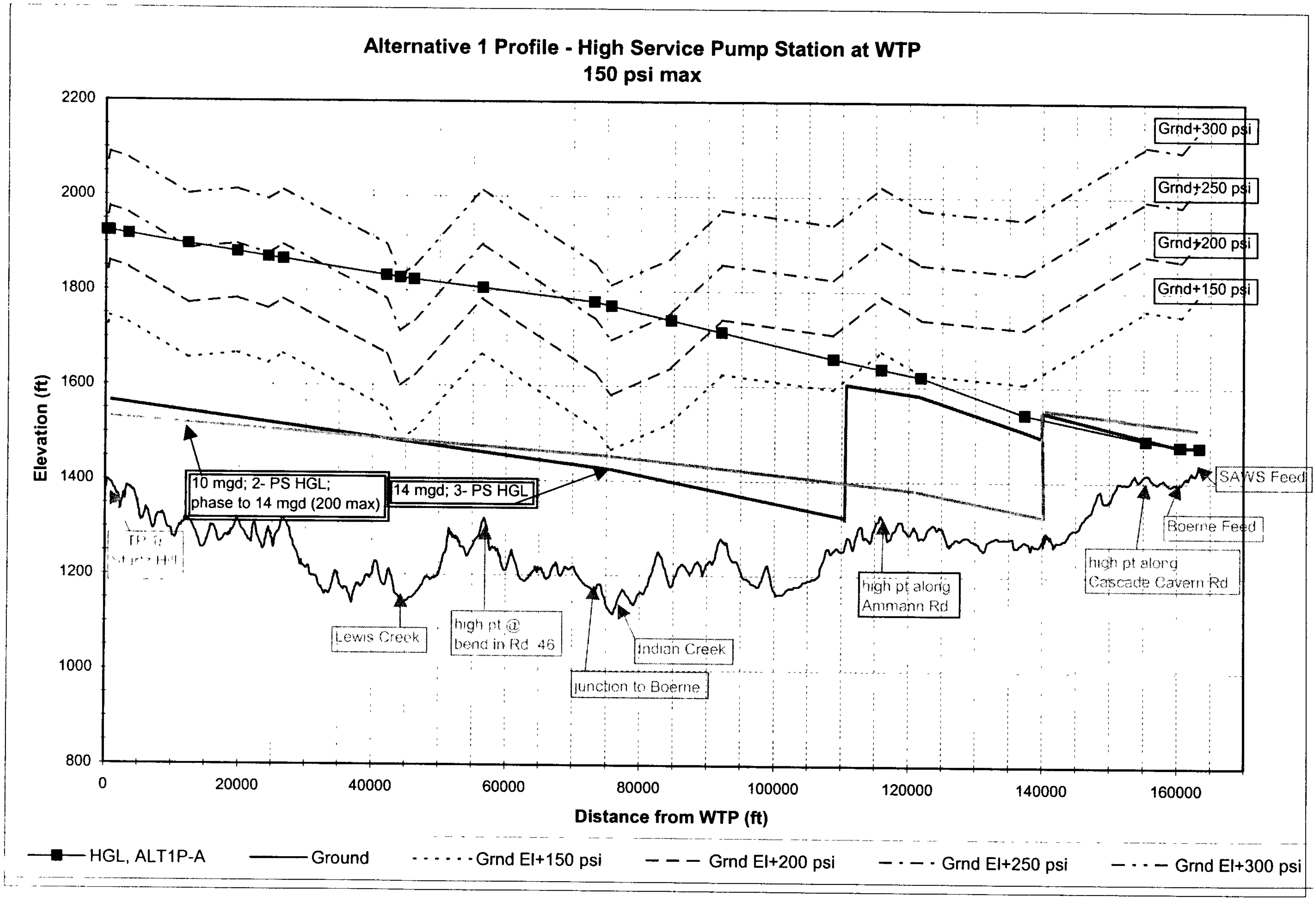
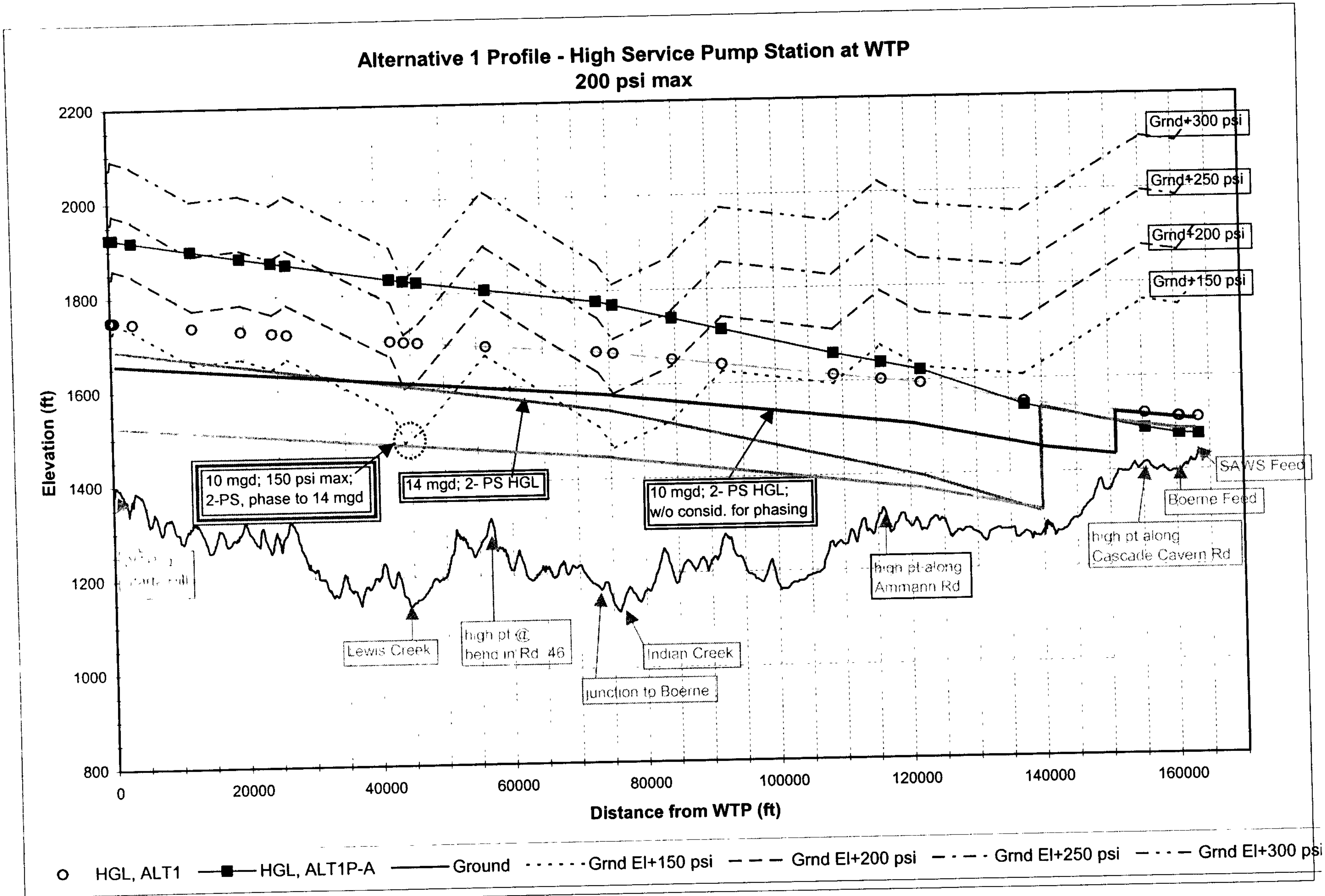
## FIGURE 1 - *Profile from WTP to SAWS*




HDR ENGINEERING, INC.

5/23/00;Alt1reducedPC.xls
r:\07081033\hyd

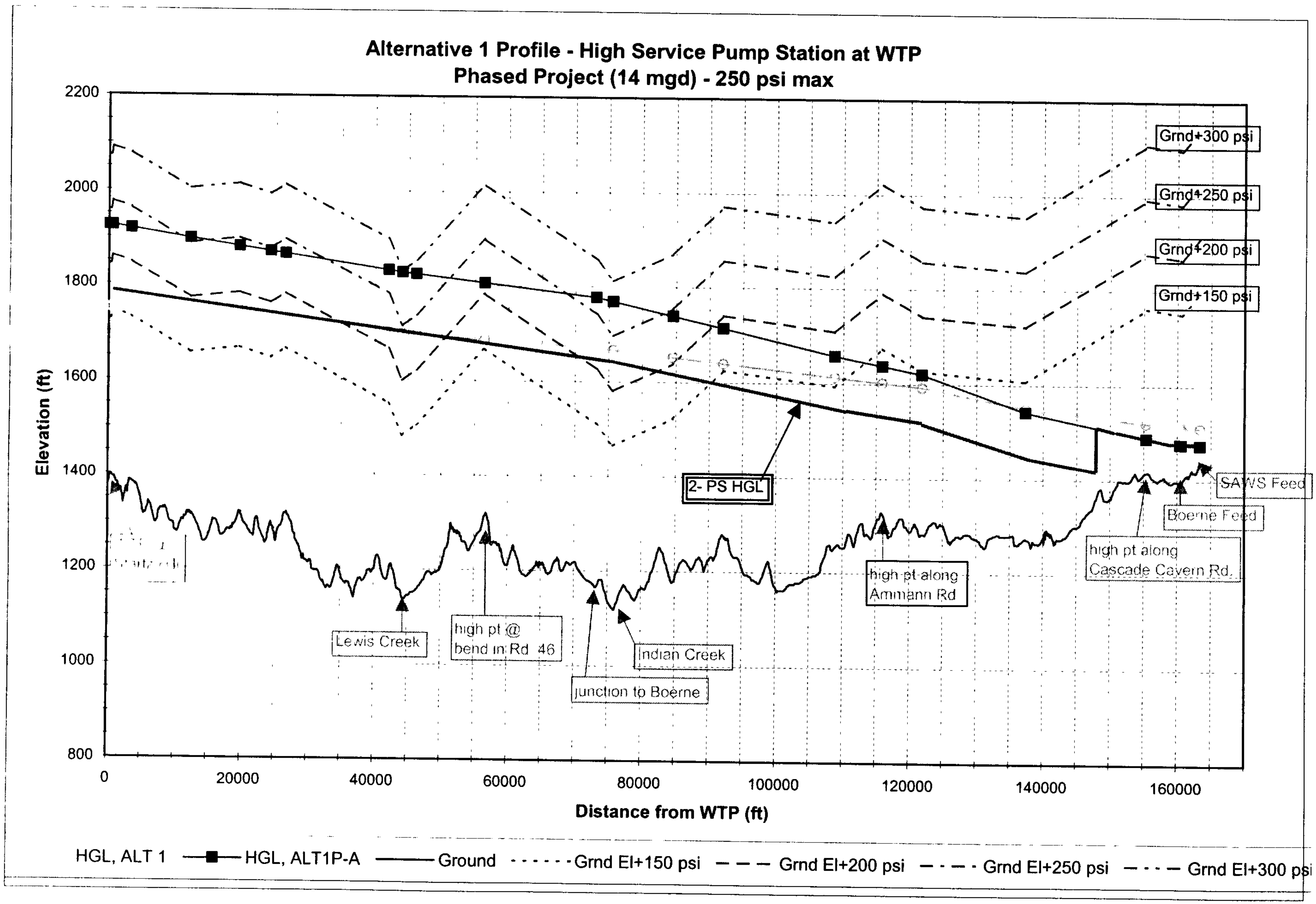
## FIGURE 2 - *Profile from WTP to SAWS*




5/23/00;Alt1reducedPC.xls
r:\07081033\hyd

HDR ENGINEERING, INC.

**FIGURE 3** - ***Profile from WTP to SAWS***



## FIGURE 4 - *Profile from WTP to SAWS*

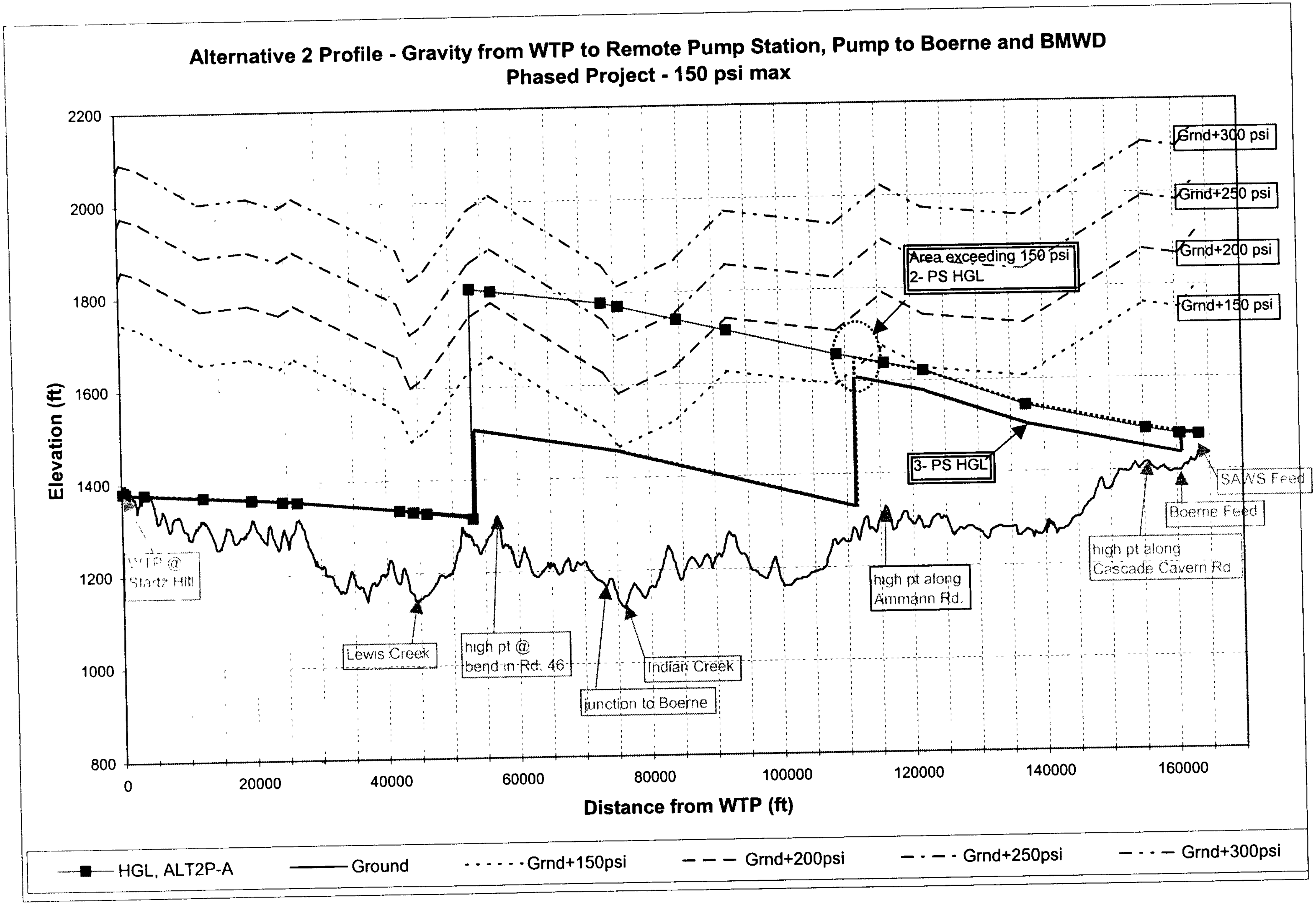
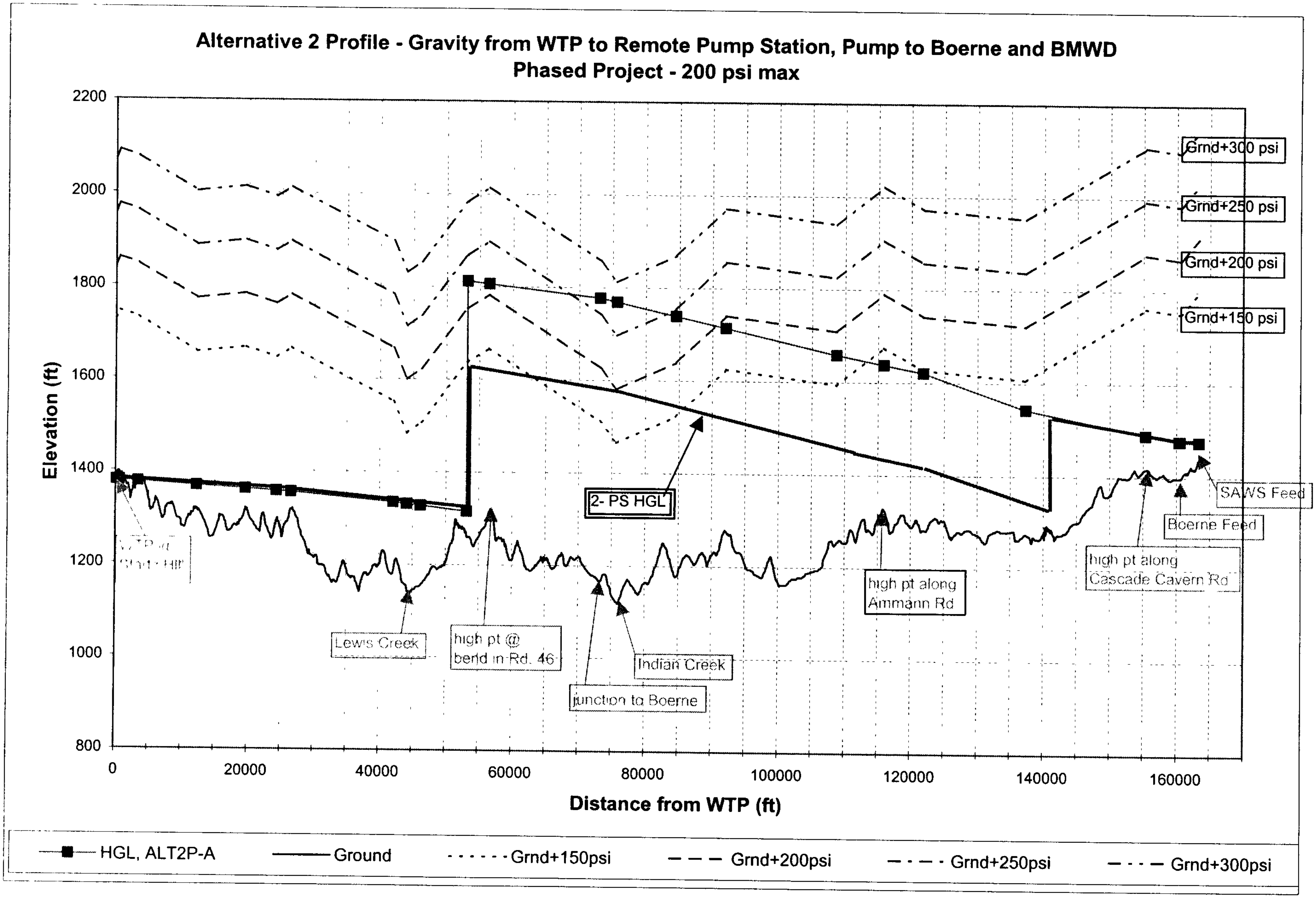


