٨, and ٩) represent the velocity of flow of the pipe and the head losses of the pipe where these values are large because these pipes are considered the pipes of pump. Column (١٠) represents the length of pipe where it depends on the available servicing area for low lift pump station.

Table (٥.٢٣) lists the design data results of low lift pump. Columns (٤, and ٥) represent the number of pumps are in service and the pumps are out of service respectively where they depend on the design capacities of the package plant (column (٢)). Column (٦) represents the discharge of pump. Column (٧) represents the total pressure head where it equals to the head loss of suction-delivery pipes. Column (٨) represents the required power for each pump where it increases by increasing the required pressure and the discharge that passed through the pump.

٥.٢.١٠ Design Results of Coagulation Solution Unit

Table (٥.٢٤) lists the design data results of coagulation solution tank. Column (٤) represents the discharge of coagulation solution tank per one package unit where it depends on the design capacities (column (٢)) and the discharge of one package unit (column (٣)). Columns (٥, and ٦) represent the number of the tank are in service, and the tank are out of service per one package unit respectively. Columns (٧, and ٨) represent the dimensions of the tank. Column (٩) represents the retention time of the tank and it was assumed constant for all cases. Column (١٠) represents the diameter of influent pipe of the tank and suction-delivery

pipes that concocted with the coagulation solution pumps (more details can be noted by applying the designed computer program).

٥.٢.١١ Design Results of Clear-Backwash Storage Unit

Table (٥.٢٥) lists the design data results of clear-backwash storage tank. Column (٤) represents the discharge of the storage tank where it depends on the discharge of one package unit and the discharge of backwashing water. Column (٥) represents the number of the tank where it equals to the number of package unit. Column (٦,٧,٨, and ٩) represent the dimensions of the tank where they depend on the discharge of package unit. The depth of the tank is assumed constant for all cases (column (٨)). Column (١٠) represents the retention time of the tack. It assumes constant for all cases .

Table (٥.٢٦) lists the design data results of the influent pipe of clear-backwashing storage tank (effluent pipe of filter). Column (٤) represents the number of pipe where it equals to the number of package unit. Column (٥) represents the diameter of pipe where it depends on the discharge that passed through this pipe (column (٦)), the friction factor (column (٧)), the velocity through it (column (٨)), and the head loss of this pipe (column (٩)). Column (١٠) represents the length of pipe where it depends on the spacing distance between the package unit and storage tank.

٥.٢.١٢ Design Results of High Lift Pumping Station

Table (٥.٢٧) lists the design data results for suction and delivery pipes of high lift pumping station. The diameter of main suction pipe (MC) equals to the diameter of main delivery pipe (MD) in all cases where the characteristics of the these pipes are equalized such as: friction factor (column (٧)), and the velocity through these pipes (column (٨)) because the same discharge passes through these pipes (column (٦)) and the same pipe length (column (١٠)). The head loss of the suction pipe

is more than the head loss of delivery pipe (column (١٩)) because the minor losses of the suction pipe is more than the delivery pipe (columns (١٣,١٤, and ١٨)). SS١ represents the suction pipe system (١) where it connects with the storage tank and it carries the water to the SS٢. SS٢ represents the suction pipe system (٢) where it carries the clear water from SS١ to MS. The number of these pipes depends on the design capacities and the number of package units. In the first case, this pipe not found (column (٤)) because the number of package unit equals to one .

Table (٥.٢٨) lists the design results of high lift pump. Columns (٤, and ٥) represent the number of pump are in service, and the pumps are out of service respectively where they depend on the design capacities (column (٢)) and the number of package units. Column (٦) represents the discharge of one pump. Column (٧) represents the total required pressure head for one pump. Column (٨) represents the required power of pump.

٥.٢.١٣ Design Results of Sludge-Overflow Channels

Table (٥.٢٩) lists the design data results of the main and secondary sludge-over flow channels. Column (٥) represents the discharge of the main and secondary channels where it is depended on the designed capacities (column (٢)). Column (٦) represents the number of channels per plant where it depends on the designed capacities and the number of package units. Column (٧,٨,٩,١٠, and ١١) represent the dimensions of the channels. Column (١٢) represents the slope of channels.

٥.٢.١٤ Design Results of Chlorine Dosages

Table (٥.٣٠) lists the design data results for pre and post chlorine dosages. Column (٤) represents the discharge that passed through the main suction pipe of high lift pumping station where the chlorine feeder is connected with this pumping station. Column (٥) represents the

chlorine dosage where it adds to the main suction pipe of high lift pumping station.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

٦.١ Conclusions

The following conclusions are obtained:

١. The program is easy in the selection of the number of basins, the number of pipes, and solving all the problems that may be obtained with running of the program such as closed loops, frequency, and divergence of the objective.

٢. The design factors that was used in the designed computer program (١, and ٧٠) are a suitable method to determine the number of package units.

٣. The time required to run the computer program is very short (about ١٠ *min*) and this will assist to test the different design capacities within the limits.

