Pressure Surge Considerations for Al Gardabiya Pump Station Phase III of the Man-made River Project

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Abstract

This paper presents a review of the pressure surge simulations carried out for Phase III of the Man Made River project in Libya with particular emphasis on the transient generated by simultaneous pump trip at Al Gardabiya Pump Station.

The omission of the surge vessel check valve and bypass system on the grounds of cost, ease of design and construction, will result in, as expected, increased surge fluctuations, as the damping effect in the form of check valve and bypass was removed.

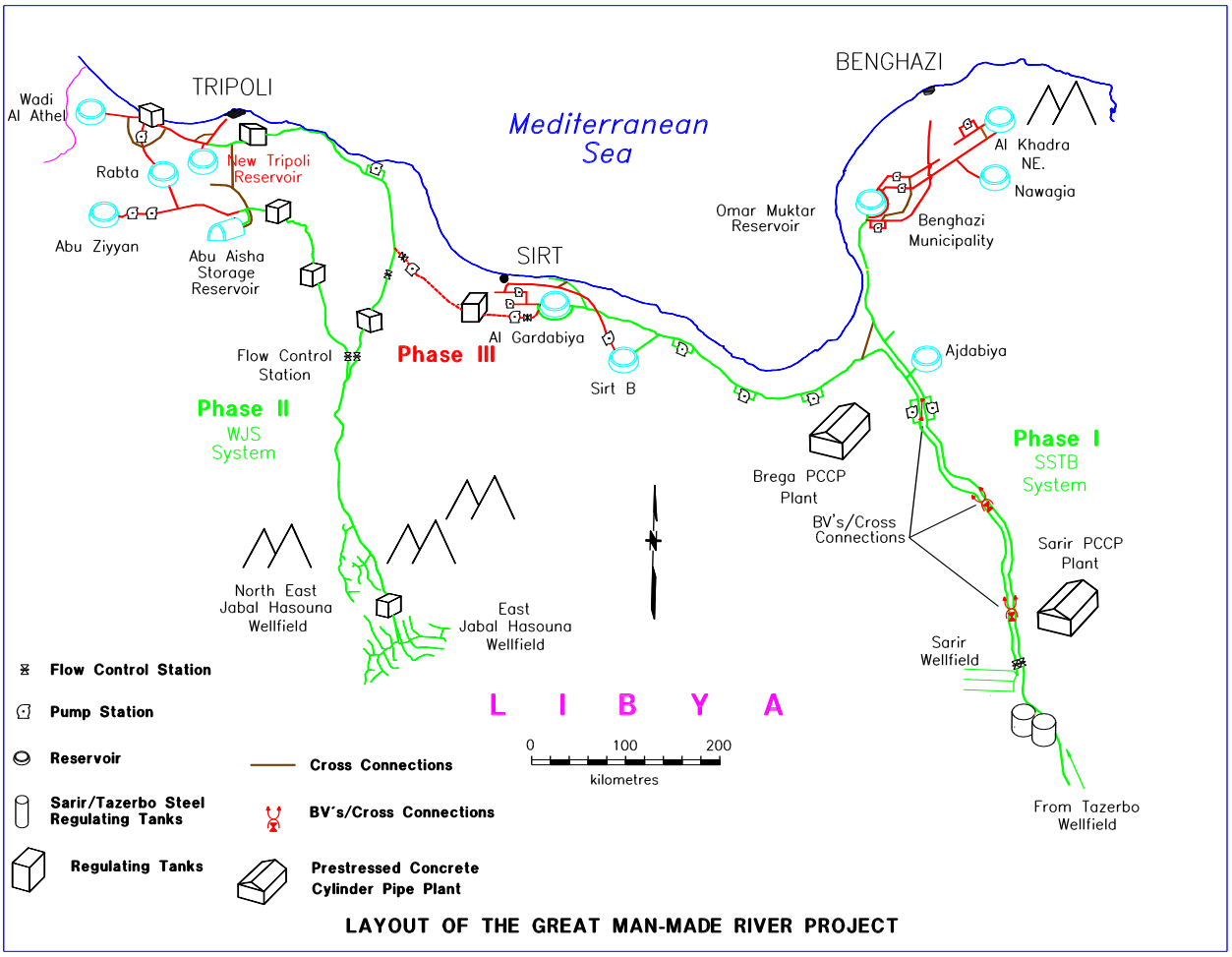
From the hydraulic and control requirements it is recommended for Al Gardabiya Pump station that the check valve and check valve bypass is included in the final surge vessel design.

1.0 INTRODUCTION

The Al Gardabiya to Assdada Conveyance Link is Phase III of the Great Man-Made River Project; it connects Phase II to Phase I at Assdada and Phase III to PhaseI at Al Gardabiya. It operates in two modes, gravity with flow from Phase II to Phase I and pumping mode from Phase I to Phase II.

Phase I of the GMRP located in the eastern part of Libya, is a gravity system at present. The System consists of wellfields at Sarir and Tazerbo supplying a holding reservoir at Ajdabiya through conveyance pipelines. Ajdabiya holding reservoir through conveyance pipelines supplies the end reservoirs at Benghazi (Omar El Mukhtar previously known as Benghazi End Reservoir) and at Sirt (Al Gardabiya Reservoir previously known as Sirt End Reservoir). The conveyance pipelines and reservoirs are constructed and operational with water supplied from Sarir and Tazerbo wellfield.[1].

Phase II of the GMRP is located in the Western part of Libya; it is known as the Hasouna Jeffara System (HJS). The system comprises three wellfields located around Jabal Hasouna.



LAYOUT OF THE GREAT MAN-MADE RIVER PROJECT

The first is East Jabal Hasouna wellfield, which supplies Fezzan Regulating Tank (RT). The other two wellfields at North East Jabal Hasouna are downstream of Fezzan Regulating Tanks and contribute to the water supply to Ash Shwayrif Flow Control Station (FCS). The flow at Ash Shwayrif splits into two conveyances, the Central and Eastern Branch. The Eastern Branch passes via a RT, through a further FCS at Wadi Tumallah and then to a regulating tank at Garabulli. Phase III tie-in point is downstream of Wadi Tumallah FCS.