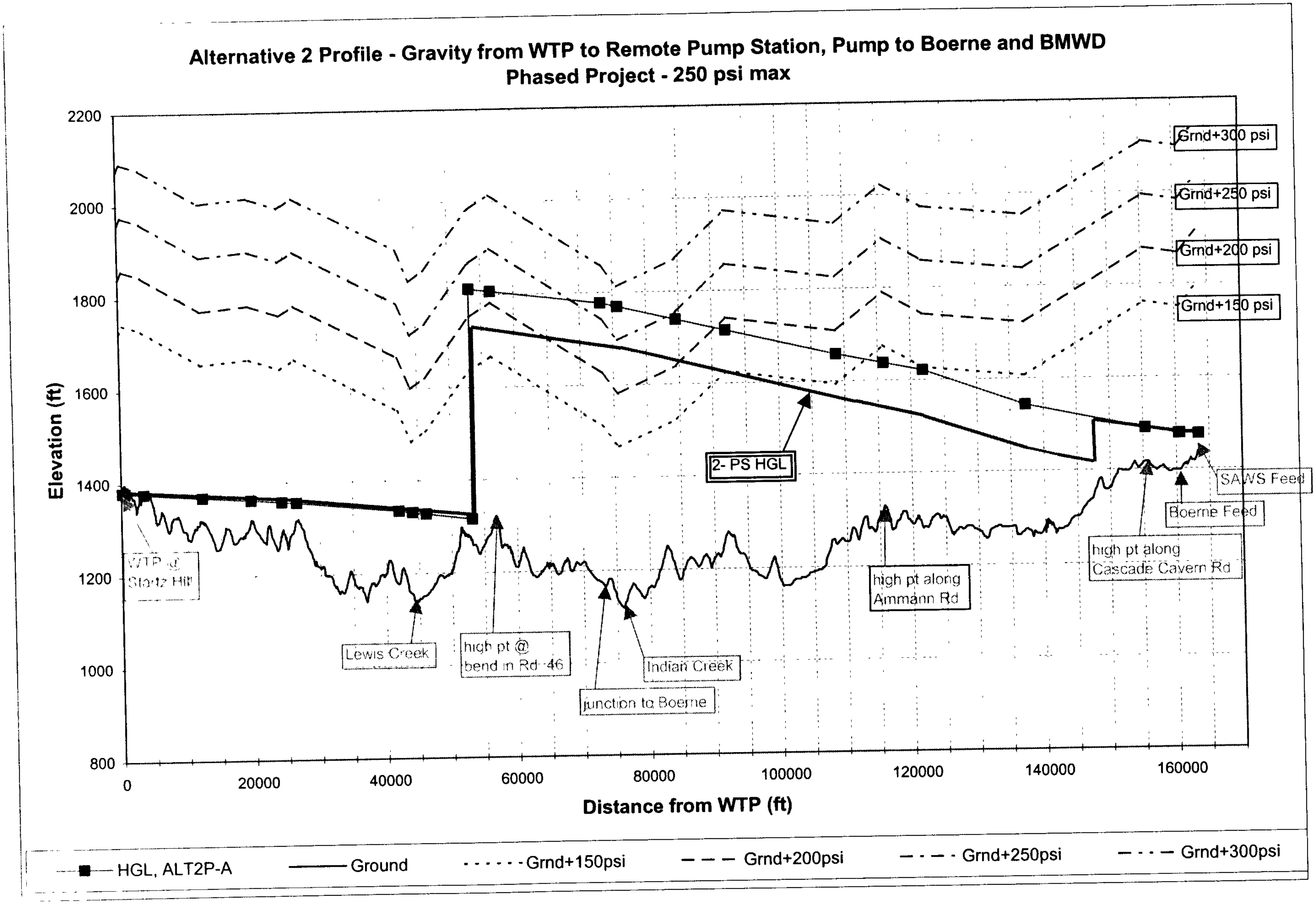
**FIGURE 5 - *Profile from WTP to SAWS***




HDR ENGINEERING, INC.

5/23/00;phase-PC.xls
r:\07081033\hyd

FIGURE 6 - *Profile from WTP to SAWS*




5/23/00;phase-PC.xls
r:\07081033\hyd

HDR ENGINEERING, INC.