٤. The filtration rates are high (١٢.١٠٩ - ١٢.٢٠٦) *m/h* and the backwashing rates are high too (١٧.٩٤ - ٢٨.٧٤) *m/h*, therefore the production of the project will increase with high filtration rates due to the reduction in filtration time and then less cost.

٥. The discharge of orifices and control orifices for underdrain system(Leopold type) is not effected with variation of temperatures during the filtration process.

٦. The diameters of all pipes in the designed package water treatment plants are standard and are between (١-١٠)*In* where are applicated in practice.

٦.٢ Recommendations for Further Studies

The following recommendations may be taken in to consideration for further studies:

١. Development of a design computer program to design primary settling basin with pipes system.

٢. For comparison purpose, it is necessary to make further study used tubes settler instead of lamella plates and study the settling efficiency according to these tubes.

٣. Using pressure filters instead of gravity filters and studying the effect of these fitters on the performance of package plant as well as can be using additional filters with activated carbon media to remove the organic materials that increased in the rivers of Iraq.

٤. Development a system to resist the hydraulic force that obtained in the high lift pumping station.

٥. Development a design computer program by using additional basins with caustic soda solution to correct the PH values of clear water.

٦. Development a design computer program by using another package units shapes such as concentric shapes and using visual basic instead of quick basic language to draw the resultants in AutoCAD programs.

Table (٥.١) : Design results of rapid mixing chamber

Case (١)	Qcap (m³/h) (٢)	Q$_{RMC}$ (m³/h) (٣)	NU$_{RMC}$ (٤)	RT$_{RMC}$ (min) (٥)	W$_{RMC}$ (m) (٦)	L$_{RMC}$ (m) (٧)	D$_{RMC}$ (m) (٨)	TD$_{RMC}$ (m) (٩)	WI (m) (١٠)	LI (m) (١١)	DOI (m) (١٢)	WOI (m) (١٣)	DOO (m) (١٤)	WOO (m) (١٥)
١	٥٠	٥٠	١	١	٠.٦٣٨	٠.٩٥٨	١.٢٧٧	١.٥٢٧	٠.٤٧٩	٠.٤٧٩	٠.٣١٩	٠.٦٣٨	٠.١٥٩	٠.٩٥٨
٢	٢٠٠	١٠٠	٢	١	٠.٨٠٤	١.٢٠٧	١.٦٠٩	١.٨٥٩	٠.٦٠٣	٠.٦٠٣	٠.٤٠٢	٠.٨٠٤	٠.٢٠١	١.٢٠٧

Table (٥.٢) : Design results of rapid mixer

Case (١)	Qcap (m³/h) (٢)	Q$_{RMC}$ (m³/h) (٣)	NU$_{MIXER}$ (٤)	PD (m) (٥)	PHI (m) (٦)	SD (m) ×١٠⁻² (٧)	NU$_{BP}$ (٨)	W$_{BP}$ (m) ×١٠⁻² (٩)	P (w) (١٠)	RPM (١١)	G (s⁻¹) (١٢)
١	٥٠	٥٠	١	٠.٢١٣	٠.٦٣٨	٢.٦٦٠	٤	٤.٢٥٧	٣٩٩.٢٧٧	١٠٠٠	٥٥٦.٢٦٣
٢	٢٠٠	١٠٠	١	٠.٢٦٨	٠.٨٠٤	٣.٣٥٢	٤	٥.٣٦٤	١٢٦٧.٦٢٥	١٠٠٠	٨٢٦.٨٣٩

Table (٥.٣) : Design results of flocculation basin

Case (١)	Qcap (m³/h) (٢)	Q$_{FT}$ (m³/h) (٣)	NU$_{FT}$ (٤)	NU$_{SMC}$ (٥)	W$_{SMC}$ (m) (٦)	D$_{SMC}$ (m) (٧)	L$_{SMC}$ (m) (٨)	RT$_{SMC}$ (min) (٩)	W$_{FT}$ (m) (١٠)	L$_{FT}$ (m) (١١)	D$_{FT}$ (m) (١٢)	TD$_{FT}$ (m) (١٣)	RT$_{FT}$ (min) (١٤)
١	٥٠	٥٠	١	٢	١.٤٣٧	١.٢٧٧	٢.٨٧٤	٦.٣٢٨	١.٤٣٧	٥.٧٤٧	١.٢٧٧	١.٥٢٧	١٢.٦٥٦
٢	٢٠٠	١٠٠	٢	٢	١.٨١٠	١.٦٠٩	٣.٦٢٠	٦.٣٢٨	١.٨١٠	٧.٢٤١	١.٦٠٩	١.٨٥٩	١٢.٦٥٦