At Assdada and Al Gardabiya there are Flow Control Stations (FCSs). Assdada FCS controls the gravity flow from Phase II to Wadi Wishkah Regulating Tank. Al Gardabiya FCS controls gravity flow from Wadi Wishkah to Phase I. In Phase III there are pumping stations at AL Gardabiya and Assdada Pump stations for flow from Phase I to Phase II with Wadi Wishkah Regulating Tank as break in pressure.[1,2].

The Phase III system can be isolated into two sections because of a hydraulic break in pressure in the form of Wadi Wishkah Regulating Tank. The two sections can be split into Wadi Wishkah to Assdada and Al Gardabiya Pump Station Forebay Tank to Wadi Wishkah Regulating Tank. This simulation covers surge analysis from Al Gardabiya pumping station and the section of the conveyance from Al Gardabiya to Wadi Wishkah only.

The omission of the surge vessel check valve and bypass system on the grounds of cost, ease of design and construction, will result in, as expected, increased surge fluctuations, as the damping effect in the form of check valve and bypass was removed.[3].

From the hydraulic and control requirements it is recommended for Al Gardbiya Pump station that the check valve and check valve bypass is included in the final surge vessel design.

2.0 Al Gardabiya Pump Station Surge Vessels

The Phase III surge vessel transient simulations were carried out using Flowmaster Transient Surge Simulation Software for fluid flow. The consideration of the omission of the surge vessel check valve and bypass system on the grounds of cost, ease of design and construction, resulted in, as expected, increased surge fluctuations, as the damping affect in the form of check valve and bypass was removed.[1,3].

The removal of the check valve and bypass system from the surge vessel does not endanger the integrity of the system or result in an increase in number of the surge vessels. The system will however take longer to come to rest, with more surge fluctuations.

To illustrate the affect of the inclusion of check valve and check valve bypass the case of simultaneous pump trip at Al Gardabiya under worst case flows of $12.8 m^3/s$ is considered. (Note this is slightly greater than the design flow for Phase III is 0.98MCMD or $11.3 m^3/s$). For the main conveyance, Pump Station suction and delivery manifolds as well as the surge vessel area maximum and minimum surge levels are well within the design bar rating. All maximum surge levels are not only within the maximum surge bar rating but the steady state bar rating. (See Figures (1) to (4)).

The reintroduction of the surge vessel check valve and bypass in the surge vessel design reduces considerably the maximum surge levels but has little affect on initial minimum

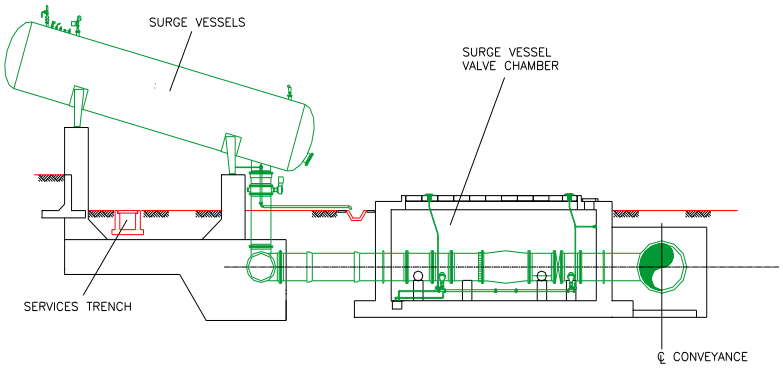
downsurge (See Figure (5). However due to the inclusion of check valve and check valve bypass considerable damping of surge fluctuations is achieved. The initial downsurge, after all pump trips, determines the size and number of the surge vessels. This is why the reintroduction of the check valve and bypass does not reduce the number of surge vessels even if the surge upsurge is considerably reduced.

The surge fluctuations at Al Gardabiya pump Station outlet are shown in Figure (6). For the surge fluctuations at Pump Station outlet it can be seen that when the surge vessel check valve and check valve bypass is omitted the surge fluctuations are out of control but considerable damping results when the check valve and check valve bypass are included.

The check valve and bypass should be reintroduced in the surge vessel design although this may result in an additional cost to the client. The inclusion of the check valve and bypass will result in a more robust system design.

3.0 Al Gardabiya Pump Station Surge Vessels Design

Transient analyses are essential and confirm that the selection of pipes and pipe fittings can withstand the anticipated pressures including surge. The transient analysis can confirm surge control (Air Vessels, Vent Pipes, Feed Tanks, Pressure Relief Valves,..etc) and proper operation sequence of the system facilities (Pumps, Valves, Tanks,..etc.)



SECTION THROUGH SURGE VESSEL/CHAMBER

The surge vessel design is designed to dampen the transient fluctuations by restricting the inflow by using an orifice plate in the inflow pipe of the surge vessel and enhancing the outflow by use a quickly opening non return valve. The surge vessel design was inherited from Phase I with a main feed pipe into the surge vessel of 1.6m diameter branching into two pipes feeding each pair of vessel through 1.2m diameter pipes. A 1.6m diameter check valve with a 600mm diameter bypass pipe is also used. The inherited surge vessel Phase II design is incompatible with the Al Gardabiya PS system.[3]

To take into account system conditions at Al Gardabiya it is proposed that the main feed should be 1.0m diameter with 0.7m diameter branching pipes feeding each pair of vessels. The surge vessels check valve should be 0.9m diameter with a 300mm diameter bypass and 90mm diameter orifice plate.[3].

The surge vessel system is formed from a pair of 250m^3 surge vessels with a total volume of 500m^3. It is inclined at 16 degrees to the horizontal surge vessel with varying surface to water area.

The centerline of the main conveyance feed pipe is at 48.1mAMSL
The base of the cylinder is at 53mAMSL
The vertical height of the inclined cylinder from base to top is 8.86m
Diameter of cylinder is 4.0m
Total length of cylinder including bell ends is 20m

4.0 Controlled Shutdown and Startup

It is clear from operational point of view, which includes control, mechanical and electrical requirements, the increase in surge fluctuations, resulting from the removal of the check valve and check valve bypass are not acceptable and some damping of surge fluctuations is required (See Figures (5) & (6)). This can be achieved by the reintroduction of the surge vessel check valve and check valve bypass in the surge vessel design.