**FIGURE 7 - *Profile from Boerne Junction to BMWD***

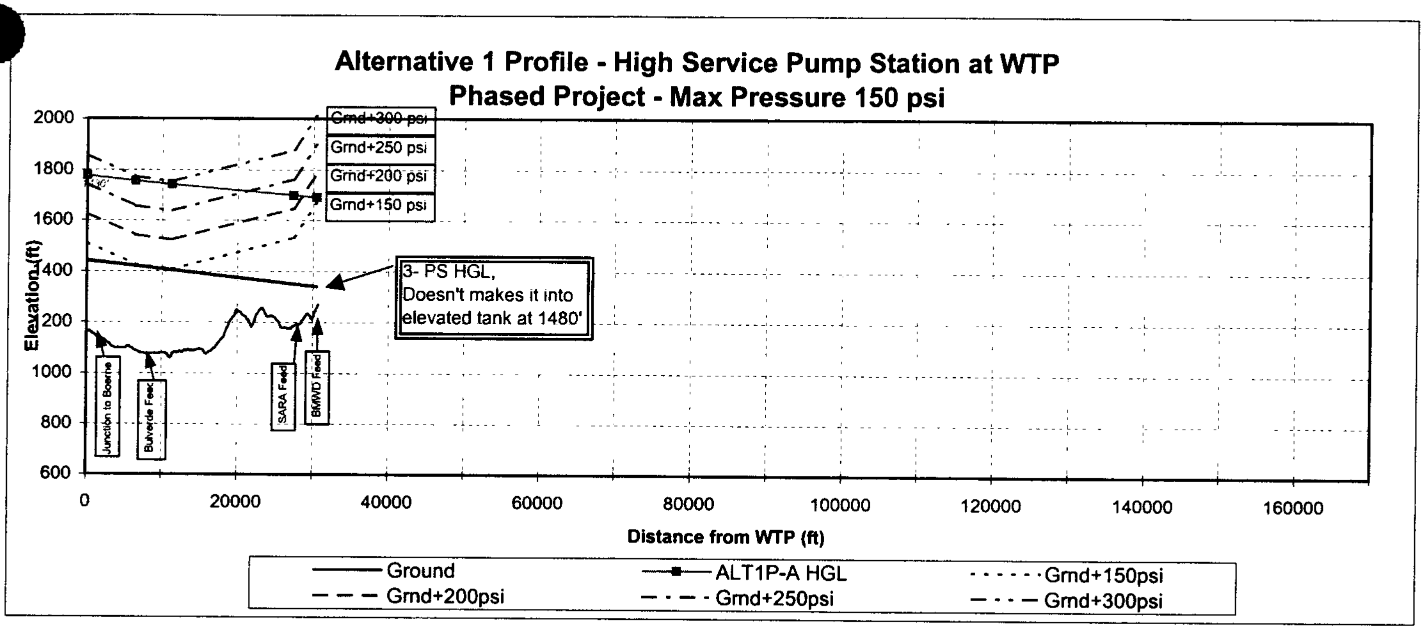



**FIGURE 8 - *Profile from Boerne Junction to BMWD***

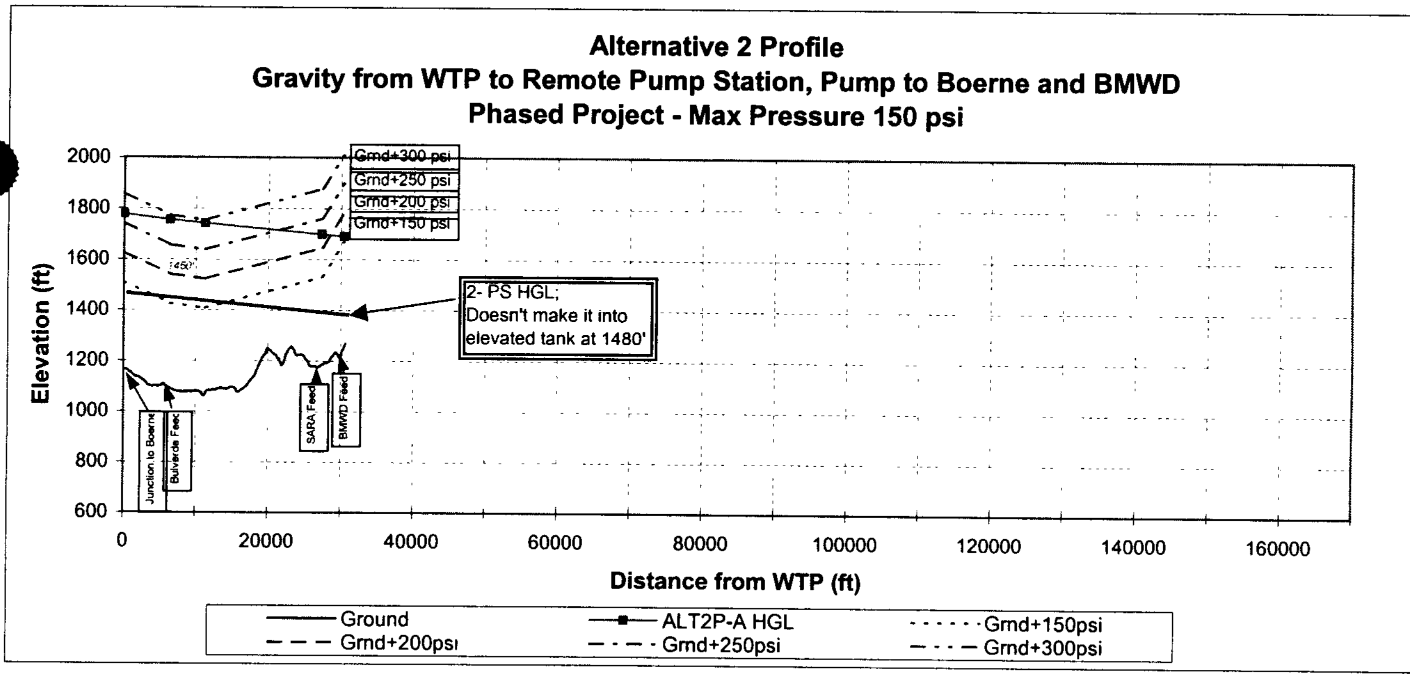


**FIGURE 9 - *Profile from Boerne Junction to BMWD***

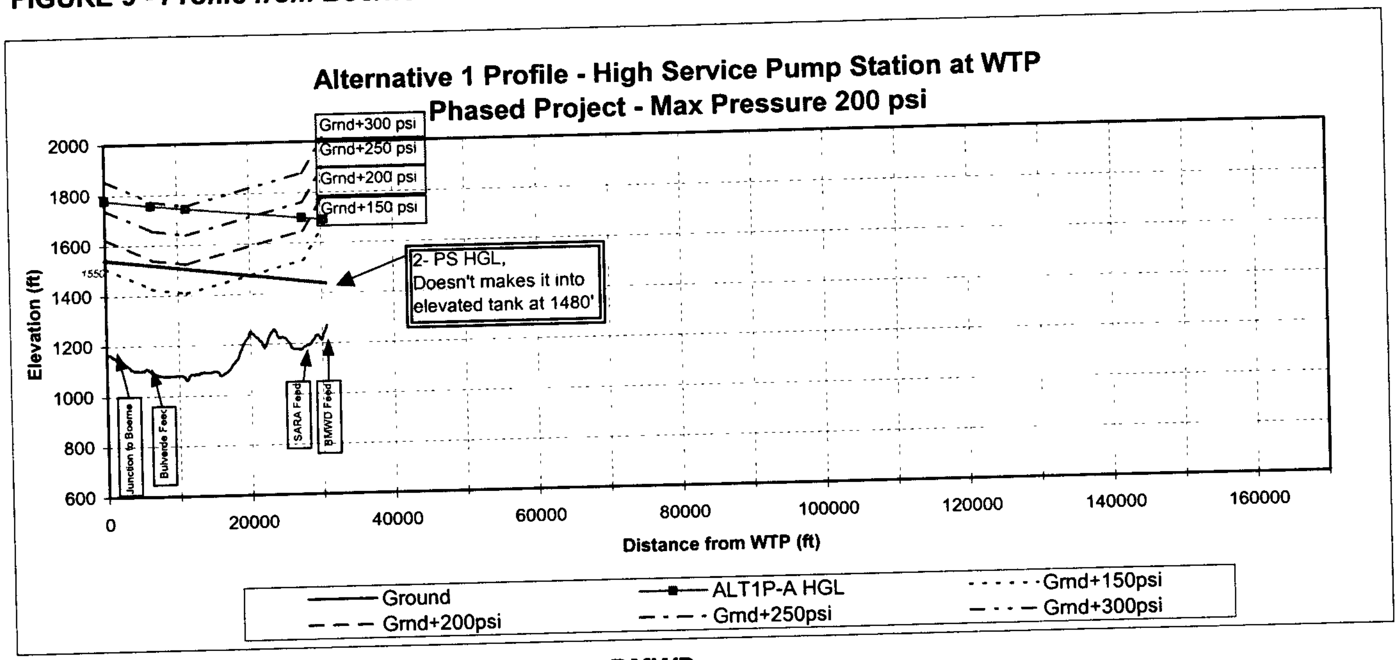



**FIGURE 10 - *Profile from Boerne Junction to BMWD***

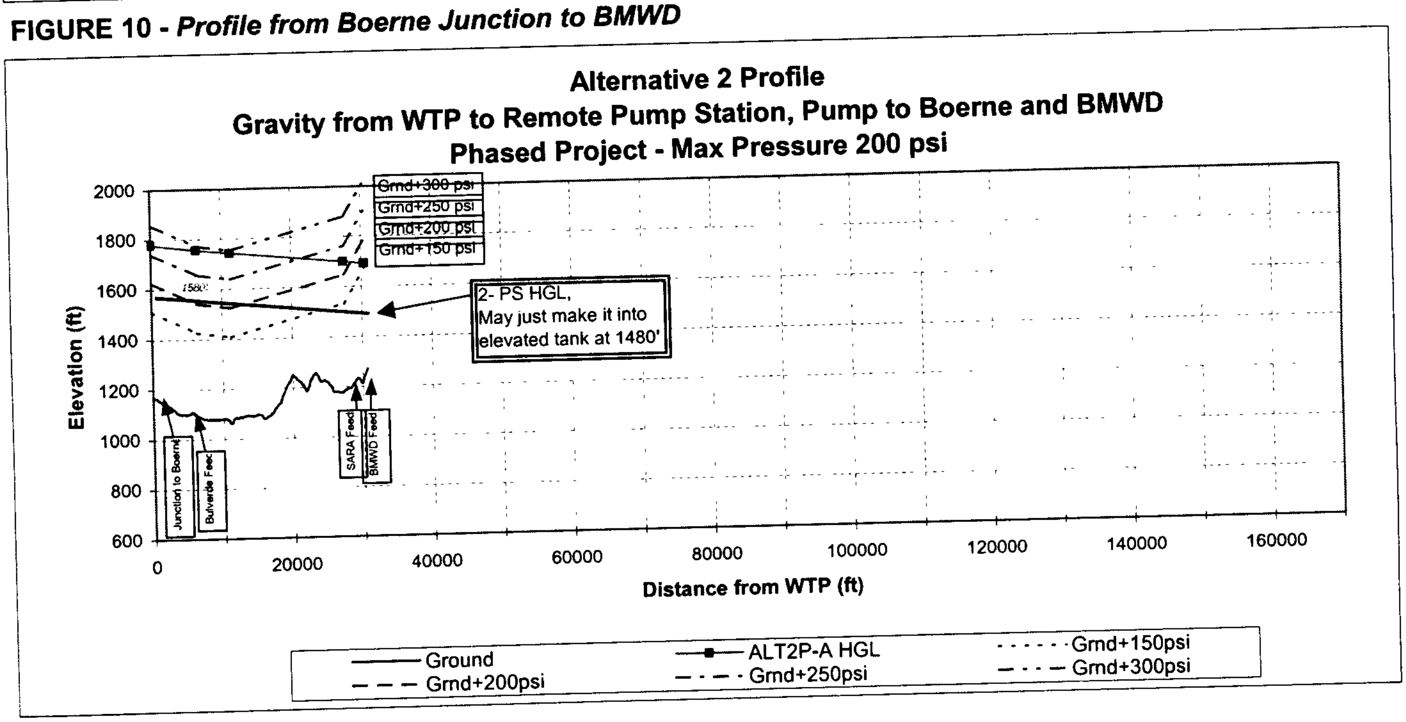


**FIGURE 11 -** ***Profile from Boerne Junction to BMWD***

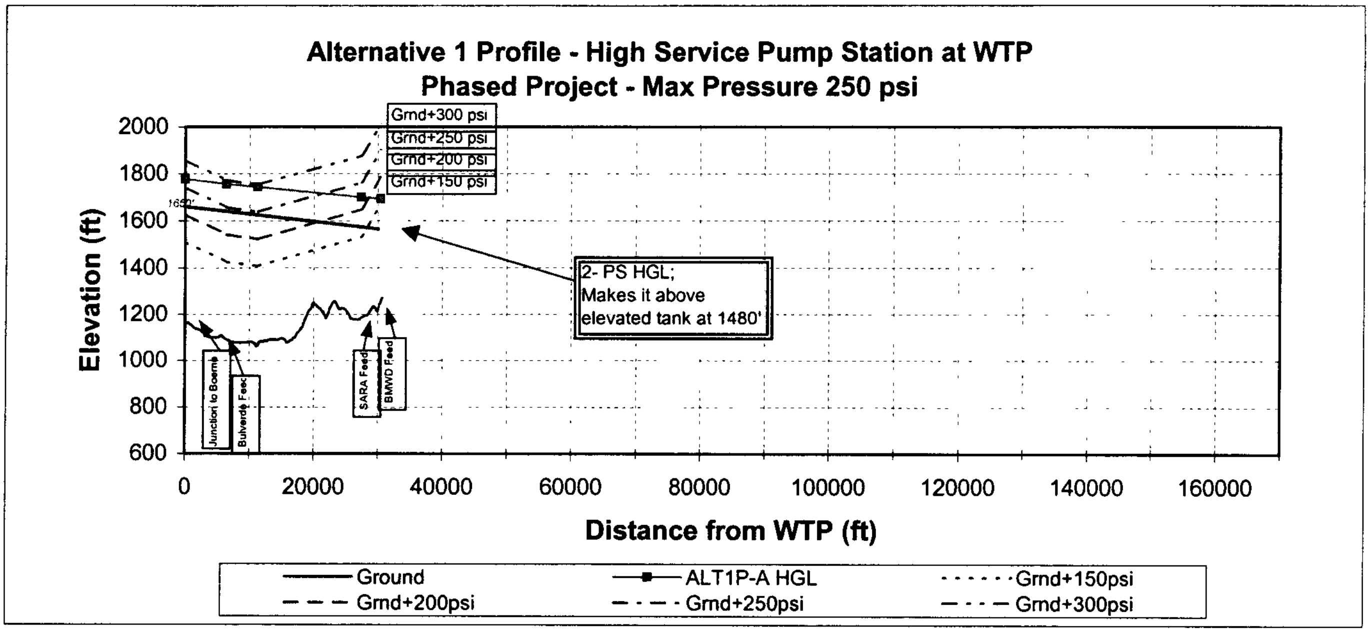
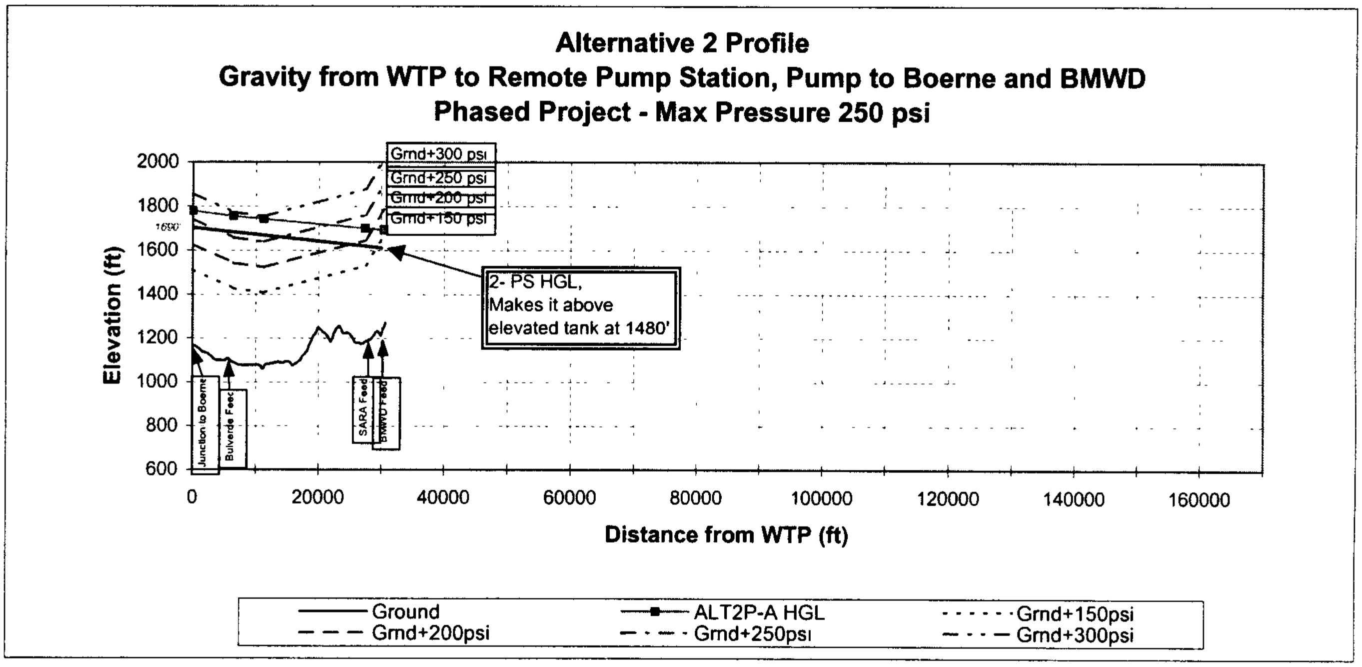



**FIGURE 12 -** ***Profile from Boerne Junction to BMWD***



# *TM No. 2 Appendix*

## *Background and Working Information*

GBRA REGIONAL WATER SYSTEM
ALTERNATIVES FOR CONVEYANCE OF POTABLE WATER FROM THE WTP TO GBRA PROJECT CUSTOMERS
EVALUATE VARIOUS MAXIMUM PRESSURE CLASSES FOR OPTIMAL BALANCE OF PIPING AND PUMPING COSTS

**PRELIMINARY ESTIMATE OF COSTS [1]**

| | ALT 1P-A | | | | ALT 2P-A | | | |
|---|---|---|---|---|---|---|---|---|
| **Basis of Comparison** | **150 psi Max** | **200 psi Max** | **250 psi Max** | **300 psi Max** | **150 psi Max** | **200 psi Max** | **250 psi Max** | **300 psi Max** |
| ***Capital Costs*** | | | | | | | | |
| Transmission Pipelines[2] | $ 14,225,000 | $ 14,746,000 | $ 15,889,000 | $ 17,754,000 | $ 15,199,000 | $ 15,641,000 | $ 16,184,000 | $ 17,031,000 |
| WTP Pump Station | $ 991,000 | $ 1,425,000 | $ 1,861,000 | $ 2,385,000 | - | - | - | - |
| Booster Pump Station 1 | $ 1,180,000 | $ 766,000 | $ 558,000 | - | $ 932,000 | $ 1,358,000 | $ 1,760,000 | $ 2,006,000 |
| Booster Pump Station 2 | $ 558,000 | - | - | - | $ 1,251,000 | $ 754,000 | $ 558,000 | - |
| Booster Pump Station 3 | - | - | - | - | $ 558,000 | - | - | - |
| System Storage | $ 799,000 | $ 399,000 | $ 399,000 | $ - | $ 1,198,000 | $ 799,000 | $ 799,000 | $ 399,000 |
| Electrical Feed | $ 193,000 | $ 193,000 | $ 216,000 | $ 239,000 | $ 204,000 | $ 184,000 | $ 200,000 | $ 196,000 |
| Total Capital Cost [3] | $ 17,946,000 | $ 17,529,000 | $ 18,923,000 | $ 20,378,000 | $ 19,342,000 | $ 18,736,000 | $ 19,501,000 | $ 19,632,000 |
| Add'l Land Acquisition (PS and Storage Tank) | $ 14,000 | $ 7,000 | $ 7,000 | $ - | $ 20,000 | $ 14,000 | $ 14,000 | $ 7,000 |
| Total Project Cost [3] | $ 17,960,000 | $ 17,536,000 | $ 18,930,000 | $ 20,378,000 | $ 19,362,000 | $ 18,750,000 | $ 19,515,000 | $ 19,639,000 |
| ***Annual O&M Costs*** | | | | | | | | |
| Annual Debt Service | $ 1,473,000 | $ 1,438,000 | $ 1,552,000 | $ 1,671,000 | $ 1,588,000 | $ 1,538,000 | $ 1,600,000 | $ 1,610,000 |
| *(Assuming 25 years, efective interest rate of 6.5%)* | | | | | | | | |
| Pumping Costs | $ 808,000 | $ 809,000 | $ 902,000 | $ 999,000 | $ 849,000 | $ 772,000 | $ 837,000 | $ 820,000 |
| Operation and Maintenance [4] | | | | | | | | |
| Pump Station | $ 68,000 | $ 55,000 | $ 60,000 | $ 60,000 | $ 69,000 | $ 53,000 | $ 58,000 | $ 50,000 |
| Transmission Facilities | $ 142,000 | $ 147,000 | $ 159,000 | $ 178,000 | $ 152,000 | $ 156,000 | $ 162,000 | $ 170,000 |
| Storage Facilities | $ 8,000 | $ 4,000 | $ 4,000 | $ - | $ 12,000 | $ 8,000 | $ 8,000 | $ 4,000 |
| | $ 1,026,000 | $ 1,015,000 | $ 1,125,000 | $ 1,237,000 | $ 1,082,000 | $ 989,000 | $ 1,065,000 | $ 1,044,000 |
| Total Annual Cost [3] | $ 2,499,000 | $ 2,453,000 | $ 2,677,000 | $ 2,908,000 | $ 2,670,000 | $ 2,527,000 | $ 2,665,000 | $ 2,654,000 |

[1] Costs are developed for purposes of preliminary evaluation and include only those costs that vary between the alternatives Thus, the costs should not be taken as final estimates for any alternative Maximum pressures represent max pressures in main pipeline, not including branch to BMWD

[2] Lengths obtained by graphical analysis of hydraulic profile using only a limited number of ground points for reference. This methodology was applied for comparative analysis only. Actual piping lengths will vary in design

[3] Items not included for cost comparison due to equivalence between alternatives include. Intake, Intake Pump Station and Water Treatment Plant, Interconnects to all participants, Equilization Tank near Boerne/SAWS Delivery Point, Environmental Studies

[4] O&M costs assume 1% of the total capital costs of pipelines and tanks, 2.5% of the total capital cost of pump stations

***Description of Alternatives***

Alt 1P-A· Single high service pump station at WTP (route along Rd 46); Phased to provide 14 mgd with add'l head to high service pump station at WTP

Alt. 2P-A. Gravity from WTP to west of Rd. 281 along Rd. 46 to remote pump station, pump to Boerne and BMWD; Phased to provide max capacity of 14 mgd

*SUMMARY OF PIPING SCHEMES*

| | ALT 1P-A | | | | ALT 2P-A | | | |
|---|---|---|---|---|---|---|---|---|
| | Max. Pressure Class[1] (psi) | | | | Max. Pressure Class[1] (psi) | | | |
| *Mainline Pres Class* | *150 psi* | *200 psi* | *250 psi* | *300 psi* | *150 psi* | *200 psi* | *250 psi* | *300 psi* |
| **No. of Req'd PS** | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 1 |
| **Pipe length, ft (p<150psi)** | 193841 | 137689 | 75841 | 50898 | 193841 | 147341 | 125841 | 103398 |
| **Pipe length, ft (150<p<200psi)** | 0 | 56152 | 73000 | 23943 | 0 | 38500 | 35500 | 24443 |
| **Pipe length, ft (200<p<250psi)** | 0 | 0 | 45000 | 57500 | 0 | 8000 | 24500 | 28500 |
| **Pipe length, ft (250<p<300psi)** | 0 | 0 | 0 | 61500 | 0 | 0 | 8000 | 37500 |
| **$PS_1$ Head Lift (ft)** | 195 | 300 | 410 | 545 | 210 | 330 | 450 | 522 |
| **$PS_1$ Flow (mgd)** | 14.0 | 14.0 | 14.0 | 14.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| **$PS_1$ hp** | 680 | 1050 | 1440 | 1910 | 630 | 990 | 1350 | 1570 |
| **$PS_2$ Head Lift (ft)** | 300 | 250 | 145 | - | 320 | 245 | 125 | - |
| **$PS_2$ Flow (mgd)** | 11.2 | 7.9 | 7.9 | - | 11.2 | 7.9 | 7.9 | - |
| **$PS_2$ hp** | 840 | 490 | 290 | - | 900 | 480 | 250 | - |
| **$PS_3$ Head Lift (ft)** | 110 | - | - | - | 75 | - | - | - |
| **$PS_3$ Flow (mgd)** | 7.9 | - | - | - | 5.1 | - | - | - |
| **$PS_3$ hp** | 20 | - | - | - | 100 | - | - | - |
| | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 |

[1] Represents maximum pressure class in main pipeline and does not include branch to BMWD.