Table (٥.٤) : Design results of tapered slow mixing chamber

Case (١)	Qcap (m³/h) (٢)	NU_SMC (٣)	DI_SMC١ (m) (٤)	L_B١ (m) (٥)	NUI_PAIR١ (٦)	NU_BS١ (٧)	P_SMC١ (w) (٨)	RPM_SMC١ (٩)	G_SMC١ (s⁻¹) (١٠)	DI_SMC٢ (m) (١١)	L_B٢ (m) (١٢)	NUI_PAIR٢ (١٣)	NU_BS٢ (١٤)	P_SMC٢ (w) (١٥)	RPM_SMC٢ (١٦)	G_SMC٢ (s⁻¹) (١٧)
١	٥٠	٢	١.١	٠.٧٧٧	٢	١٦	٦٤.٨٩	٦	٣٧.١٨٣	١.١	٠.٧٧٧	٢	١٦	٤٩.٩٨	٥.٥	٣٢.٦٣٣
٢	٢٠٠	٢	١.٤	١.١٠٩	٢	١٦	١٧٨.٥١	٦	٤٣.٦٠٩	١.٤	١.١٠٩	٢	١٦	١٣٧.٤٩	٥.٥	٣٨.٢٧٣

Table (٥.٥) : Design results of settling chamber with lamella plates

Case (١)	Qcap (m³/h) (٢)	Q_SC (m³/h) (٣)	NU_SC (٤)	SOR_AP (m/h) (٥)	SOR_AC (m/h) (٦)	RT_sc (min) (٧)	W_SC (m) (٨)	L_SC (m) (٩)	TL_SC (m) (١٠)	D_SC (m) (١١)	TD_SC (m) (١٢)	H_LAM (m) (١٣)	L_LAM (m) (١٤)	W_LAM (m) (١٥)	NU_LAM (١٦)	S_LAM (m) (١٧)	α (DEG) (١٨)	A_RE (m²) (١٩)	A_PR (m²) (٢٠)
١	٥٠	٥٠	١	٢٤.٩٣٦	٣.٨٨٨	١.٢٥٧	١.٤٣٧	١.٤٣٧	١.٧٢٤	١.٢٧٧	١.٥٢٧	٠.٦٣٨	٠.٨٣٤	١.٤٣٧	٢٤	٠.٠٦٠	٥٠	٢.٠٠٥	٢.٠٦٤
٢	٢٠٠	١٠٠	٢	٣٨.٦١١	٤.٧٧٨	١.٠٥٠	١.٨١٠	١.٨١٠	٢.١٧٢	١.٦٠٩	١.٨٠٩	٠.٨٠٤	١.٠٥٠	١.٨١٠	٣١	٠.٠٦٠	٥٠	٢.٥٩٠	٣.٢٧٧

Table (٥.٦) : Design results of effluent channel of settling chamber with V-Notch weir

Case (١)	Qcap (m³/h) (٢)	Q_SC (m³/h) (٣)	NU_ECH (٤)	W_ECH (m) (٥)	L_ECH (m) (٦)	D_ECH (m) (٧)	TD_ECH (m) (٨)	FHL_ECH ×10⁻³ (m/m) (٩)	NU_W (١٠)	W_W (m) (١١)	H_W ×10⁻² (m) (١٢)	LOAD_W (m³/m/day) (١٣)
١	٥٠	٥٠	٢	٠.١٢٠	١.٤٣٧	٠.١١٩	٠.١٤٩	٣.٤٥٥	٢٨	٠.١٠٠	٢.٥٠٤	٢٠٨.٧٩٣
٢	٢٠٠	١٠٠	٢	٠.١٦٠	١.٨١٠	٠.١٥٨	٠.١٩٣	٣.٠٢٢	٣٦	٠.١٠٠	٢.٩٨٨	٣٣١.٤٣٨

Table (٥.٧) : Design results of sludge hopper

Case (١)	Qcap (m³/h) (٢)	Q_PAC.U (m³/h) (٣)	Q_HOPPER (m³/h) (٤)	NU_HOPPER (٥)	W_HOPPER (m) (٦)	D_HOPPER (m) (٧)	L_HOPPER (m) (٨)
١	٥٠	٥٠	١٠	١	٠.٦١٣	٠.٥٠٠	٨.١١٠
٢	٢٠٠	١٠٠	٢٠	١	٠.٩٦٠	٠.٥٠٠	١٠.١٢٨

Table (٥.٨) : Design results of sludge pipes

	Pipe									Appurtenances								
Case (١)	Qcap (m³/h) (٢)	Q_PAC.U (m³/h) (٣)	NU_P (٤)	DM_P (in) (٥)	Q_P ×10⁻³ (m³/s) (٦)	F ×10⁻² (٧)	V_P (m/s) (٨)	HL_P (m) (٩)	L_P (m) (١٠)	ET (١١)	BV (١٢)	OU (١٣)	T٩T (١٤)	E٩ (١٥)	E٦ (١٦)	CV (١٧)	GV (١٨)	AA (١٩)
١	٥٠	٥٠	٣	٤	٤.٦٣٠	٢.١٩٨	٠.٥٧١	٠.١٠٢	١.٥٣٧	١	٠	١	٠	١	٠	٠	١	٠
٢	٢٠٠	١٠٠	٣	٤	٩.٢٥٩	٢.١٨١	١.١٤٢	٠.٤٠٩	١.٥٥١	١	٠	١	٠	١	٠	٠	١	٠