With the inclusion of check valve and check valve bypass with orifice plate, from the electrical and control aspects the pumps can be started or shut down sequentially in 3 minutes. It may be possible to start and shutdown the pump sequentially in less than 3 minutes but this is not recommended. Other consideration should be taken into account in

the controlled minimum operational times of pumps other than hydraulic. The system can be restarted after controlled shutdown in about 60 minutes after which there is negligible surge fluctuations (See Figure (7)). There is hardly any surge fluctuations during controlled pump startup and the system can be shutdown after startup in about 25 minutes (See Figure (8)). After emergency simultaneous pump trip the pumps can be restarted if the check valve and check valve bypass with orifice plate are included in the design in about 65 minutes (See Figure (5)).

The check valve and check valve bypass and orifice plate have been reintroduced into the surge vessel design after its omission to dampen the surge fluctuations caused by the operation of Al Gardabiya Pump Station. Once the surge fluctuations are dampened Al Gardabiya pump station can be operated realistically.

5.0 Al Gardabiya to Wadi Wishkah Conveyance Elevations & Bar Rating

Lowering the elevations at the high points on the Al Gardabiya to Wadi Wishkah conveyance has resulted in considerable reduction of surge vessel numbers. The reduction of heights at Sta. 35+393km and Sta. 44+869km will result in a reduced number of 16 pairs of surge vessels at Al Gardabiya PS as shown in Figure (1).

The overall design is now more cost effective, despite the inclusion of check valve and check valve bypass as well as the cost of lowering the invert levels at limited high points in the conveyance, as the surge vessel numbers have been greatly reduced from 21 pairs of operating surge vessels to 16 pairs.

6.0 Conclusions and Recommendation

Efficient and sound guidelines for surge vessel design and operation have been proposed and discussed. The transient results are strongly in favour of the inclusion of a check valve and check valve bypass with an orifice plate.

From the hydraulic and control requirements it is recommended that the check valve and check valve bypass be included in the final surge vessel design.

References

[1] Al Gardabiya / Assdada System, Conceptual Design Report, Jan 2000.

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[3] Al Gardabiya / Assdada System, Optimisation of Surge Facilities Report, March 2001.

[4] Mechanics of Fluids , B.S. Massey 9th Edition Aug 2011.

[5] Fox & Mc Donald Introduction to Fluid Mechanics 10th Edition 2020.

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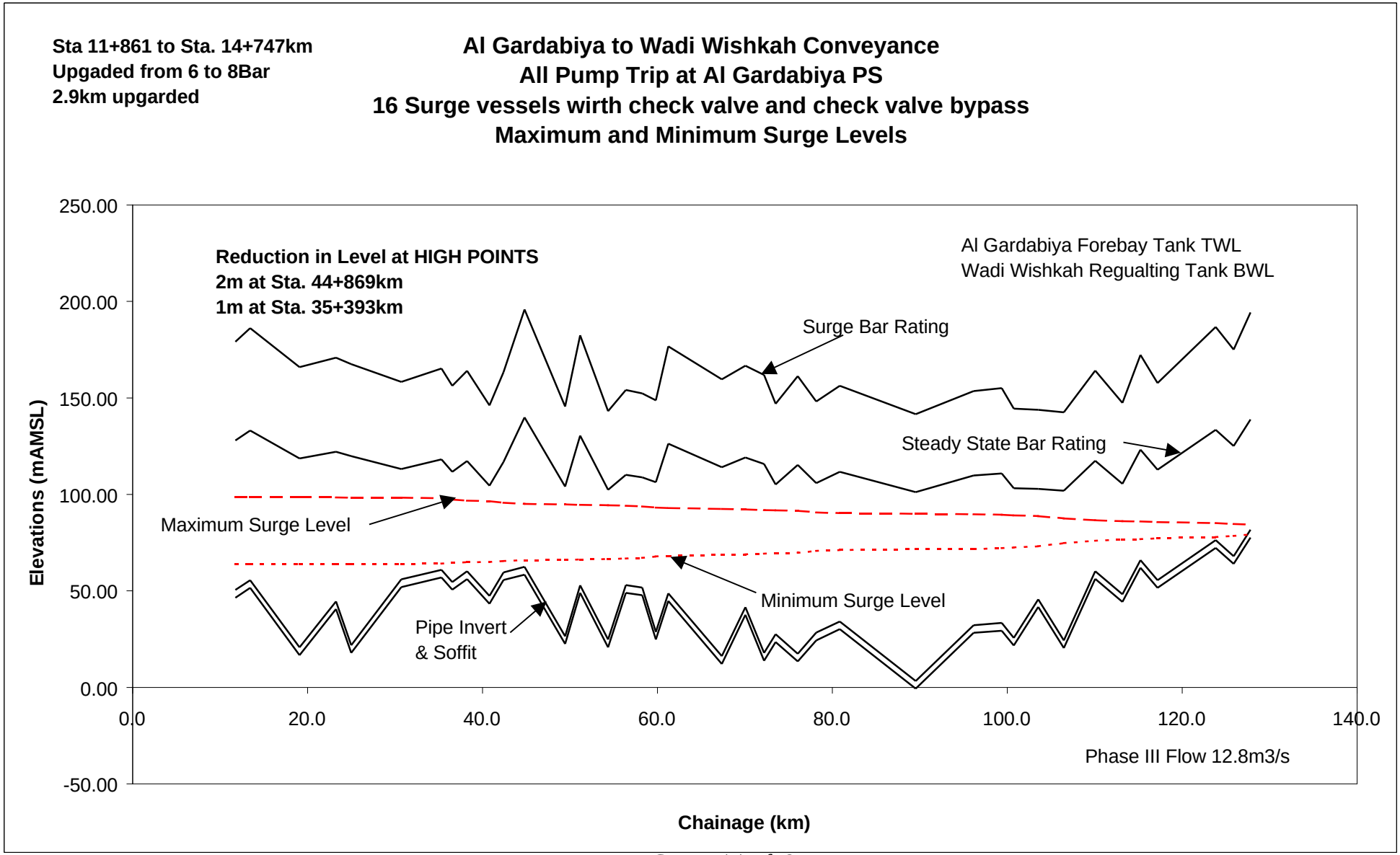
Sta 11+861 to Sta. 14+747km
Upgaded from 6 to 8Bar
2.9km upgarded
Al Gardabiya to Wadi Wishkah Conveyance
All Pump Trip at Al Gardabiya PS
16 Surge vessels wirth check valve and check valve bypass
Maximum and Minimum Surge Levels
Reduction in Level at HIGH POINTS
2m at Sta. 44+869km
1m at Sta. 35+393km
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
Surge Bar Rating
Steady State Bar Rating
Maximum Surge Level
Minimum Surge Level
Pipe Invert
& Soffit
Phase III Flow 12.8m3/s
Elevations (mAMSL)
Chainage (km)
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0