## DETAILED LENGTH BREAKDOWN[1]

| | | Length of Piping (ft) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ALT.1P-A | | | | ALT.2P-A | | | |
| Dia (in) | Specific PC/Mainline Max PC (psi) | 150 | 200 | 250 | 300 | 150 | 200 | 250 | 300 |
| 36 | <150 | 0 | 0 | 0 | 0 | 26506 | 26506 | 26506 | 26506 |
| 33 | <150 | 0 | 0 | 0 | 0 | 15536 | 15536 | 15536 | 15536 |
| 30 | 300 | 0 | 0 | 0 | 28152 | 0 | 0 | 0 | 5152 |
| | 250 | 0 | 0 | 17652 | 45000 | 0 | 0 | 8152 | 15000 |
| | 200 | 0 | 24152 | 55500 | 0 | 0 | 9652 | 12000 | 0 |
| | <150 | 73152 | 49000 | 0 | 0 | 31110 | 21458 | 10958 | 10958 |
| 24 | 300 | 0 | 0 | 0 | 10848 | 0 | 0 | 0 | 9848 |
| | 250 | 0 | 0 | 9348 | 7000 | 0 | 0 | 11848 | 8000 |
| | 200 | 0 | 11000 | 7500 | 21500 | 0 | 12848 | 7500 | 22000 |
| | <150 | 48668 | 37668 | 31820 | 9320 | 48668 | 35820 | 29320 | 8820 |
| 20 | <150 | 38617 | 38617 | 38617 | 38617 | 38617 | 38617 | 38617 | 38617 |
| 18 | <150 | 2961 | 2961 | 2961 | 2961 | 2961 | 2961 | 2961 | 2961 |
| 14 | 300 | 0 | 0 | 0 | 22500 | 0 | 0 | 8000 | 22500 |
| | 250 | 0 | 0 | 18000 | 5500 | 0 | 8000 | 4500 | 5500 |
| | 200 | 0 | 21000 | 10000 | 2443 | 0 | 16000 | 16000 | 2443 |
| | <150 | 30443 | 9443 | 2443 | 0 | 30443 | 6443 | 1943 | 0 |
| Totals | | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 | 193841 |

[1] Lengths obtained by graphical analysis of hydraulic profile using only a limited number of ground points for reference. This methodology was applied for comparative analysis only. Actual piping lengths will vary in design.

## DETAILED COST BREAKDOWN[1]

| | | Length of Piping (ft) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ALT.1P-A | | | | ALT.2P-A | | | |
| Dia. (in.) | Specific PC/Mainline Max. PC (psi) | 150 | 200 | 250 | 300 | 150 | 200 | 250 | 300 |
| 36 | <150 | | | | | $ 3,173,285 | $ 3,173,285 | $ 3,173,285 | $ 3,173,246 |
| 33 | <150 | | | | | $ 1,639,289 | $ 1,639,289 | $ 1,639,289 | $ 1,639,295 |
| 30 | 300 | | | | $ 3,709,112 | | | | $ 678,792 |
| | 250 | | | $ 2,058,146 | $ 5,246,803 | | | $ 950,488 | $ 1,748,934 |
| | 200 | | $ 2,492,051 | $ 5,726,599 | | | $ 995,912 | $ 1,238,184 | |
| | <150 | $ 6,679,617 | $ 4,474,262 | | | $ 2,840,700 | $ 1,959,362 | $ 1,000,591 | $ 1,000,591 |
| 24 | 300 | | | | $ 1,111,644 | | | | $ 1,009,170 |
| | 250 | | | $ 847,728 | $ 634,798 | | | $ 1,074,442 | $ 725,484 |
| | 200 | | $ 882,779 | $ 601,895 | $ 1,725,432 | | $ 1,031,086 | $ 601,895 | $ 1,765,558 |
| | <150 | $ 3,456,403 | $ 2,675,183 | $ 2,259,858 | $ 661,907 | $ 3,456,403 | $ 2,543,938 | $ 2,082,307 | $ 626,397 |
| 20 | <150 | $ 2,429,143 | $ 2,429,143 | $ 2,429,143 | $ 2,429,174 | $ 2,429,143 | $ 2,429,143 | $ 2,429,143 | $ 2,429,171 |
| 18 | <150 | $ 177,245 | $ 177,245 | $ 177,245 | $ 177,233 | $ 177,245 | $ 177,245 | $ 177,245 | $ 177,233 |
| 14 | 300 | | | | $ 1,581,037 | | | $ 562,146 | $ 1,581,037 |
| | 250 | | | $ 1,119,318 | $ 342,014 | | $ 497,475 | $ 279,829 | $ 342,014 |
| | 200 | | $ 1,155,638 | $ 550,304 | $ 134,439 | | $ 880,486 | $ 880,486 | $ 134,439 |
| | <150 | $ 1,482,557 | $ 459,869 | $ 118,973 | | $ 1,482,557 | $ 313,771 | $ 94,623 | |
| **Totals** | | **$ 14,224,965** | **$ 14,746,170** | **$ 15,889,208** | **$ 17,753,593** | **$ 15,198,622** | **$ 15,640,990** | **$ 16,183,952** | **$ 17,031,360** |
| *Previous Analysis using more conservative approach to est. pressure class* | | | | | *$ 18,368,189* | | | | *$ 16 914 202* |

[1] Costs based on lengths obtained by graphical analysis of hydraulic profile using only a limited number of ground points for reference. This methodology was applied for comparative analysis only. Actual piping lengths will vary in design

# Pumping Costs
## Phasing

Equation for pumping/energy costs (assumes continuous operation)

$$\frac{\left(Qmgd \times 694.4\frac{gpm}{mgd} \times H(ft)\right)}{3960 \times 0.70} \times 0.746\frac{kW}{hp} \times 8{,}760\frac{hrs}{yr} \times 0.08\frac{\$}{kWh} = Cost\$/yr$$

where overall efficiency = 0 7
energy rate ($/kWh)= 0 08

**Alt 1P-A -Increase Pump Head, Q= 14 MGD**
-Involves a single high service pumping station to Boerne
***150 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Pump 3 | Total |
|---|---|---|---|---|
| Pump Head (ft)= | 195 | 300 | 10 | |
| Flow, Q (mgd)= | 14 0 | 11 2 | 7 9 | |
| Pump hp = | 680 | 840 | 20 | *1540* |
| Est PS Capital Cost (mil$)= | 0 99 | 1 18 | 0 56 | *2 7* |
| O&M Energy Cost ($/yr)= | $ 357 530 | $ 440,036 | $ 10 346 | $ *807 912* |
| Power Connection Cost ($)= | $ 85 000 | $ 105 000 | $ 2,500 | $ *192,500* |

**Alt 1P-A -Increase Pump Head, Q= 14 MGD**
Involves a single high service pumping station to Boerne
***200 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Total |
|---|---|---|---|
| Pump Head (ft)= | 300 | 250 | |
| Flow Q (mgd)= | 14 0 | 7 9 | |
| Pump hp = | 1050 | 490 | *1540* |
| Est PS Capital Cost (mil$)= | 1 43 | 0 77 | *2 2* |
| O&M Energy Cost ($/yr)= | $ 550 046 | $ 258,652 | $ *808,698* |
| Power Connection Cost ($)= | $ 131,250 | $ 61,250 | $ *192,500* |

**Alt 1P-A -Increase Pump Head, Q= 14 MGD**
-Involves a single high service pumping station to Boerne
***250 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Total |
|---|---|---|---|
| Pump Head (ft)= | 410 | 145 | |
| Flow Q (mgd)= | 14 0 | 7 9 | |
| Pump hp = | 1440 | 290 | *1730* |
| Est PS Capital Cost (mil$)= | 1 86 | 0 56 | *2 4* |
| O&M Energy Cost ($/yr)= | $ 751,729 | $ 150 018 | $ *901 747* |
| Power Connection Cost ($)= | $ 180 000 | $ 36 250 | $ *216,250* |

**Alt 1P-A -Increase Pump Head, Q= 14 MGD**
-Involves a single high service pumping station to Boerne
***300 psi maximum in Mainline***

| | Pump 1 |
|---|---|
| Pump Head (ft)= | 545 |
| Flow Q (mgd)= | 14 0 |
| Pump hp = | **1910** |
| Est PS Capital Cost (mil$)= | 2 39 |
| O&M Energy Cost ($/yr)= | $ 999,250 |
| Power Connection Cost ($)= | $ 238,750 |

**Alt. 2P-A - Upsize Dia.s in Gravity Line, Q= 14 MGD**
-Involves gravity to remote PS, pump to BMWD & Boerne
***150 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Pump 3 | Total |
|---|---|---|---|---|
| Pump Head (ft)= | 210 | 320 | 75 | |
| Flow, Q (mgd)= | 12 0 | 11 2 | 5 1 | |
| Pump hp = | 630 | 900 | 100 | *1630* |
| Est PS Capital Cost (mil$)= | 0 93 | 1 25 | 0.56 | *2 7* |
| O&M Energy Cost ($/yr)= | $ 330,027 | $ 469,372 | $ 50,093 | $ *849,493* |
| Power Connection Cost ($)= | $ 78,750 | $ 112,500 | $ 12,500 | $ *203,750* |

**Alt. 2P-A - Upsize Dia.s in Gravity Line, Q= 14 MGD**
-Involves gravity to remote PS, pump to BMWD & Boerne
***200 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Total |
|---|---|---|---|
| Pump Head (ft)= | 330 | 245 | |
| Flow, Q (mgd)= | 12 0 | 7 9 | |
| Pump hp = | 990 | 480 | *1470* |
| Est PS Capital Cost (mil$)= | 1 36 | 0 75 | *2.1* |
| O&M Energy Cost ($/yr)= | $ 518,614 | $ 253,479 | $ *772,094* |
| Power Connection Cost ($)= | $ 123,750 | $ 60,000 | $ *183,750* |

**Alt. 2P-A - Upsize Dia.s in Gravity Line, Q= 14 MGD**
-Involves gravity to remote PS, pump to BMWD & Boerne
***250 psi maximum in Mainline***

| | Pump 1 | Pump 2 | Total |
|---|---|---|---|
| Pump Head (ft)= | 450 | 125 | |
| Flow, Q (mgd)= | 12 0 | 7 9 | |
| Pump hp = | 1350 | 250 | *1600* |
| Est PS Capital Cost (mil$)= | 1 76 | 0.56 | *2 3* |
| O&M Energy Cost ($/yr)= | $ 707,201 | $ 129,326 | $ *836,528* |
| Power Connection Cost ($)= | $ 168,750 | $ 31,250 | $ *200,000* |

**Alt 2P-A - Upsize Dia.s in Gravity Line, Q= 14 MGD**
-Involves gravity to remote PS, pump to BMWD & Boerne
***300 psi maximum in Mainline***

| | Pump 1 |
|---|---|
| Pump Head (ft)= | 522 |
| Flow, Q (mgd)= | 12 0 |
| Pump hp = | **1570** |
| Est. PS Capital Cost (mil$)= | 2 01 |
| O&M Energy Cost ($/yr)= | $ 820,354 |
| Power Connection Cost ($)= | $ 196,250 |

| ENR= | 6039 | 6127 |
|---|---|---|
| | 2nd quarter, 1999 | last quarter, 1999 |

**Pumping Station Costs**

| (hp) | (mil$) | (mil$) |
|---|---|---|
| <400 | 0 55 | 0.56 |
| 400 | 0 65 | 0 66 |
| 1000 | 1 35 | 1 37 |
| 2000 | 2 45 | 2 49 |
| 3000 | 3 38 | 3.43 |
| 4000 | 4 08 | 4 14 |
| 5000 | 4 61 | 4 68 |
| 6000 | 5 04 | 5 11 |
| 7000 | 5 47 | 5.55 |
| 8000 | 5 76 | 5 84 |
| 9000 | 6 04 | 6 13 |
| 10000 | 6 3 | 6 39 |
| 15000 | 7 28 | 7 39 |
| 3000 | 9 23 | 9 36 |
| 60000 | 12 01 | 12 19 |
| 80000 | 13 05 | 13 24 |
| 100000 | 13 98 | 14 18 |

*Reference. HDR Cost Estimating, Section 5 of Studies Level Engineering and Costing Methodology, Senate Bill 1 Report.*

Costs for pumping stations include costs for pumps, housing, motors, electrical control, site work, and all materials needed

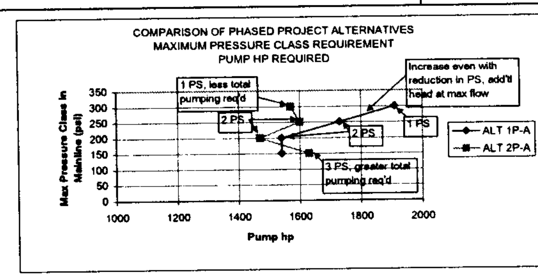
$$PowerConn\ (\$50{,}000\,\text{min}) = \frac{\$125}{1hp} \times Stationhp$$

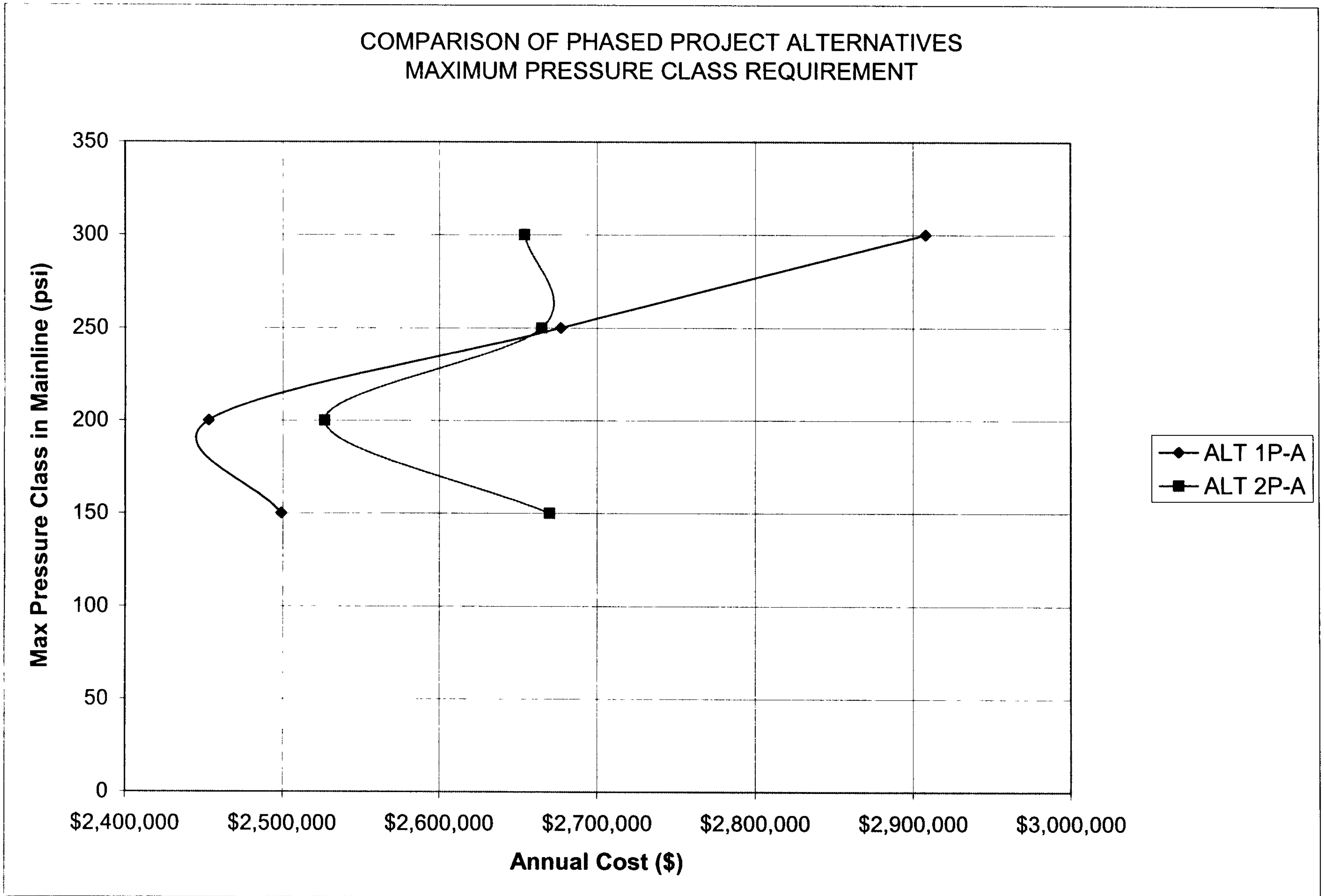
Costs for electrical power connection include the distance to the nearest power source and the electrical demand of the pumping station The following equation was developed to estimate power connection costs

***Description of Alternatives***
Alt. 1 - Single high service pump station at WTP (route along Rd 46).
Alt. 1P-A. Add'l head to high service pump station at WTP