Table (٥.٩) : Design results of collection basin

Case (١)	Qcap (m³/h) (٢)	Q_PAC.U (m³/h) (٣)	NU_CT (٤)	W_CT (m) (٥)	L_CT (m) (٦)	D_CT (m) (٧)	TD_CT (m) (٨)	RT_CT (min) (٩)
١	٥٠	٥٠	١	١.٤٣٧	٠.٩٠٠	١.٧٧٧	١.٨٧٨	٢.٥٠٠
٢	٢٠٠	١٠٠	٢	١.٨١٠	٢.١٠٠	٢.١٠٩	٢.١٦٦	٢.٥٠٠

Table (٥.١٠) : Design results of vertical over flow pipe

	Pipe									Appurtenances								
Case (١)	Qcap (m³/h) (٢)	$Q_{PAC.U}$ (m³/h) (٣)	NU_P (٤)	DM_P (in) (٥)	Q_P ×١٠⁻³ (m³/s) (٦)	F ×١٠⁻² (٧)	V_P (m/s) (٨)	HL_P (m) (٩)	L_P (m) (١٠)	ET (١١)	BV (١٢)	OU (١٣)	T٩T (١٤)	E٩ (١٥)	E٦ (١٦)	CV (١٧)	GV (١٨)	AA (١٩)
١	٥٠	٥٠	١	٤	١.٣٨٩	٢.١٧٥	١.٧١٣	٠.٤٠١	٢.٧٢٩	١	٠	١	٠	٢	٠	٠	١	٠
٢	٢٠٠	١٠٠	١	٦	٢.٧٧٨	١.٧٣٦	١.٥٢٣	٠.٢٨٩	٣.٠١٧	١	٠	١	٠	٢	٠	٠	١	٠

Table (٥.١١) : Design results of filter basin

Case (١)	Qcap (m³/h) (٢)	$Q_{PAC.U}$ (m³/h) (٣)	NU_{FL} (٤)	FR_{FL} (m²/m/h) (٥)	W_{FL} (m) (٦)	L_{FL} (m) (٧)	TD_{FL} (m) (٨)
١	٥٠	٥٠	١	١٢.١٠٩	١.٤٣٧	٤.٩٠٠	٢.٧٥٠
٢	٢٠٠	١٠٠	٢	١٢.٢٠٦	١.٨١٠	٨.٦٠٠	٢.٧٥٠

Table (٥.١٢) : Design results of underdrain system (Leopold type)

Case (١)	Qcap (m³/h) (٢)	$Q_{PAC.U}$ (m³/h) (٣)	T (C°) (٤)	L_B (m) (٥)	W_B (m) (٦)	D_B (m) (٧)	NU_O (٨)	DM_O (m) (٩)	NU_{CO} (١٠)	DM_{CO} (m) (١١)	Q_O ×١٠⁻⁵ (m³/s) (١٢)	Q_{CO} ×١٠⁻⁴ (m³/s) (١٣)
١	٥٠	٥٠	٤٥	١.٠	٠.٢٧٩	٠.١٢٥	١٩٤	٠.٠٠٦	٢١.٥	٠.٠١٥	١.٧٣٣	١.٥٦٤
٢	٥٠	٥٠	٥	١.٠	٠.٢٧٩	٠.١٢٥	١٩٤	٠.٠٠٦	٢١.٥	٠.٠١٥	١.٧٣٣	١.٥٦٤

| ٣ | ٢٠٠ | ١٠٠ | ٤٥ | ١.٠ | ٠.٢٧٩ | ٠.١٢٥ | ١٩٤ | ٠.٠٠٦ | ٢١.٥ | ٠.٠١٥ | ١.٧٤٨ | ١.٥٧٧ |
| ٤ | ٢٠٠ | ١٠٠ | ٥ | ١.٠ | ٠.٢٧٩ | ٠.١٢٥ | ١٩٤ | ٠.٠٠٦ | ٢١.٥ | ٠.٠١٥ | ١.٧٤٨ | ١.٥٧٧ |

Table (٥.١٣) : Design results of Head loss occur with filter run

Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	FR_{FL} (m³/m/h) (٤)	HL_{SM} (m) (٥)	HL_{TSM} (m) (٦)	HL_{GM} ×١٠⁻² (m) (٧)	HL_O ×١٠⁻² (m) (٨)	HL_{CO} (m) (٩)	THL (m) (١٠)
١	٥٠	٥٠	١٢.١٠٩	٠.٥١٧	٠.٥٨١	١.٠٥١	٥.٣٠٠	٠.١١١	١.٢٧٣
٢	٢٠٠	١٠٠	١٢.٢٠٦	٠.٥٢١	٠.٥٨٦	١.٠٥٩	٥.٤٠٩	٠.١١٣	١.٢٨٤