FIGURE (1) of 8

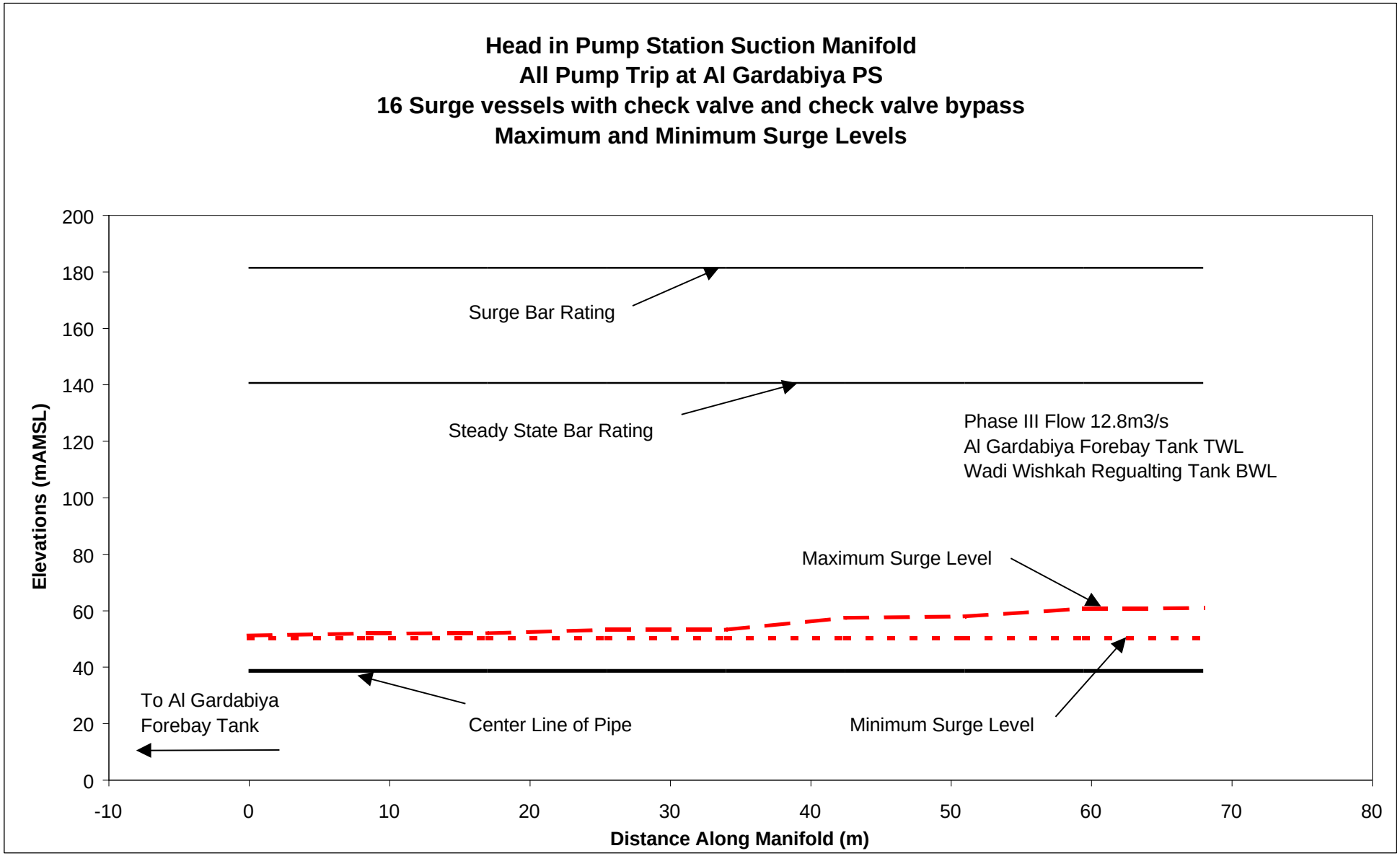
Head in Pump Station Suction Manifold
All Pump Trip at Al Gardabiya PS
16 Surge vessels with check valve and check valve bypass
Maximum and Minimum Surge Levels
Elevations (mAMSL)
200
180
160
140
120
100
80
60
40
20
0
-10
0
10
20
30
40
50
60
70
80
Distance Along Manifold (m)
Surge Bar Rating
Steady State Bar Rating
Phase III Flow 12.8m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
Maximum Surge Level
To Al Gardabiya
Forebay Tank
Center Line of Pipe
Minimum Surge Level