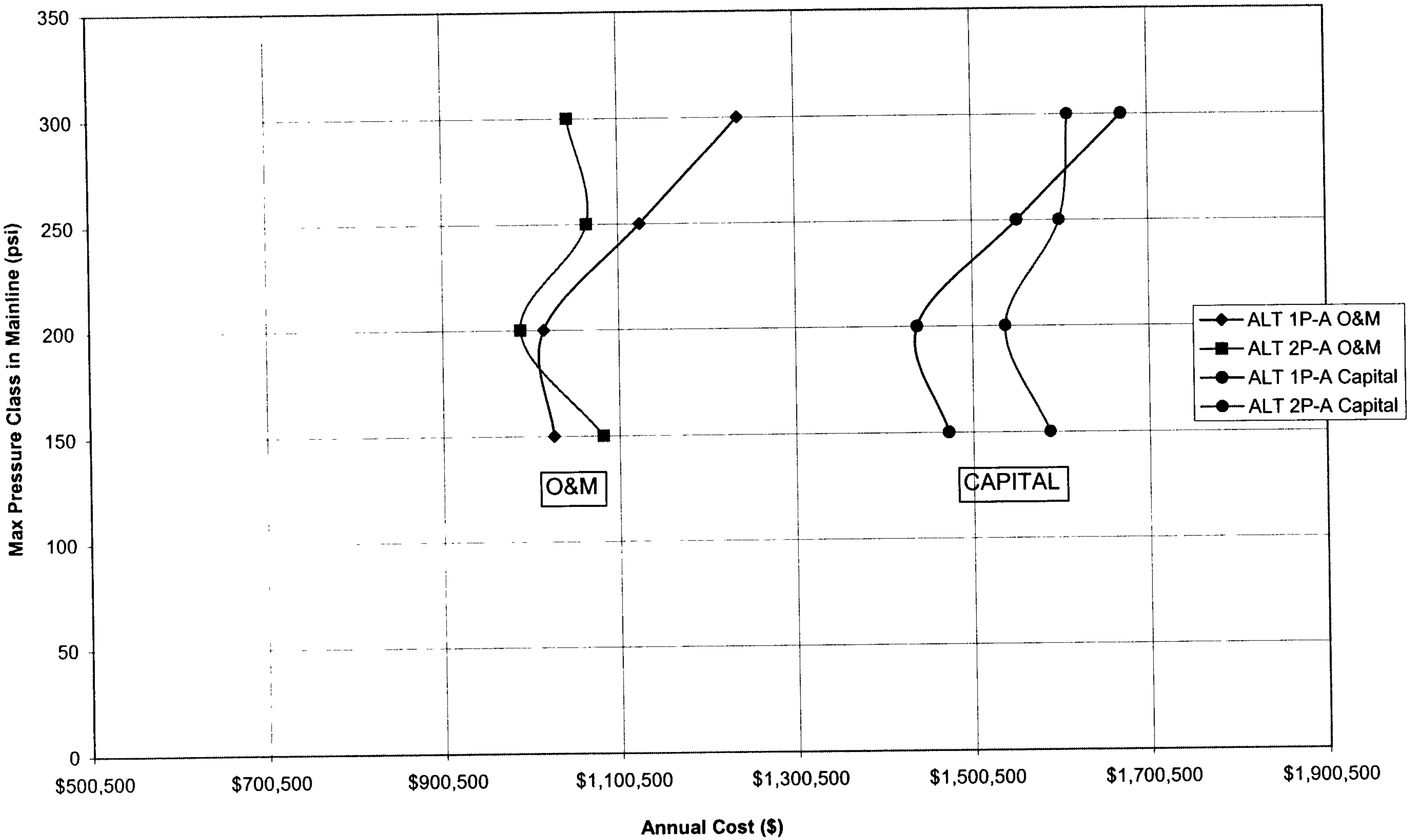
Alt. 2 - Gravity from WTP to west of Rd 281 along Rd 46 to remote pump station, pump to Boerne and BMWD
Alt 2P-A. Increase pipe size in gravity line to provide Max capacity of 14 mgd

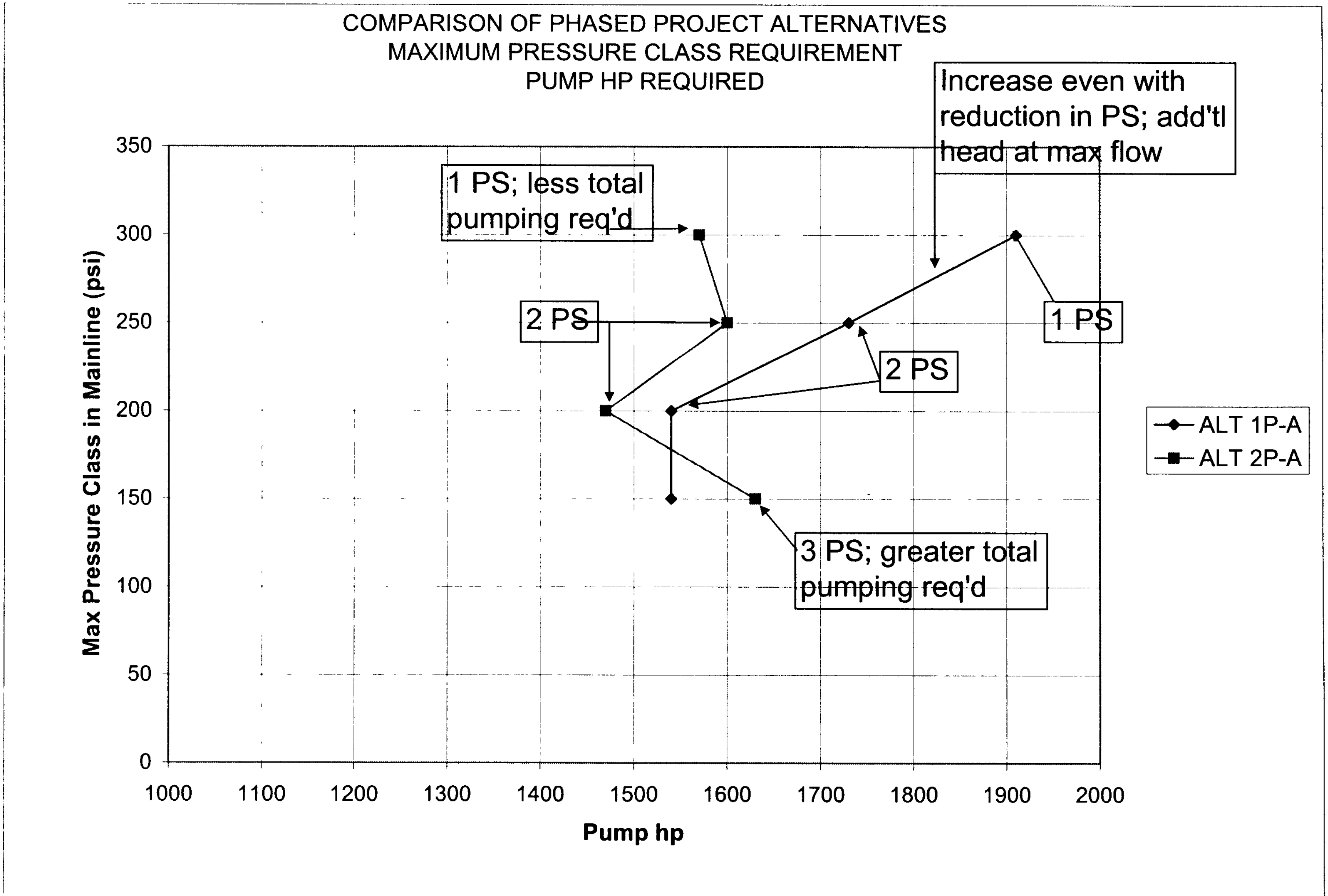
| | ALT 1P-A | | | | ALT 2P-B | | | |
|---|---|---|---|---|---|---|---|---|
| Max Pressure in Mainline | 150 | 200 | 250 | 300 | 150 | 200 | 250 | 300 |
| Pump hp | 1540 | 1540 | 1730 | 1910 | 1630 | 1470 | 1600 | 1570 |




COMPARISON OF PHASED PROJECT ALTERNATIVES
MAXIMUM PRESSURE CLASS REQUIREMENT
Max Pressure Class in Mainline (psi)
350
300
250
200
150
100
50
0
$2,400,000
$2,500,000
$2,600,000
$2,700,000
$2,800,000
$2,900,000
$3,000,000
Annual Cost ($)
ALT 1P-A
ALT 2P-A

## COMPARISON OF PHASED PROJECT ALTERNATIVES
## MAXIMUM PRESSURE CLASS REQUIREMENT
## CAPITAL AND O&M COSTS




COMPARISON OF PHASED PROJECT ALTERNATIVES
MAXIMUM PRESSURE CLASS REQUIREMENT
PUMP HP REQUIRED
Increase even with reduction in PS; add'tl head at max flow
1 PS; less total pumping req'd
2 PS
1 PS
2 PS
3 PS; greater total pumping req'd
ALT 1P-A
ALT 2P-A
Max Pressure Class in Mainline (psi)
350
300
250
200
150
100
50
0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Pump hp

## *Appendix C*
## *Technical Memorandum No. 3*

*To:* File: 07081-033-036

*From:* Christianne Gaylord
(Registered in California, C57977)

*Date:* February 21, 2000 (Revised May 23, 2000)

HDR

*Technical Memorandum*

*Subject:* **Guadalupe-Blanco River Authority Regional Water System For Portions of Comal, Kendall, and Bexar Counties**
***HDR Project No. 07081-033-036***
Technical Memorandum No. 3
Hydraulic Design Alternatives for Reduced Maximum Pressure Class

---

**Purpose**

The purpose of this technical memorandum (TM) is to further supplement previous hydraulic analysis of design alternatives evaluated for the Guadalupe-Blanco River Authority (GBRA) Regional Water System for portions of Comal, Kendall, and Bexar Counties. In response to concerns raised during Milestone Meeting No. 1, the maximum pipe pressure class criteria for the mainline of the system was evaluated further to establish the optimum pressure class for the hydraulic design alternatives. Results of the 200 psi optimum maximum pressure class are summarized in Technical Memorandum No. 2 (TM No. 2), *Determination of Maximum Pressure Class*.

Based on the results of TM No. 2, additional evaluation for feasible hydraulic design alternatives was performed and is summarized herein, in TM No. 3. This evaluation includes a comparison of the differential probable costs for a reduced maximum pressure class design of the preferred alternative piping and pumping station scenario (pump to all delivery points) evaluated previously in TM No. 1, *Water Delivery System Hydraulic Design and Expansion Alternatives*. A final hydraulic design alternative is recommended based on the optimum 200 psi maximum pressure within almost all of the proposed system.

**Basis of Analysis**

This analysis is intended to supplement previous analyses presented in TM No. 1 and TM No. 2 and utilizes the following basic information:

- Preliminary Pipeline Route (same as that used for TM s No. 1 and 2 analyses).
- Alternative Pipeline Route – Power Transmission Line
- Ground Profiles for Preliminary and Alternative Pipeline Routes.
- System Demand Distribution and Phased Project Distribution.
- Preferred Hydraulic Design Approach – Pump to all Delivery Points.
- Phased Project Equivalent Pipe Sizing.
- Hazen-Williams Friction Coefficient of 120.
- Optimum Maximum Pressure Class of 200 psi for Reduced Maximum Pressure Class.

Refer to TMs No. 1 and 2 for a detailed description of the above information. TM No. 3 serves to further evaluate the feasibility of the preferred hydraulic design alternative for criteria developed in TM No.2, specifically reduction of the maximum pressure within the majority of transfer piping from 300 psi to 200 psi. The analysis described herein further evaluates the feasibility of hydraulic design alternatives for reduced maximum pressure of 200 psi, and details the additional facilities required to accomplish phased project expansion to 15 mgd (16,803 acft/yr).

This phased project capacity value allows for meeting the annual delivery quantity in 347 days, or 95% of the year, to allow for losses and/or downtimes. It should be noted that the 15 mgd value of maximum capacity for the system is also based on a particular demand distribution assumed for expanded flow capacity and may vary based on the actual demand distribution of additional flows.

**Base Project Alternatives and Phasing Options for Future Capacity Expansion**

In TMs No. 1 and 2, hydraulic design Alternatives 1 and 2 were evaluated to investigate the potential for expansion of the project facilities to deliver water that may be made available by maximizing capacity of the system. The most feasible expansion options for the preferred Alternative 1 (pumped delivery to all customers) have been evaluated further for the purposes of this TM and include the following:

*Alternative 1 (as presented in TM No. 1 and No. 2)- Pump base project demand of 9.9 mgd to all delivery points with single PS located at WTP. Maximum pressure class of 250 psi.*

- **ALT 1P-A1**. Increase capacity and head of high service pump station at WTP and pressure class of pipelines to 300 psi for maximum capacity expansion.
- **ALT 1P-A2**. Increase capacity of system by addition of remote pump station, maintain 250 psi maximum pressure for maximum capacity expansion.

*Alternative 1(a) – Reduced Maximum Pressure - Pump base project demand of 9.9 mgd to all delivery points with maximum pressure to 150 psi, requiring both a WTP pump station and remote pump station.*

- **ALT 1(a)P-1**. Increase pressure class of pipelines to 200 psi for maximum capacity expansion.
- **ALT 1(a)P-2**. Increase capacity of system by addition of a second remote pump station, maintain 150 psi maximum pressure for phased project maximum capacity expansion.

Comparison of the above phasing alternatives was accomplished using a capacity value of 14 mgd, the maximum capacity of the Alternative 1 system (with a single pump station at the WTP). This maximum capacity value is used initially to establish a basis of comparison between the alternatives for selection of the most feasible hydraulic design approach. The actual maximum capacity of the selected system will be determined and applied for the preferred final design alternative.

**Methodology for Evaluation of Reduced Maximum Pipe Pressure Class**

The methodology for determination of the reduced maximum pipe pressure class consisted of utilizing the hydraulic grade lines (HGLs) developed in TMs No. 1 and 2. Since the piping diameter and flow for the base and phased projects remain unchanged, the slope of the HGL also remains the same. For simplicity, graphical analysis using these HGLs was conducted to develop the reduced maximum pressure alternative.

The HGL required for the reduced maximum pipe pressure class condition was mapped to provide a minimum working pressure of 10 psi at any point in the line, requiring addition of a booster pump station once the minimum pressure is reached midway through the pipeline.

**Hydraulic Grade Line, HGL**

The resulting HGL profiles for the base and reduced maximum pressure class alternatives are graphed from the WTP to SAWS in Figures 1 and 2, respectively. The profiles indicate HGL profiles for both the base and phased project conditions.

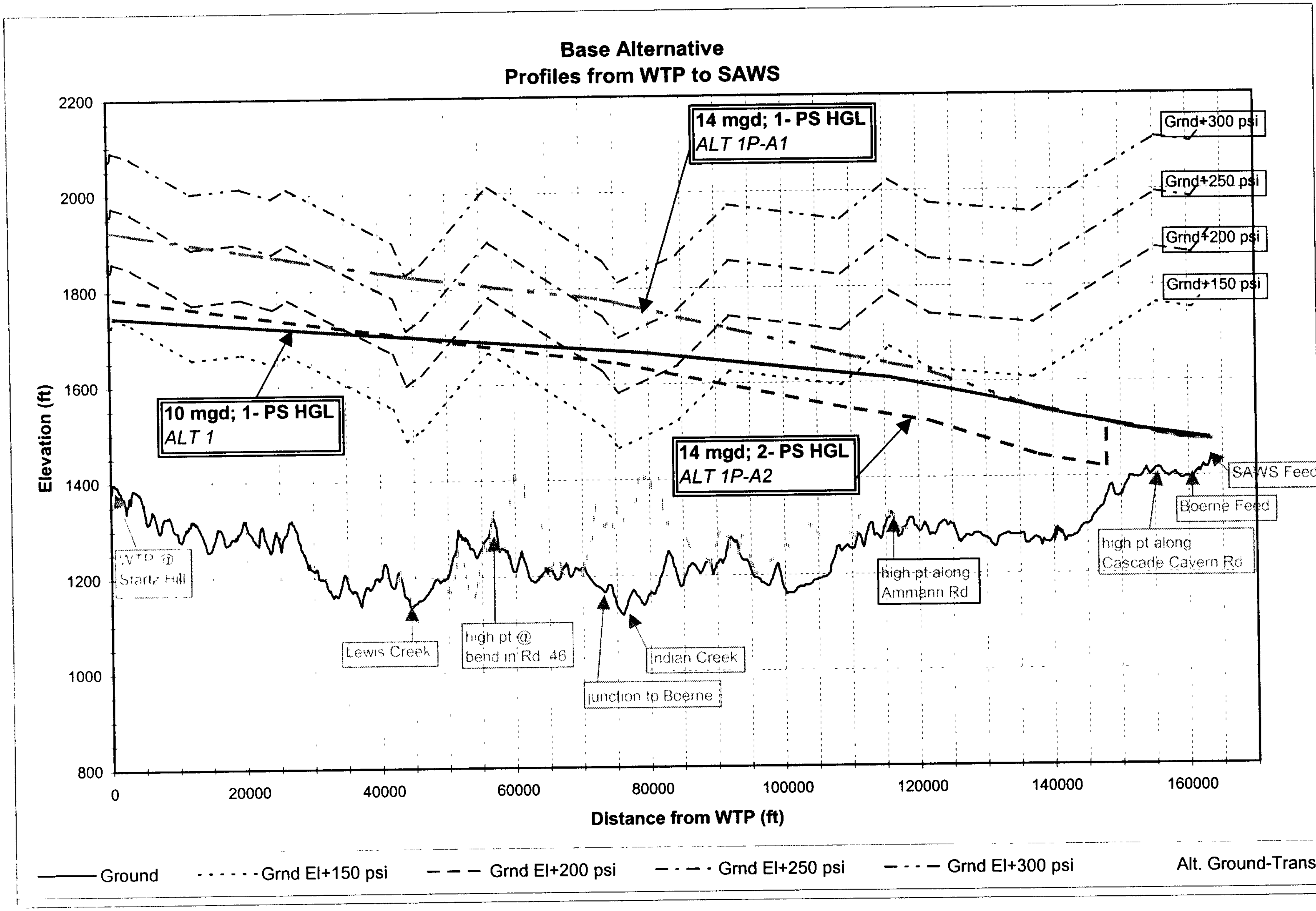
The reduced maximum pressure of 150 psi alternative is feasible for the current pipeline alignment, but not for the alternative alignment along the power transmission line. If the power transmission line alignment were to be selected, a maximum pressure class of at least 200 psi must be allowed under base project conditions, as indicated in Figure 2.