Table (٥.١٤) : Design results of filter backwashing system

Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	T (C°) (٤)	BWV (m/min) (٥)	Re_{MIN} (٦)	Re_{OBT} (٧)	BWR (m³/m/min) (٨)	α (٩)	I_{ES} (m) (١٠)	R_S% (١١)	I_{ETS} (m) (١٢)	R_{TS}% (١٣)	I_E (m) (١٤)	R% (١٥)
١	٥٠	٥٠	٤٥	٠.٤٣٣	١٠.٩٩٦	٩٢.٩١٠	٠.٤٧٩	٠.٦٤٨	٠.٢٧٦	١٠.٦٠٧	٠.٦٠٨	٢١.٦٦٠	٠.٨٨٤	١٧.٩٨١
٢	٥٠	٥٠	٥	٠.٢٢١	٢.١٥٧	١٨.٢٢٥	٠.٢٩٩	٠.٦١٨	٠.٢٥٩	٣.٨٥٤	٠.٠٧١	١٤.٢٣٩	٠.٨٣١	١٠.٧٧٧
٣	٢٠٠	١٠٠	٤٥	٠.٤٣٣	١٠.٩٩٦	٩٢.٩١٠	٠.٤٧٩	٠.٦٤٨	٠.٢٧٦	١٠.٦٠٧	٠.٦٠٨	٢١.٦٦٠	٠.٨٨٤	١٧.٩٨١
٤	٢٠٠	١٠٠	٥	٠.٢٢١	٢.١٥٧	١٨.٢٢٥	٠.٢٩٩	٠.٦١٨	٠.٢٥٩	٣.٨٥٤	٠.٠٧١	١٤.٢٣٩	٠.٨٣١	١٠.٧٧٧

Table (٥.١٥) : Design results of Total head loss occur with filter backwashing run

Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	T (C°) (٤)	BWR (m³/m/min) (٥)	HL_{SM} (m) (٦)	HL_{TSM} (m) (٧)	HL_{GM} ×١٠⁻² (m) (٨)	HL_{UDS} (m) (٩)	Q_{PC} ×١٠⁻² (m³/h) (١٠)	HL_{PC} ×١٠⁻³ (m) (١١)	S_{PC} ×١٠⁻³ (m/m) (١٢)	Pb ×١٠⁻³ (١٣)	TSH (m) (١٤)	TH (m) (١٥)
١	٥٠	٥٠	٤٥	٠.٤٧٩	٠.٢٠٦	٠.١٣٧	١.٥٠٦	٠.٩٢٨	٣.٩١٩	١٣.٣١٢	٨.١٥٠	٤.٦٥٦	٢.٥٨٥	٣.٨٨٠
٢	٥٠	٥٠	٥	٠.٢٩٩	٠.٢٠٦	٠.١٣٧	٠.٠٤٧	٠.٣٦١	٢.٤٤٥	٥.١٨٠	٣.١٧٢	١.٨١٢	٢.٥٣١	٣.٢٩٤

٣	٢٠٠	١٠٠	٤٥	٠.٤٧٩	٠.٢٠٦	٠.١٣٧	١.٥٠٦	٠.٩٢٨	٣.٩١٩	١٣.٣١٢	٨.١٥٠	٤.٦٥٦	٢.٥٨٥	٣.٨٨٠
٤	٢٠٠	١٠٠	٥	٠.٢٩٩	٠.٢٠٦	٠.١٣٧	٠.٠٤٧	٠.٣٦١	٢.٤٤٥	٥.١٨٠	٣.١٧٢	١.٨١٢	٢.٥٣١	٣.٢٩٤

Table (٥.١٦) : Design results of wash water trough

Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	FR_{FL} (m³/m/h) (٤)	SP_T (m) (٥)	NU_T (٦)	Q_T (m³/min) (٧)	W_T (cm) (٨)	D_T (cm) (٩)	S_T (m/m) (١٠)
١	٥٠	٥٠	١٢.١٠٩	٥.٠٦٢	١	١.٩٨١	١٨	١٩.٢٢٩	٠.٠٠١
٢	٢٠٠	١٠٠	١٢.٢٠٦	٥.٠٦٢	٢	١.٩٦٦	٢٢	٢٢.٤٣٩	٠.٠٠١

Table (٥.١٧) : Design results of backwashing pipes system

Pipes system	Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	NU_P (٤)	DM_P (in) (٥)	Q_P ×10⁻² (m³/s) (٦)	F ×10⁻² (٧)	V_P (m/s) (٨)	HL_P (m) (٩)	L_P (m) (١٠)	ET (١١)	BV (١٢)	OU (١٣)	T٩T (١٤)	E٩ (١٥)	CV (١٦)	GV (١٧)	AA (١٨)
١	١	٥٠	٥٠	١	٦	٣.٣٠٢	١.٧٣٥	١.٨١٠	٠.٨٣٨	٢	١	١	١	٠	٠	١	١	٠
	٢	٢٠٠	١٠٠	١	١٠	٦.٠٥٢	١.٣٤٩	١.٢٩٣	٠.٤١٧	٢	١	١	١	٠	٠	١	١	٠
٢	١	٥٠	٥٠	٤	٦	٣.٣٠٢	٠.٧٦٤	١.٨١٠	١.٠٢٧	٠.٧٤٣	١	١	١	٠	١	١	١	٠
	٢	٢٠٠	١٠٠	٤	١٠	٦.٠٥٢	١.٣٤٩	١.٢٩٣	٠.٣٨٦	٠.٩٣٠	١	١	١	٠	١	١	١	٠
٣	١	٥٠	٥٠	١	٦	٣.٣٠٢	١.٧٣٥	١.٨١٠	٠.٨٥٢	٢.٧٥	١	١	١	٠	٠	١	١	٠
	٢	٢٠٠	١٠٠	١	١٠	٦.٠٥٢	١.٣٤٩	١.٢٩٣	٠.٤٢٠٦	٢.٧٥	١	١	١	٠	٠	١	١	٠