FIGURE (2) of 8

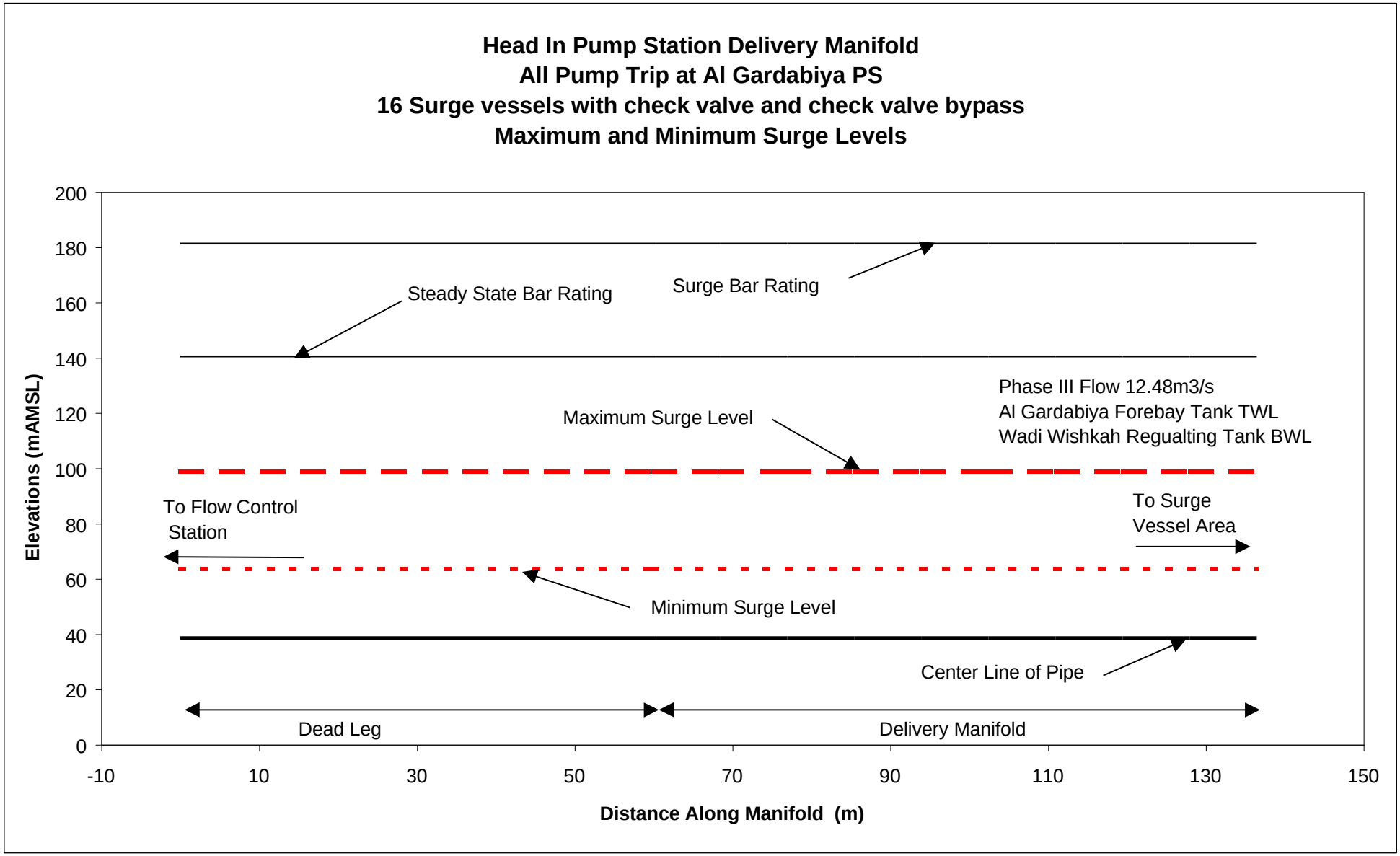
Head In Pump Station Delivery Manifold
All Pump Trip at Al Gardabiya PS
16 Surge vessels with check valve and check valve bypass
Maximum and Minimum Surge Levels
Elevations (mAMSL)
200
180
160
140
120
100
80
60
40
20
0
-10
10
30
50
70
90
110
130
150
Distance Along Manifold (m)
Steady State Bar Rating
Surge Bar Rating
Phase III Flow 12.48m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
Maximum Surge Level
To Flow Control Station
To Surge Vessel Area
Minimum Surge Level
Center Line of Pipe
Dead Leg
Delivery Manifold

FIGURE (3) of 8

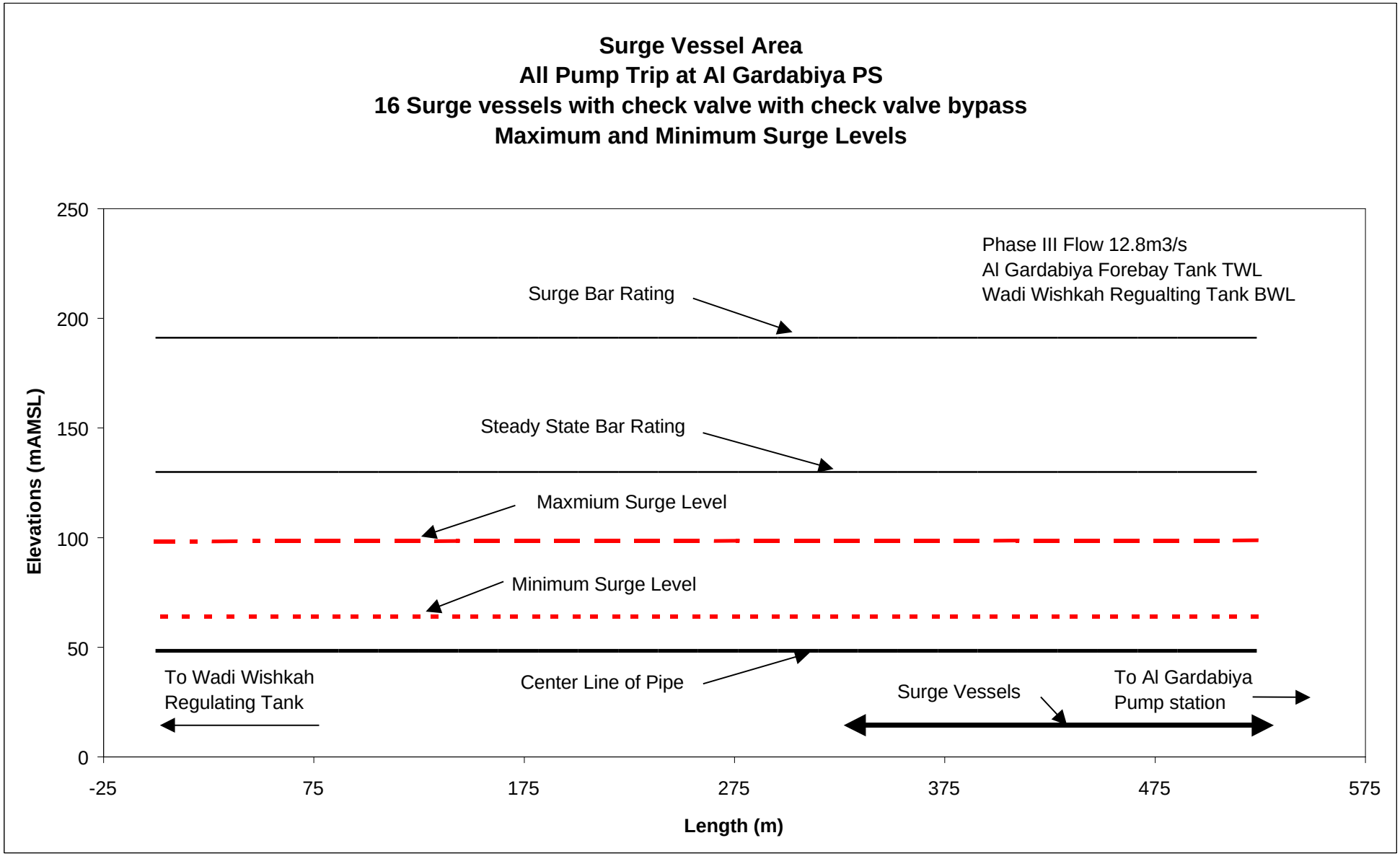
Surge Vessel Area
All Pump Trip at Al Gardabiya PS
16 Surge vessels with check valve with check valve bypass
Maximum and Minimum Surge Levels
Phase III Flow 12.8m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
Surge Bar Rating
Steady State Bar Rating
Maxmium Surge Level
Minimum Surge Level
Center Line of Pipe
To Wadi Wishkah
Regulating Tank
Surge Vessels
To Al Gardabiya
Pump station
Elevations (mAMSL)
Length (m)
250
200
150
100
50
0
-25
75
175
275
375
475
575