Evaluation of the most feasible reduced maximum pressure class alternative was continued using the pipeline alignment used previously in TM No.s 1 and 2, as detailed below. The effect of interchanging this alignment with the Power Transmission Line Route (Alternative) is addressed in the *Recommended Hydraulic Design Alternative* Section of this TM.

***Required Piping Lengths***

The required piping lengths for each alternative were evaluated directly from the HGL profiles. Since this graphic methodology varies distinctly from the spreadsheet calculation methodology used in TM No.1, the resulting distances are not equivalent. In fact, since only the extreme high and low ground points were used to create the HGL profiles, estimation of required pressure class by graphical methods results in an averaged value, rather than the maximum estimated value predicted from TM No. 1 spreadsheet calculations. However, for the purposes of this comparison, the base alternative (250 psi max for 9.9 mgd; 300 psi max for full capacity expansion) was estimated graphically to produce an averaged value comparable to the remaining analyses. The resulting measured lengths are tabulated for corresponding pressure class ranges in Table 1, *Summary of Required Piping – Reduced Maximum Pressure Class Evaluation*.

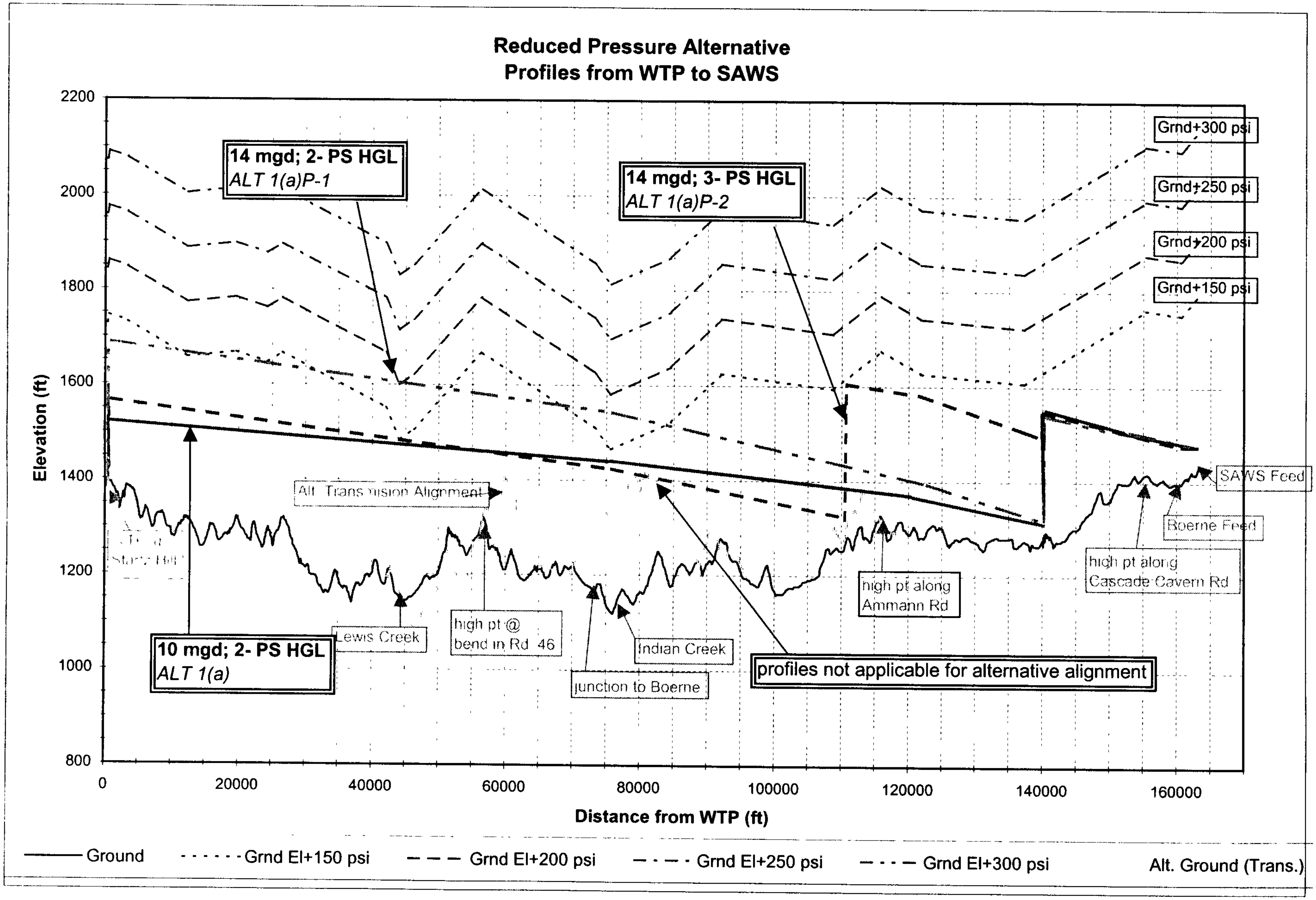
## FIGURE 1




5/24/00;Alt1reducedPC.xls
r:\07081033\hyd

HDR ENGINEERING, INC.

## FIGURE 2




HDR ENGINEERING, INC.

5/24/00;Alt1reducedPC.xls
r:\07081033\hyd

TABLE 1 – *Summary of Required Piping – Reduced Maximum Pressure Class Evaluation*

| | Base Project | | Phased Project | | | |
|---|---|---|---|---|---|---|
| | Alt1 | Alt1(a) | Alt1P-A1 | Alt1P-A2 | Alt1(a)P-1 | Alt1(a)P-2 |
| ***Max. Pressure Class[1]/No. PSs*** | ***250 psi; 1 PS*** | ***150 psi; 2 PS*** | ***300 psi; 1 PS*** | ***250 psi; 2 PS*** | ***200 psi; 2 PS*** | ***150 psi; 3 PS*** |
| Pipe length, ft (p<150psi) | 75841 | 193841 | 50898 | 75841 | 137689 | 193841 |
| Pipe length, ft (150<p<200psi) | 73000 | 0 | 23943 | 73000 | 56152 | 0 |
| Pipe length, ft (200<p<250psi) | 45000 | 0 | 57500 | 45000 | 0 | 0 |
| Pipe length, ft (250<p<300psi) | 0 | 0 | 61500 | 0 | 0 | 0 |

[1] Represents maximum pressure class in main pipeline and does not include branch to BMWD.

***Required Pumping Facilities***

The required pumping facilities for each hydraulic design alternative were evaluated. The resulting pumping requirements associated with the base and reduced maximum pressure alternatives is summarized in Table 2, *Summary of Pumping Requirements – Reduced Maximum Pressure Class Evaluation*.

TABLE 2 – *Summary of Pumping Requirements – Reduced Maximum Pressure Class Evaluation*

| | Base Project | | Phased Project | | | |
|---|---|---|---|---|---|---|
| | Alt1 | Alt1(a) | Alt1P-A1 | Alt1P-A2 | Alt1(a)P-1 | Alt1(a)P-2 |
| ***Max. Pressure Class[1]/No. PSs*** | ***250 psi; 1 PS*** | ***150 psi; 2 PS*** | ***300 psi; 1 PS*** | ***250 psi; 2 PS*** | ***200 psi; 2 PS*** | ***150 psi; 3 PS*** |
| $PS_1$ hp | 910 | 360 | 1910 | 1440 | 1090 | 670 |
| $PS_2$ hp | - | 420 | - | 270 | 530 | 910 |
| $PS_3$ hp | - | - | - | - | - | 500 |
| Total hp | 910 | 780 | 1910 | 1710 | 1620 | 2080 |

***Required System Storage***

Because it is a unique component of the hydraulic design alternatives evaluated, the additional storage that may be required at remote pumping facilities was considered. For all practical purposes, the minimum storage needed at a remote pumping facility was assumed as 0.25 million gallons for the base project and 0.50 million gallons for the phased project.

**Relative Cost Comparison of Alternatives**

Costs for facilities and O&M required for each alternative were evaluated to provide a cost comparison between alternatives.

***Cost Basis***

For the purpose of this comparison, only unique components were evaluated for cost, not including all common components. The resulting cost value is useful for determining the relative difference between alternatives and should in no way be construed as total for any alternative.

The cost comparison included consideration for the following unique components:

- Transmission pipelines
- WTP/Remote Booster Pump Stations
- System Storage
- Electrical Feed
- Additional Land Acquisition (Remote PS and Storage Tank)
- Pumping Costs
- Operation and Maintenance for Pump Stations, Transmission and Storage Facilities

The cost comparison does not include the following common components:

- Intake
- WTP
- RW Pipeline
- Interconnects
- Equilization Tank
- Environmental Studies and Mitigation
- Land ROW Cost
- Engineering and Financing Costs

The following assumptions were used for cost development:

- Annual debt service calculated for a period of 25 years at an interest rate of 6.5%.
- Pumping efficiency (wire to water ratio) of 0.70.
- Pumping energy cost considered at $0.08 per kilo-watt hour.

The resulting costs for each maximum pressure class requirement for each evaluated alternative is listed in Table 3, *Preliminary Estimate of Costs – Reduced Maximum Pressure Class Evaluation*. The results are also shown schematically for base and phased project conditions for each alternative in Figure 3, *Alternatives, Reduced Maximum Pressure Evaluation*.

**TABLE 3 –** *Preliminary Estimate of Costs – Reduced Maximum Pressure Class Evaluation*

| | Base Project | | Phased Project | | | |
|---|---|---|---|---|---|---|
| | *ALT 1* | *ALT 1(a)* | *ALT 1P-A1* | *ALT 1P-A2* | *ALT 1(a)P-1* | *ALT 1(a)P-2* |
| **Basis of Comparison** | **1 PS 250 psi Max** | **2 PS 150 psi Max** | **1 PS 300 psi Max** | **2 PS 250 psi Max** | **2 PS 200 psi Max** | **3 PS 150 psi Max** |
| ***Capital Costs*** | | | | | | |
| Transmission Pipelines[3] | $ 15,889,000 | $ 14,225,000 | $ 17,754,000 | $ 15,889,000 | $ 14,746,000 | $ 14,225,000 |
| WTP Pump Station | $ 1,269,000 | $ 558,000 | $ 2,385,000 | $ 1,861,000 | $ 1,470,000 | $ 979,000 |
| Booster Pump Station 1 | - | $ 558,000 | - | $ 558,000 | $ 813,000 | $ 1,263,000 |
| Booster Pump Station 2 | - | - | - | - | - | $ 558,000 |
| System Storage | $ - | $ 282,000 | $ - | $ 399,000 | $ 399,000 | $ 799,000 |
| Electrical Feed | $ 114,000 | $ 98,000 | $ 239,000 | $ 214,000 | $ 203,000 | $ 260,000 |
| Total Capital Cost [4] | $ 17,272,000 | $ 15,721,000 | $ 20,378,000 | $ 18,921,000 | $ 17,631,000 | $ 18,084,000 |
| Add'l Land Acquisition (PS and Storage Tank) | $ - | $ 7,000 | $ - | $ 7,000 | $ 7,000 | $ 14,000 |
| Total Project Cost [4] | $ 17,272,000 | $ 15,728,000 | $ 20,378,000 | $ 18,928,000 | $ 17,638,000 | $ 18,098,000 |
| ***Annual O&M Costs*** | | | | | | |
| Annual Debt Service *(Assuming 25 years, efective interest rate of 6.5%)* | $ 1,416,000 | $ 1,290,000 | $ 1,671,000 | $ 1,552,000 | $ 1,446,000 | $ 1,484,000 |
| Pumping Costs | $ 478,000 | $ 408,000 | $ 999,000 | $ 891,000 | $ 843,000 | $ 1,084,000 |
| Operation and Maintenance [5] | | | | | | |
| Pump Station | $ 32,000 | $ 28,000 | $ 60,000 | $ 60,000 | $ 57,000 | $ 70,000 |
| Transmission Facilities | $ 159,000 | $ 142,000 | $ 178,000 | $ 159,000 | $ 147,000 | $ 142,000 |
| Storage Facilities | $ - | $ 2,800 | $ - | $ 4,000 | $ 4,000 | $ 8,000 |
| | $ 669,000 | $ 581,000 | $ 1,237,000 | $ 1,114,000 | $ 1,051,000 | $ 1,304,000 |
| Total Annual Cost [4] | $ 2,085,000 | $ 1,870,800 | $ 2,908,000 | $ 2,666,000 | $ 2,497,000 | $ 2,788,000 |

(1) Costs are developed for purposes of preliminary evaluation and include only those costs that vary between the alternatives Thus, the costs should not be taken as final estimates for any alternative. Maximum pressures represent max pressures in main pipeline, not including branch to BMWD.

(2) For comparison purposes, costs are based on a Phased Project production of 15,683 acft/yr (14 mgd) - the maximum capacity of Alternative 1 (ALT 1 and ALT 1P-A1)

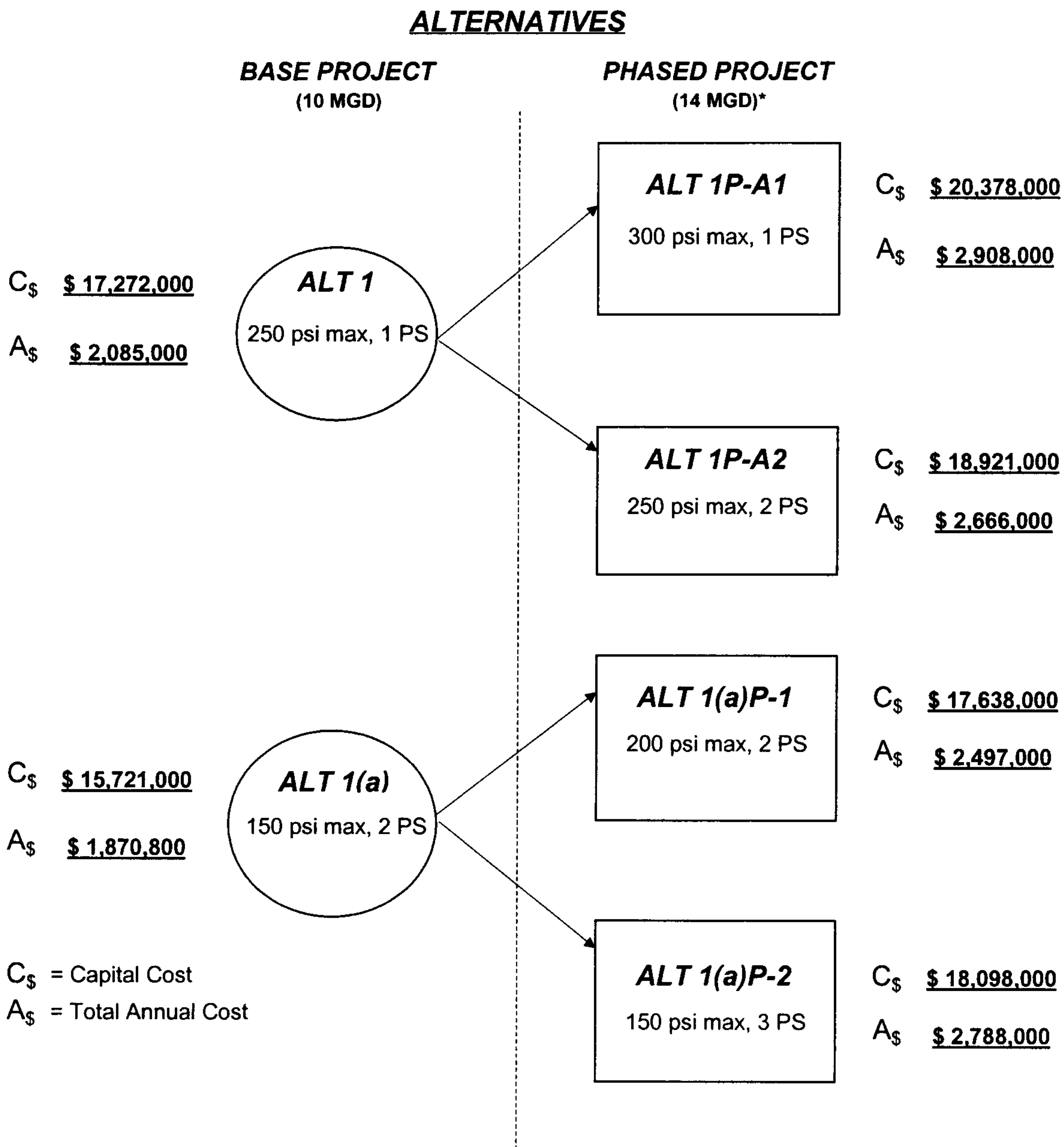
(3) Lengths obtained by graphical analysis of hydraulic profile using only a limited number of ground points for reference. This methodology was applied for comparative analysis only Actual piping lengths will vary in design.