Table (٥.١٨) : Design results of backwashing pump

Case (١)	Qcap (m³/h) (٢)	Q_{PAC.U} (m³/h) (٣)	NU_{PUMP} (٤)	NUO_{PUMP} (٥)	Q_{PUMP} (m³/s) (٦)	TH_{PUMP} (m) (٧)	P_{PUMP} (kw) (٨)

١	٥٠	٥٠	١		١	٠.٠٣٣	٧.٢٢٧	٤٨.٩٦٢
٢	٢٠٠	١٠٠	١		١	٠.٠٦٥	٤.٩١٦	٦٥.٦٣٣

Table (٥.١٩) : Design results of Backwashing waste water pipe

	Pipe									Appurtenances								
Case (١)	Qcap (m³/h) (٢)	Q_PACU (m³/h) (٣)	NU_P (٤)	DM_P (in) (٥)	Q_P ×١٠⁻² (m³/s) (٦)	F ×١٠⁻² (٧)	V_P (m/s) (٨)	HL_P (m) (٩)	L_P (m) (١٠)	ET (١١)	BV (١٢)	OU (١٣)	T٩ T (١٤)	E٩ (١٥)	E٦ (١٦)	CV (١٧)	GV (١٨)	AA (١٩)
١	٥٠	٥٠	١	٦	٣.٣٠٢	١.٧٣٤	١.٨١٠	٠.٤٠٩	٢.٧٢٩	١	٠	١	٠	١	٠	٠	١	٠
٢	٢٠٠	١٠٠	٢	٦	٣.٢٧٦	١.٧٣٤	١.٧٩٦	٠.٤٠٣	٣.٠١٧	١	٠	١	٠	١	٠	٠	١	٠

Table (٥.٢٠) : Backwashing procedure

Case (١)	Qcap (m³/h) (٢)	Q_PAC.U (m³/h) (٣)	Q_BW (m³/h) (٤)	T_BW (h) (٥)	T_W (min) (٦)
١	٥٠	٥٠	١٨.٤٩٧	٢٤	٩.٣٣٦
٢	٢٠٠	١٠٠	٣٦.٧٠٣	٢٤	٩.٣٣٦

Table (٥.٢١) : Design results of package units

Case (١)	Qcap (m³/h) (٢)	Q_PAC.U (m³/h) (٣)	NU_PAC.U (٤)	W_PAC.U (m) (٥)	L_PAC.U (m) (٦)

١	٥٠	٥٠	١	١.٤٣٧	١٣.٩١٠
٢	٢٠٠	١٠٠	٢	١.٨١٠	٢٠.٩١٨

Table (٥.٢٢) : Design results of suction and delivery pipes for low lift pump

Case (١)	Qcap (m³/h) (٢)	Pipes								Connection pipe diameter		Appurtenances						TH (m) (١٩)
		Type (٣)	NU$_P$ (٤)	DM$_P$ (in) (٥)	Q$_P$ ×١٠⁻³ (m³/s) (٦)	F ×١٠⁻² (٧)	V$_P$ (m/s) (٨)	HL$_P$ (m) (٩)	L$_P$ (m) (١٠)	P١ (in) (١١)	P٢ (in) (١٢)	ET (١٣)	OU (١٤)	T٩T (١٥)	E٩ (١٦)	CV (١٧)	GV (١٨)	
١	٥٠	MS	١	٤	١٣.٨٩٠	٢.١٧٥	١.٧١٣	١.٧٣٨	٣٠.٥٢	٤	-	١	٢	٠	١	١	٢	٢.٢٩٧
		MD	١	٤	١٣.٨٩٠	٢.١٧٥	١.٧١٣	٠.١٩٢	٦.١٩	٤	-	٠	٠	٠	٠	٢	٢	٠.٤٠٦
		DD١	١	٤	١٣.٨٩٠	٢.١٧٥	١.٧١٣	٠.٥٨١	٦.٣٠٢	-	-	٠	١	٠	١	٠	١	٠.٥٨١
		DD٢	٠	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
٢	٢٠٠	MS	١	٨	٥٥.٥٥٥	١.٤٩٩	١.٧١٣	١.٠٩٨	٣٠.٥٢	٦	٦	١	٢	٠	١	١	٢	١.٨٦٣
		MD	١	٨	٥٥.٥٥٥	١.٤٩٩	١.٧١٣	٠.٣٧٥	٦.٥٠٩	٦	٦	٠	٠	٠	٠	٢	٢	٠.٥٨٦
		DD١	٢	٦	٢٧.٧٧٨	١.٧٣٦	١.٥٢٢	٠.٣٧٨	٦.٦٣٤	-	-	٠	١	٠	١	٠	١	٠.٧٥٦
		DD٢	١	٦	٢٧.٧٧٨	١.٧٣٦	١.٥٢٢	٠.٣٠٠	٤.٨٣٥	-	-	٠	٠	١	٠	٠	١	٠.٣٠٠