FIGURE (4) of 8

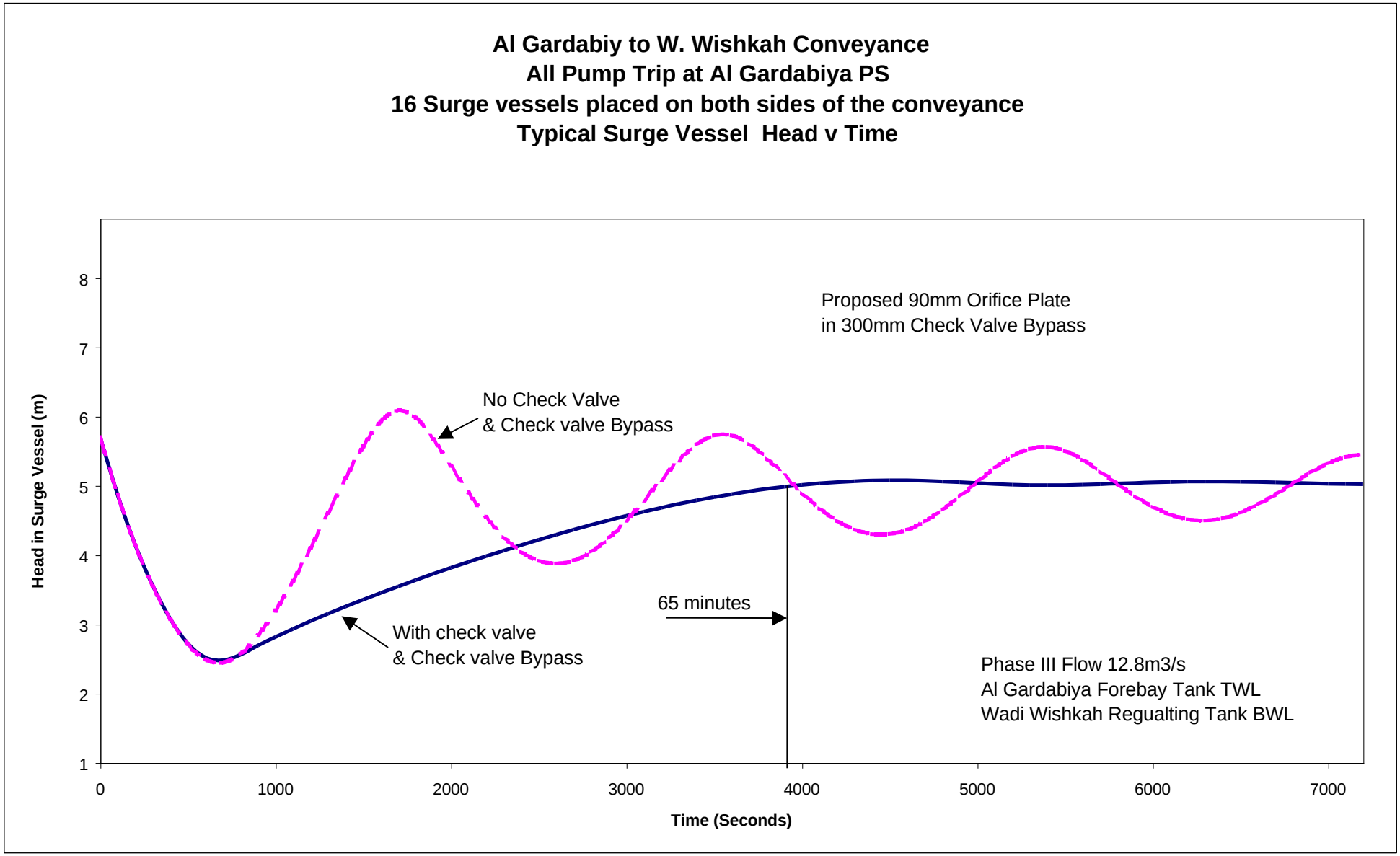
Al Gardabiy to W. Wishkah Conveyance
All Pump Trip at Al Gardabiya PS
16 Surge vessels placed on both sides of the conveyance
Typical Surge Vessel Head v Time
Head in Surge Vessel (m)
Time (Seconds)
Proposed 90mm Orifice Plate
in 300mm Check Valve Bypass
No Check Valve
& Check valve Bypass
With check valve
& Check valve Bypass
65 minutes
Phase III Flow 12.8m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
1
2
3
4
5
6
7
8
0
1000
2000
3000
4000
5000
6000
7000