(4) Items not included for cost comparison due to equivalence between alternatives include: Intake, Intake Pump Station and Water Treatment Plant, Interconnects to all participants, Equilization Tank near Boerne/SAWS Delivery Point, Environmental Studies

(5) O&M costs assume 1% of the total capital costs of pipelines and tanks; 2 5% of the total capital cost of pump stations

The reduced maximum pressure class to 200 psi (for phased expansion) is preferred since a 12% increase in capital costs is incurred for an increase in capacity of 42%.

***FIGURE 3**– Alternatives, Reduced Maximum Pressure Evaluation.*




* Maximum capacity of Alternative 1 (ALT 1 and ALT 1P-A1)

### Sensitivity to Hazen-Williams Friction Coefficient and Power Cost

The sensitivity to the results of analysis due to the choice of Hazen-Williams friction coefficient (C) and power cost per kilowatt-hour (kwh) were evaluated. All analyses for piping and pump sizing so far have considered a C value of 120 and power cost of $0.08 per kwh. In reality, the system is very likely to operate under varying conditions with a C value as high as C=130 and a power cost as low as $0.06 per kwh. To quickly evaluate the effect these changes would have on pumping costs, an evaluation of the base alternative for C=130 and power cost of $0.06 per kwh was performed. Alteration of these values resulted in up to a 33% reduction in pumping costs. Applying this factor to all evaluated alternatives, significantly alters the weight for consideration of annual O&M costs. The estimated effect is shown in Table 4, *Sensitivity to C-value and Power Cost; C=130 and $0.06 per kwh.*

**TABLE 4** – *Sensitivity to C-value and Power Cost[1]; C=130 and $0.06 per kwh.*

| | Base Project | | Phased Project | | | |
|---|---|---|---|---|---|---|
| | Alt1 | Alt1(a) | Alt1P-A1 | Alt1P-A2 | Alt1(a)P-1 | Alt1(a)P-2 |
| ***Max. Pressure Class/No. PSs*** | ***250 psi; 1 PS*** | ***150 psi; 2 PS*** | ***300 psi; 1 PS*** | ***250 psi; 2 PS*** | ***200 psi; 2 PS*** | ***150 psi; 3 PS*** |
| Total Annual Cost | $1,927,000 | $1,714,000 | $2,578,000 | $2,372,000 | $2,211,000 | $2,430,000 |

[1]For comparison purposes, costs are based on a Phased Project production of 15,683 acft/yr (14 mgd) – the maximum capacity of Alternative 1 (Alt 1 and Alt 1P-A1).

### Recomended Hydraulic Design Alternative

The preceding evaluations indicate the reduced maximum pressure alternative to clearly be preferable to the single pump station at the WTP with high 300 psi pressure class. Not only is the cost saving significant, but concern for high pressures in the line exceeding 200 psi is addressed by selection of this alternative. Thus, the reduced maximum pressure alternative is the recommended hydraulic design alternative.

#### *Alternative Alignment - Power Transmission Line*

As mentioned previously, the reduced maximum pressure alternative for a maximum pressure of 150 psi is applicable for the current pipeline alignment, but not for the alternative alignment along the power transmission line. Since the alternative pipeline alignment could potentially be the preferred route, the final recommended hydraulic design alternative would need to be suitable for this alternative route as well.

As a result, the reduced maximum pressure for both the base and phased project conditions shall be 200 psi.

#### *Maximum System Capacity – Phased Project*

The maximum capacity of the recommended hydraulic system as configured with a remote pumping station is a fraction higher than that of the single pumping station alternative –the 15,683 acft/yr (14 mgd) value used in previous evaluations for comparison between the alternatives. A maximum delivery capacity of 16,000 acft/yr (15 mgd production, assuming 5% losses) with nearly all pipeline system pressures below 200 psi has been applied to further evaluation for the recommended system. The resulting HGL profiles for the 10 mgd base project and 15 mgd phased project flows are indicated in Figure 4.

### *Required Piping Lengths*

The required piping lengths for the base and phased projects for this recommended hydraulic design alternative were evaluated using spreadsheet calculation methods previously used for TM No.1 analyses. This spreadsheet analysis approach was used rather than the graphical analysis used in TM No. 2 because it provides more detailed and conservative estimate for design. Hence, the estimated length of required piping for pressures in the range of 150-200 psi would be higher than the value estimated using graphical analysis. The estimated required piping lengths are listed in Table 5, *Piping for Recommended Alternative– 200 psi Maximum Pressure Class.*

**TABLE 5** – *Piping For Recommended Alternative- 200 psi Maximum Pressure Class.*

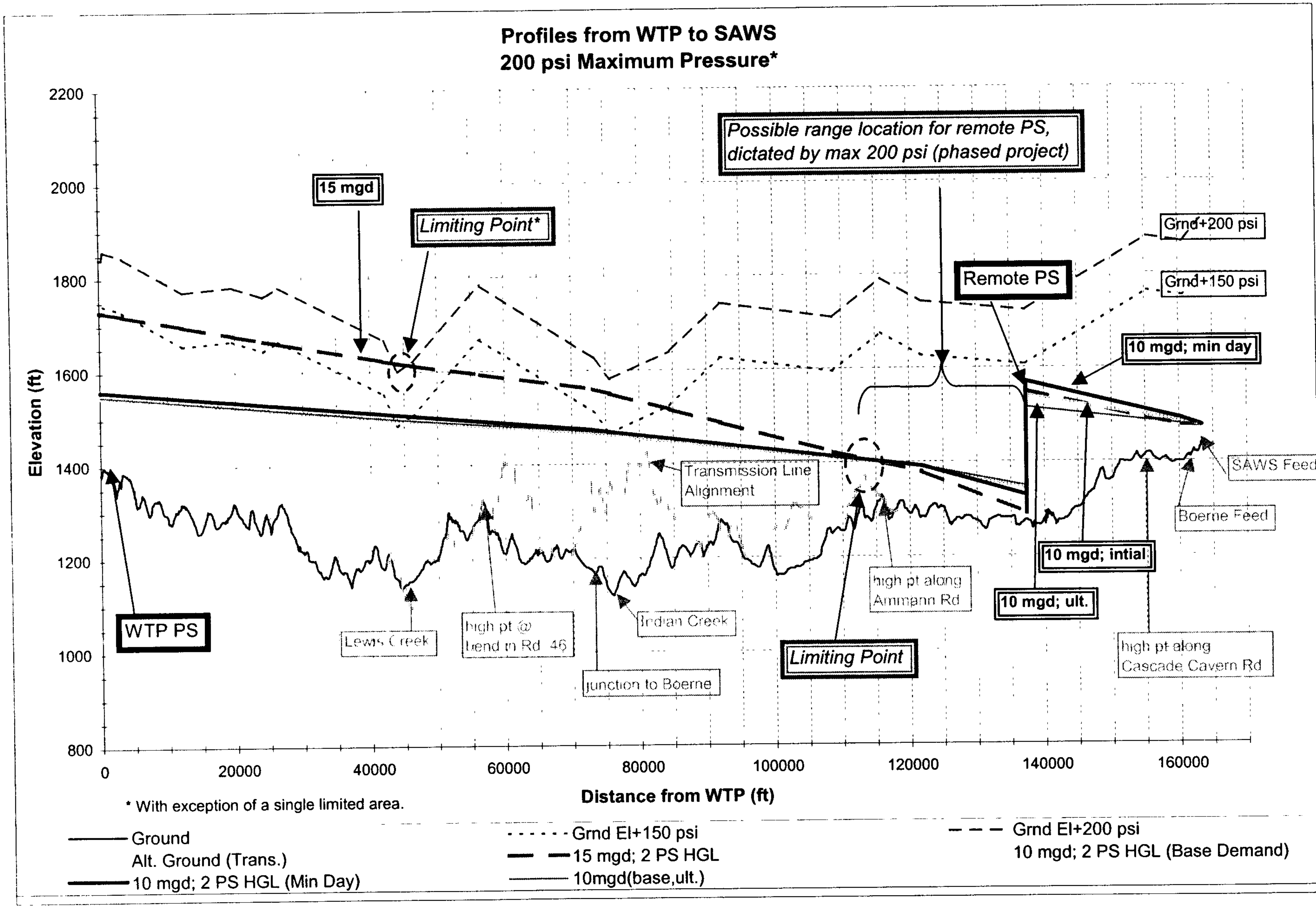
| | Base Project, 10 MGD | Phased Project, 15 MGD |
|---|---|---|
| | Alt1(b) | Alt1(b)P-1 |
| ***Max. Pressure Class[1]/No. PSs*** | ***200 psi; 2 PS*** | ***200 psi; 2 PS*** |
| Pipe length, ft (p<150psi) | 167,024 | 84,661 |
| Pipe length, ft (150<p<200psi) | 26,817 | 102,267 |
| Pipe length, ft (200<p<250psi)[2] | 0 | 6,913 |
| Pipe length, ft (250<p<300psi) | 0 | 0 |

[1] Represents maximum pressure class in almost all of main pipeline and does not include branch to BMWD.
[2] A single limited area is subject to pressures just above 200 psi. The estimation of pipe length for this pressure class range is very conservative and will likely be reduced during design, given detailed route topography.

### *Required Pumping Facilities*

The required pumping facilities for the base and phased projects for this recommended hydraulic design alternative were evaluated. The resulting pumping requirements are summarized in Table 6, *Pumping for Recommended Alternative– 200 psi Maximum Pressure Class.*

## FIGURE 4




HDR ENGINEERING, INC.

5/24/00;rec-alt,C=120.xls
r:\07081033\hyd

**TABLE 6** – *Pumping For Recommended Alternative- 200 psi Maximum Pressure Class[1].*

| | Base Project, 10 MGD | Phased Project, 15 MGD |
|---|---|---|
| | Alt1(b) | Alt1(b)P-1 |
| ***Max. Pressure Class[1]/No. PSs*** | ***200 psi; 2 PS*** | ***200 psi; 2 PS*** |
| $PS_1$ hp | 440 | 1,320 |
| $PS_2$ hp | 510 | 570 |
| Total hp | 950 | 1,890 |

[1] Represents maximum pressure class in almost all of main pipeline and does not include branch to BMWD.

### *Relative Cost Comparison*

Based on the relative costing methodology described previously, costs for the base and phased project alternatives have been tabulated below in Table 7, *Preliminary Partial Estimate of Costs for Recommended Alternative.* Note that the difference between the transmission pipeline capital costs for the phased and base project represents additional costs for a larger amount of higher pressure class required for the phased expansion and would actually be incurred up-front, during base project construction.

**TABLE 7** – *Preliminary Partial Estimate of Costs for Recommended Alternative.*

**PRELIMINARY ESTIMATE OF COSTS [(1)]**

| Basis of Comparison - 200 psi Max Pressure* | Base Project, 10 MGD | Phased Project, 15 MGD |
|---|---|---|
| ***Capital Costs*** | | |
| Transmission Pipelines | $ 14,451,000 | $ 15,401,000 |
| WTP Pump Station | $ 707,000 | $ 1,727,000 |
| Remote Pump Station, Immediately D/S of F.O.R. Delivery | $ 790,000 | $ 861,000 |
| System Storage | $ 282,000 | $ 399,000 |
| Electrical Feed | $ 119,000 | $ 236,000 |
| Total Capital Cost [(2)] | $ 16,349,000 | $ 18,624,000 |
| Add'l Land Acquisition (PS and Storage Tank) | $ 7,000 | $ 7,000 |
| Total Project Cost [(2)] | $ 16,356,000 | $ 18,631,000 |
| ***Annual O&M Costs*** | | |
| Annual Debt Service *(Assuming 25 years, efective interest rate of 6.5%)* | $ 1,341,000 | $ 1,528,000 |
| Pumping Costs | $ 498,000 | $ 986,000 |
| Operation and Maintenance [(3)] | | |
| Pump Station | $ 16,000 | $ 22,000 |
| Transmission Facilities | $ 145,000 | $ 154,000 |
| Storage Facilities | $ 3,000 | $ 4,000 |
| Total Annual Cost [(2)] | $ 2,003,000 | $ 2,694,000 |

[(1)] Costs are developed for purposes of preliminary evaluation and include only those costs that vary between the alternatives. Thus, the costs should not be taken as final estimates for any alternative

[(2)] Items not included for cost comparison due to equivalence between alternatives include: Intake, Intake Pump Station and Water Treatment Plant, Interconnects to all participants, Equilization Tank near Boerne/SAWS Delivery Point, Environmental Studies

[(3)] O&M costs assume 1% of the total capital costs of pipelines and tanks; 2.5% of the total capital cost of remote pump stations and 2.25% of the total capital cost of on-site pump stations.

*Majority of Project

**Conclusion**

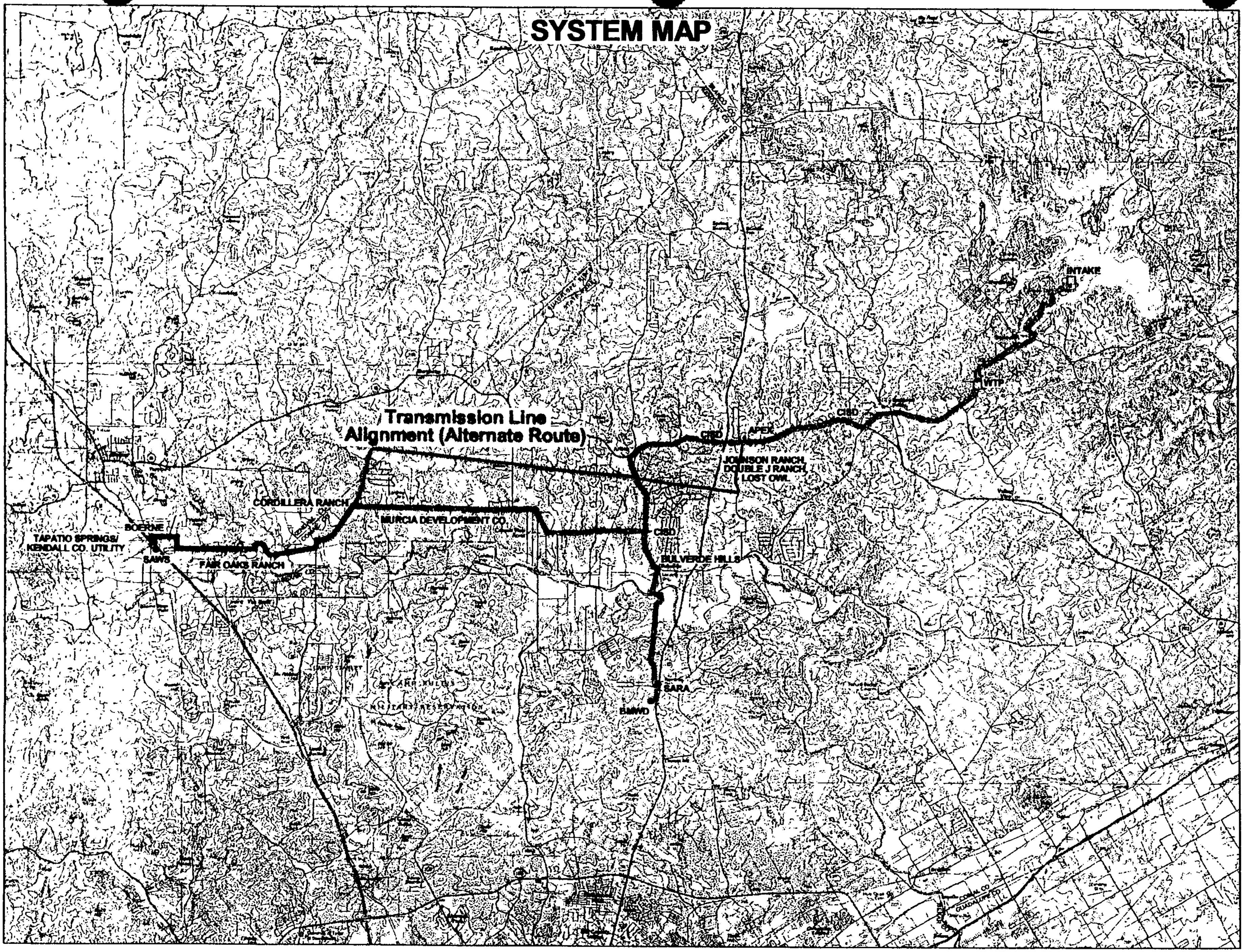
The recommended hydraulic design alternative for conveyance of flow to GBRA project customers for the base project (10 mgd) and phased project (15 mgd) deliveries has been presented. The factors contributing to recommendation of this design alternative include the following items:

- Optimum maximum pressure class of 200 psi within most of system.
- Alleviate potential maintenance and design concerns associated with extreme high pipeline pressures greater than 200 psi.
- Pumped conveyance to all delivery points.
- Flexibility in selection of WTP location.
- Flexibility in selection of pipeline route; Valid design for all current alternative pipeline routes.
- Phased expansion to full capacity of system (51% increase in capacity) can be accomplished with an 14% increase in capital costs, of which only 7% must be spent initially during base project construction for higher class transmission pipelines.