Table (٥.٢٣) : Design results of Low lift pump

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	NU$_{PUMP}$ (٤)	NUO$_{PUMP}$ (٥)	Q$_{PUMP}$ ×١٠⁻³ (m³/s) (٦)	H$_{PUMP}$ (m) (٧)	P$_{PUMP}$ (kw) (٨)

١	٥٠	٥٠	١	١	١٣.٣٨٩	٧.٤٩٩	٢١.٢٢١
٢	٢٠٠	١٠٠	٢	١	٢٧.٧٧٨	٨.٦٦٢	٤٩.٠٢٥

Table (٥.٢٤) : Design results of coagulation solution tank

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	Q$_{GT}$ (m³/s) (٤)	NU$_{GT}$ (٥)	NUO$_{GT}$ (٦)	D$_{GT}$ (m) (٧)	DIM$_{GT}$ (m) (٨)	RT$_{GT}$ (h) (٩)	DM$_P$ (in) (١٠)
١	٥٠	٥٠	٠.٠٥٠	١	١	٠.٨٠٠	٠.٣٠٠	٠.٥٠٠	١
٢	٢٠٠	١٠٠	٠.١٠٠	١	١	٠.٨٠٠	٠.٤٠٠	٠.٥٠٠	١

Table (٥.٢٥) : Design results of Clear and backwashing storage tank

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	Q$_{CBW}$ (m³/h) (٤)	NU$_{CBW}$ (٥)	W$_{CBW}$ (m) (٦)	L$_{CBW}$ (m) (٧)	D$_{CBW}$ (m) (٨)	TD$_{CBW}$ (m) (٩)	RT$_{CBW}$ (h) (١٠)
١	٥٠	٥٠	٥٠	١	١.٤٣٧	٦.٠٠٠	٤	٤.٢٥٠	٠.٥
٢	٢٠٠	١٠٠	١٠٠	٢	١.٨١٠	٩.٥٠٠	٤	٤.٢٥٠	٠.٥

Table (٥.٢٦) : Design results of influent pipe of clear and back washing storage tank

	Pipe									Appurtenances							
Case (١)	Qcap (m³/h) (٢)	Q$_{PAU}$ (m³/h) (٣)	NU$_P$ (٤)	DM$_P$ (in) (٥)	Q$_P$ ×١٠$^{-٢}$ m³/s (٦)	F ×١٠$^{-٢}$ (٧)	V$_P$ (m/s) (٨)	HL$_P$ (m) (٩)	L$_P$ (m) (١٠)	ET (١١)	BV (١٢)	OU (١٣)	TR (١٤)	E٩ (١٥)	CV (١٦)	GV (١٧)	AA (١٨)
١	٥٠	٥٠	١	٦	١.٣٨٩	١.٧٦١	٠.٧٦١	٠.٠٩٧	٧	١	٠	١	١	١	٠	٢	٠

| ٢ | ٢٠٠ | ١٠٠ | ٢ | ١٠ | ٢.٧٧٨ | ١.٧٣٦ | ١.٥٢٣ | ٠.٣٨٧ | ٧ | ١ | ٠ | ١ | ١ | ١ | ٠ | ٢ | ٠ |

Table (٥.٢٧) : Design results of suction and delivery pipes of high lift pump

Case (١)	Qcap (m³/h) (٢)	Type (٣)	NUp (in) (٤)	DMp (in) (٥)	Qp ×10⁻³ (m³/s) (٦)	F ×10⁻² (٧)	Vp m/s (٨)	HLp (m) (٩)	Lp (m) (١٠)	P1 (in) (١١)	P2 (in) (١٢)	ET (١٣)	OU (١٤)	T9T (١٥)	E9 (١٦)	CV (١٧)	GV (١٨)	TH (m) (١٩)
١	٥٠	MS	١	٤	١٣.٨٩٠	٢.١٧٥	١.٧١٣	٠.٨١٢	٣.٠٠٠	٤	-	١	٢	١	١	١	٢	١.٣٥٧
		MD	١	٤	١٣.٨٩٠	٢.١٧٥	١.٧١٣	٠.٥٢٤	٣.٠٠٠	٤	-	٠	١	٢	١	٠	٢	١.٠٦٨
		SS١	١	٤	١٣.٨٩٠	٢.١٧٥	٠.٧٦١	٠.١٣٧	١.٥٠٠	-	-	١	١	٠	١	١	١	٠.١٣٧
		SS٢	٠	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
٢	٢٠٠	MS	١	٨	٥٥.٥٥٥	١.٤٩٩	١.٧١٣	٠.٧٤٩	٣.٠٠٠	٦	٦	١	٣	٢	٠	١	٣	١.٥٣٧
		MD	١	٨	٥٥.٥٥٥	١.٤٩٩	١.٧١٣	٠.٤٥٩	٣.٠٠٠	٦	٦	٠	٠	٠	٠	٢	٢	١.٢٤٧
		SS١	٢	٦	٢٧.٧٧٨	١.٧٣٦	١.٥٢٢	٠.١٧٢	١.٥٠٠	-	-	١	١	٠	١	١	١	٠.٣٤٤
		SS٢	١	٦	٢٧.٧٧٨	١.٧٣٦	١.٥٢٢	٠.٢٧٦	٤.٨١٠	-	-	٠	١	٠	٠	٠	١	٠.٢٧٦