FIGURE (5) of 8

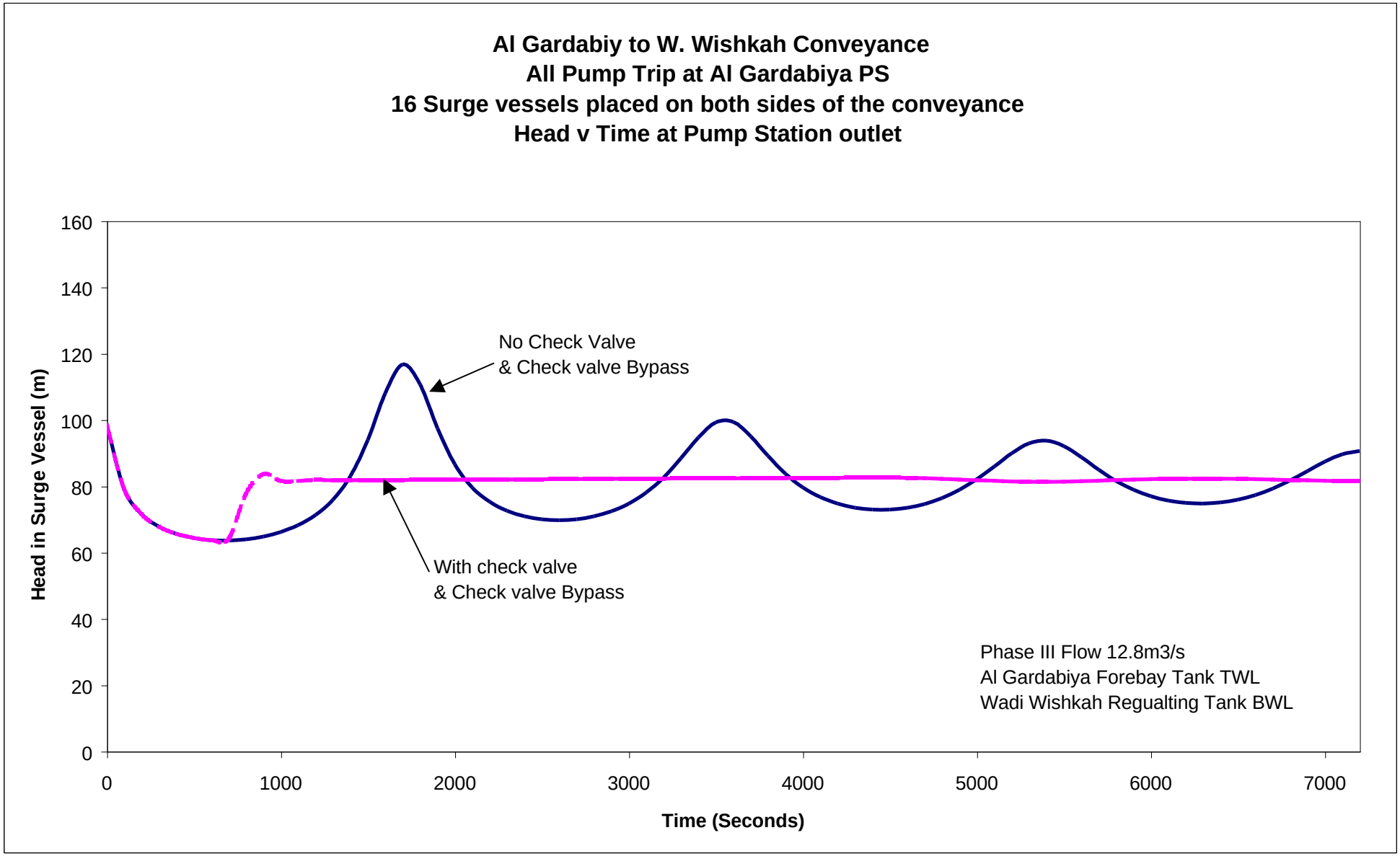
Al Gardabiy to W. Wishkah Conveyance
All Pump Trip at Al Gardabiya PS
16 Surge vessels placed on both sides of the conveyance
Head v Time at Pump Station outlet
Head in Surge Vessel (m)
Time (Seconds)
No Check Valve
& Check valve Bypass
With check valve
& Check valve Bypass
Phase III Flow 12.8m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
0
20
40
60
80
100
120
140
160
0
1000
2000
3000
4000
5000
6000
7000

FIGURE (6) of 8

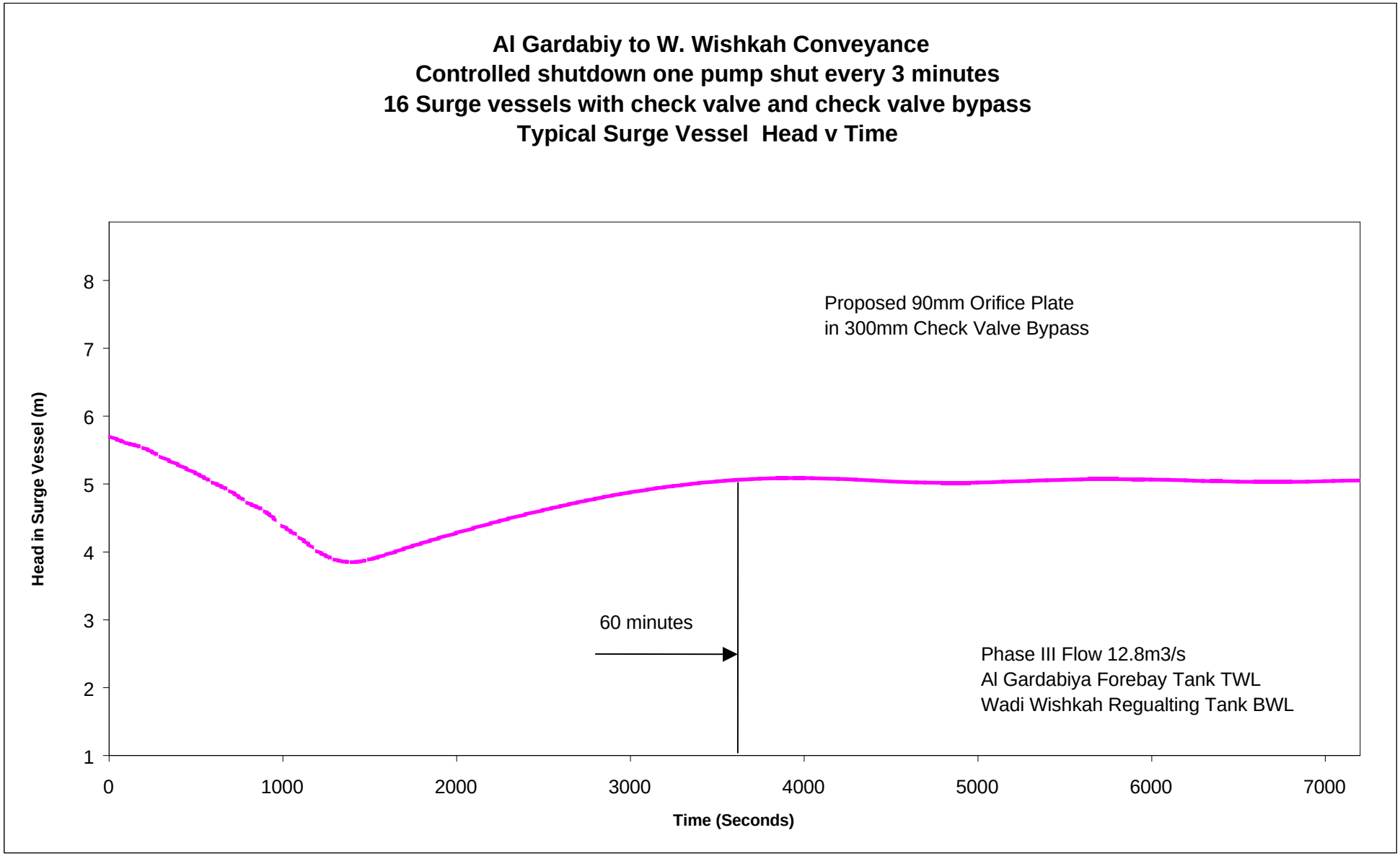
Al Gardabiy to W. Wishkah Conveyance
Controlled shutdown one pump shut every 3 minutes
16 Surge vessels with check valve and check valve bypass
Typical Surge Vessel Head v Time
Head in Surge Vessel (m)
Time (Seconds)
Proposed 90mm Orifice Plate
in 300mm Check Valve Bypass
60 minutes
Phase III Flow 12.8m3/s
Al Gardabiya Forebay Tank TWL
Wadi Wishkah Regualting Tank BWL
1
2
3
4
5
6
7
8
0
1000
2000
3000
4000
5000
6000
7000