Table (٥.٢٨) : Design results of high lift pump

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	NU$_{PUMP}$ (٤)	NUO$_{PUMP}$ (٥)	Q$_{PUMP}$ ×١٠⁻³ (m³/s) (٦)	H$_{PUMP}$ (m) (٧)	P$_{PUMP}$ (kw) (٨)
١	٥٠	٥٠	١	١	١٣.٣٨٩	٢٢.٥٦٣	٦٣.٨٤٩
٢	٢٠٠	١٠٠	٢	١	٢٧.٧٧٨	٢٣.٦٤٣	١٣٣.٨١٠

Table (٥.٢٩) : Design results of sludge and over flow channels (Trenches)

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	Channel type (٤)	Q$_C$ (m³/s) (٥)	NU$_C$ (٦)	L$_C$ (m) (٧)	W$_C$ (m) (٨)	D$_C$ (m) (٩)	TD$_C$ (m) (١١)	S$_C$ (m/m) (١٢)
١	٥٠	٥٠	Secondary	٥٢.٦٢٥	١	١٤.٩١٠	٠.١٤٠	٠.١٧٠	٠.١٩٥	٣.٤٠٠
			Main	٥٢.٦٢٥	١	١٢.٥٠٧	٠.١٤٠	٠.١٧٠	٠.١٩٥	٤.١٧٧
٢	٢٠٠	١٠٠	Secondary	١٠٢.٢٤٢	٢	٢١.٩١٨	٠.٢٠٠	٠.٢٢٠	٠.٢٤٥	٢.١٦٠
			Main	٢٠٦.٠٥٢	١	١٧.٧٢٠	٠.٢٩٠	٠.٣١٠	٠.٣٣٥	١.٣٣٢

Table (٥.٣٠) : Design results of chlorine dosages

Case (١)	Qcap (m³/h) (٢)	Q$_{PAC.U}$ (m³/h) (٣)	Q$_{ULPSP}$ (m³/s) (٤)	Dose (kg/h) (٥)
١	٥٠	٥٠	٥٠	٠.٣٠٠
٢	٢٠٠	١٠٠	٢٠٠	١.٢٠٠

١٠٣

١٠٣.٢٠

| Filter | Coll.T | S.C | F.T | R.M.C |

EL$_{PP}$ =

١٠٠.٥

C.BW.T
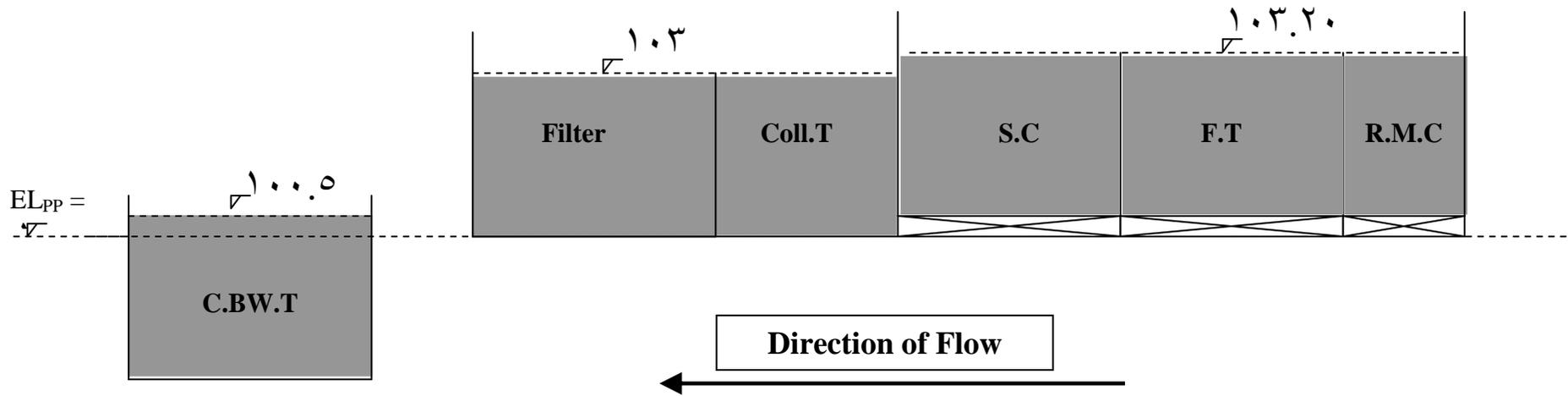
Direction of Flow

Figure (٥.١) : Plan of the hydraulic gradient for all basins of package plant with capacity $75\dfrac{m^3}{h}$

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