FIGURE (7) of 8

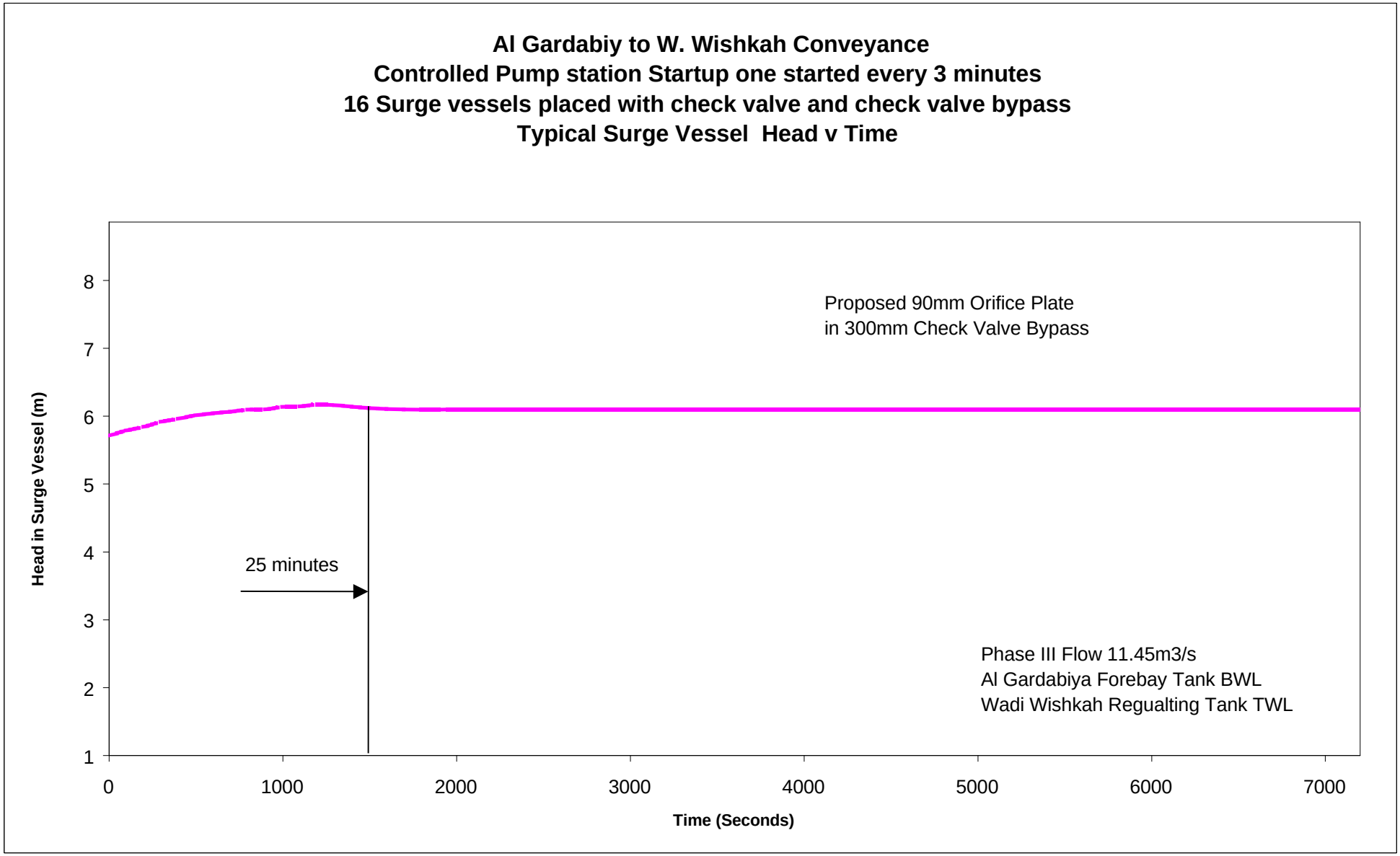
Al Gardabiy to W. Wishkah Conveyance
Controlled Pump station Startup one started every 3 minutes
16 Surge vessels placed with check valve and check valve bypass
Typical Surge Vessel Head v Time
Head in Surge Vessel (m)
Time (Seconds)
Proposed 90mm Orifice Plate
in 300mm Check Valve Bypass
25 minutes
Phase III Flow 11.45m3/s
Al Gardabiya Forebay Tank BWL
Wadi Wishkah Regualting Tank TWL
1
2
3
4
5
6
7
8
0
1000
2000
3000
4000
5000
6000
7000

FIGURE (8) of 8