## *TM No. 3 Appendix*

## *Background and Working Information*

# SYSTEM MAP




GBRA Regional Water System

GBRA

HDR

# *Appendix D*
# *Technical Memorandum No. 4*

*To:* File: 07081-033-036

*From:* Christianne Gaylord
(Registered in California, C57977)

HDR

Technical Memorandum

*Date:* March 28, 2000 (Revised May 24, 2000)

*Subject:* **Guadalupe-Blanco River Authority Regional Water System**
**For Portions of Comal, Kendall, and Bexar Counties**
***HDR Project No. 07081-033-036***
Technical Memorandum No. 4
Pump Station Design

---

## Purpose

The purpose of this technical memorandum (TM) is to describe the basis of pump station design and selection for proposed pump stations for the Guadalupe-Blanco River Authority (GBRA) Regional Water System Project for portions of Comal, Kendall, and Bexar Counties.

Based on the results of TMs No. 1-3, evaluation for hydraulic pumping conditions was performed and is summarized herein, in TM No. 4. This evaluation includes pump selections for the three proposed pump stations: 1) Raw water pump station, 2) Water Treatment Plant (WTP) pump station, 3) Remote pump station. A description of the economic and non-economic considerations involved with the pump selections is provided.

## Basis of Analysis

This analysis is intended to supplement previous analyses presented in TMs No. 1 through 3 and utilizes the following basic information:

- Preliminary Pipeline Route. (TMs No. 1-3)
- Alternative Pipeline Route – Power Transmission Line. (TMs No. 1-3)
- Ground Profiles for Preliminary and Alternative Pipeline Routes.
- System Average Demand Distribution and Phased Project Distribution. (TMs No. 1-3)
- Recommended Hydraulic Design Alternative.
  *Alternative 1* – Pump to all delivery points. (TMs No. 1, 3)
- Phased Project Equivalent Pipe Sizing. (TMs No. 1-3)
- Required Piping Lengths- Recommended Alternative. (TM No. 3)
- Optimum Maximum Pressure Class of 200 psi for Treated Water Piping. (TM No. 2,3)

Refer to TMs No. 1-3 for a detailed description of the above information. The analysis described herein evaluates the feasibility of various pump selections required to meet base project conditions of 10 mgd (10,527 acft/yr), and details the additional facilities that will be required to accomplish phased project expansion to 15 mgd (16,000 acft/yr). (It should be noted that the 15 mgd value of maximum capacity for the system is based on the particular assumed future demand distribution of 75% additional flow west; 25% east of the Boerne junction. This value may vary based on the actual demand distribution of additional flows in the future.)

*Hazen-Williams Friction Coefficient*

A Hazen-Williams friction coefficient of 130 has been used for design of the pumps. This selected value is based on HDR's extensive experience with design, construction, and operation of pumping and piping systems. Past experience has found this value, inclusive of minor transmission piping losses, as representative of actual operating conditions for similar systems. Final design should include a check of system hydraulic calculations using a C-value of 134 in addition to all actual minor losses.

*Minimum Day Demand Distribution*

The minimum demands within the system were estimated to accommodate the design for the full range of expected conditions. Minimum demands were estimated from available information provided from project customers during participant meetings held throughout late 1999 and early 2000. Where information was not available, the minimum daily demand was estimated as half of the average daily demand where peaking needs are met from available on-site storage and one-quarter the average daily demand where peaking needs are to be met by the system. The minimum daily demands estimated for initial operation of the system is tabulated below in Table 1, Minimum Daily Demand.

***TABLE 1*** *– Minimum Daily Demand*

| | Min. Daily / Ave Daily (ratio) | Ave Daily Demand (mgd) | Min. Day, 2000 Demand Distrib.[1] (mgd) |
|---|---|---|---|
| ***IN-DISTRICT*** | | | |
| ***City of Boerne*** | 0.53 | 1.12 | 0.469 |
| ***City of Fair Oaks*** | 0.40 | 1.17 | 0.496 |
| ***Comal Independent School District*** | 0 | 0.02 | 0.000 |
| ***Apex Water Services*** | 0.5 | 0.35 | 0.094 |
| ***Bulverde Utility Co. (owned and operated by BMWD)*** | 0.5 | 0.22 | 0.117 |
| ***Murcia Development Co.*** | 0.25 | 0.09 | 0.023 |
| ***Lost Owl (Comal Water Co.)*** | 0.5 | 0.02 | 0.005 |
| ***Clyde Johnson*** | 0.5 | 0.02 | 0.011 |
| ***Double J. Ranch - no demand information*** | 0 | - | 0.000 |
| ***Cordillera*** | 0.5 | 0.048 | 0.025 |
| ***Tapatio Springs/Kendall Co. Utility Co.*** | 0.5 | 0.39 | 0.141 |
| ***OUT-OF-DISTRICT*** | | | |
| ***San Antonio River Authority*** | - | - | 0.047 |
| ***Bexar Metropolitan Water District*** | 0.5 | 5.85 | 2.004 |
| ***-returnable*** | | | 1.011 |
| ***San Antonio Water System*** | - | - | 1.699 |
| ***-returnable*** | | | 3.727 |
| ***Totals*** | | | 9.9 mgd |

[1] Represents the lesser value of the calculated min daily demand and daily commitment. Includes consideration for 5% system losses.

**Recommended Hydraulic Design Alternative**
In TMs No.s 1- 3, the preferred hydraulic design alternative, Alternative 1, was developed. TM No. 1 evaluations indicated pumped delivery to all points is preferrable, TM No. 2 indicated optimal maximum pressure class of 200 psi, and TM No. 3 further developed the alternative to provide pumped delivery to all points with a maximum pressure class of 200 psi within most of the system. The resulting preferred alternative is described as follows:

*Alternative 1 (as presented in TM No. 1-3)- Pump base project demand of 10 mgd and future phased project expansion demand of 15 mgd to all delivery points.*

- Maximum pressure class of 200 psi for Treated Water Piping.
- Remote pump station located near/at Fair Oaks Ranch delivery point, approximately 26 miles downstream of the WTP.
- Piping diameters and lengths same as that presented in TM No.s 1-3.
- Base and phased project demand distribution and assumptions presented in TM No.s 1-3.

The system map for the preferred alternative is shown in Figure 1, System Map. The alternative pipeline routes and estimated primary delivery locations are indicated.

**Pump Station Locations**
The pump station locations have been assigned for determination of system operations, but may change as the design progresses. However, these selected locations best represent the current information to date and the resulting evaluation is not expected to change significantly as the design is refined.

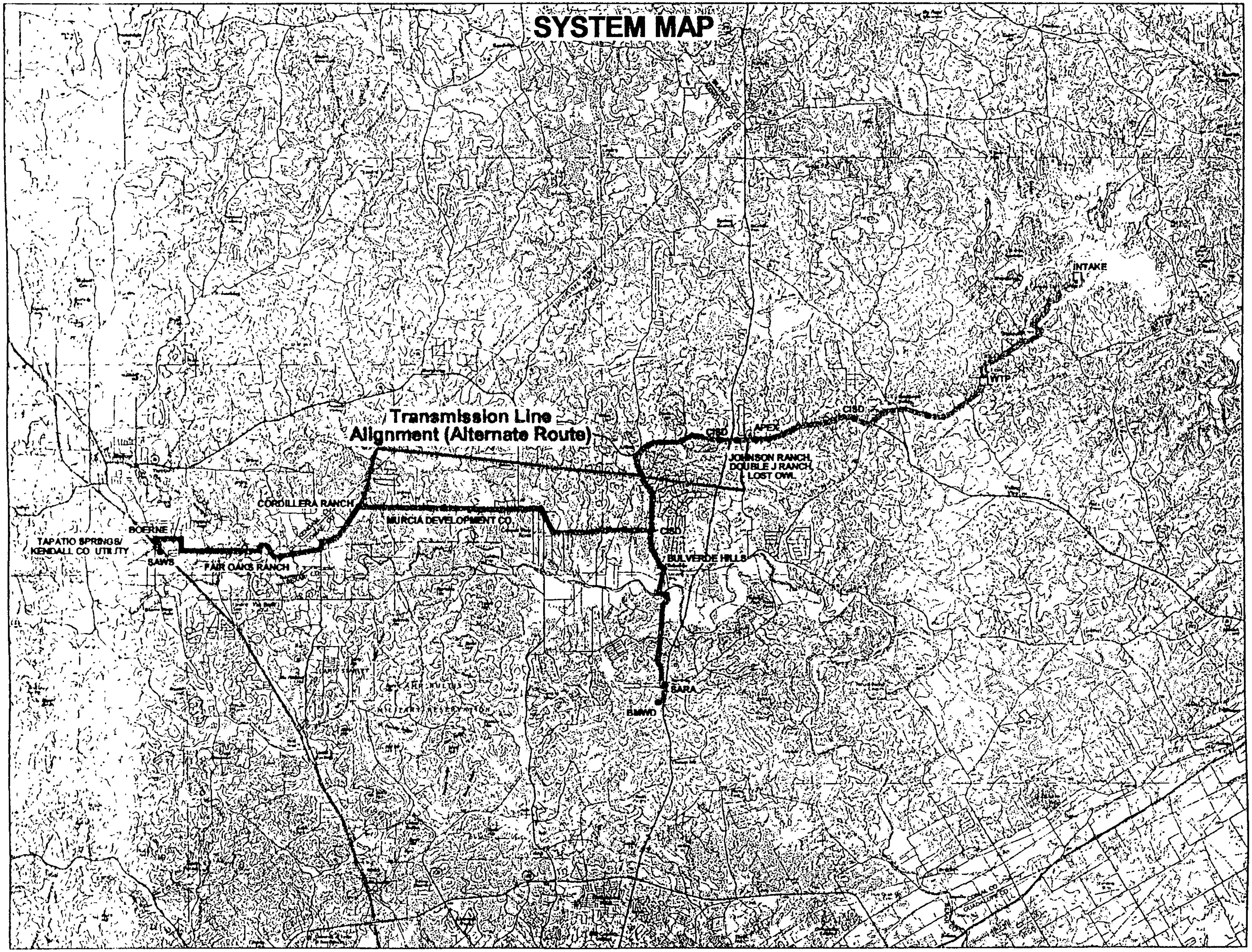
Approximate locations of the intake and water treatment plant have previously been identified for the system in which TM No.1-3 analyses are based. Location of the remote pump station was determined by selecting the area most feasible, based on the existing topography and calculated hydraulic grade line (HGL).

Figure 2, System HGL Profiles from the WTP to the end delivery point (SAWS), indicates the results of this evaluation. The HGL profiles for both the base and phased project conditions are shown. As indicated on the profile, two limiting points exist. The primary limiting point pertinent to all profiles is due to high ground along the transmission line alignment. A minimum of 10 psi, per early criteria developed in TM No. 1, is required in the line at this limiting point. The other limiting point occurs by limiting the maximum line pressure to 200 psi during phased-project expansion conditions. The maximum pressure criteria is mildly relaxed in this limited area as pressures are not expected to exceed 210 psi.

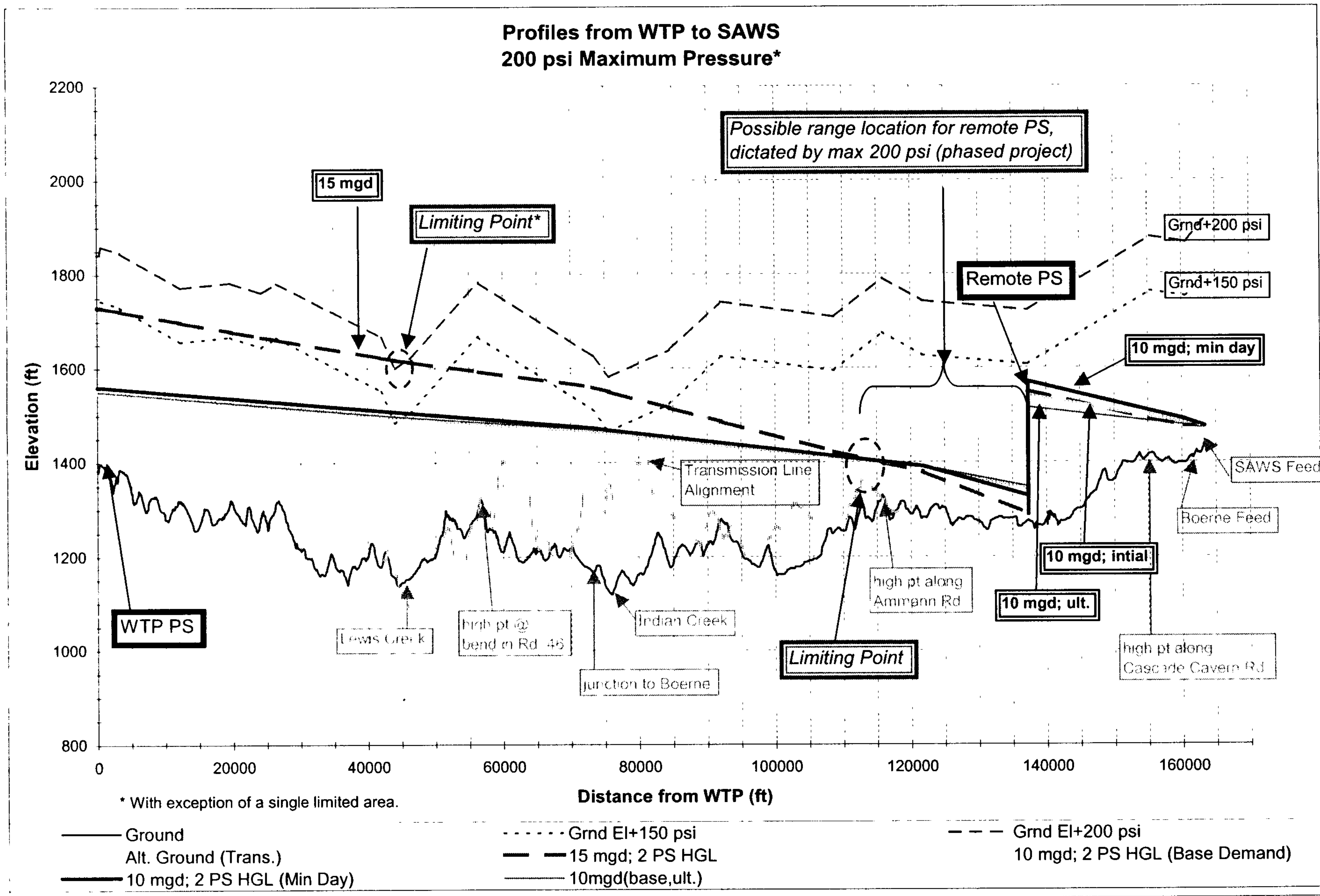
The pump station can be located anywhere between the high ground along the transmission line and the Fair Oaks delivery location. However, locating the remote pump station near/at the assumed Fair Oaks Ranch delivery point is most feasible since it saves the additional pump head (energy cost) that would be required at any point upstream.

**Pump Station System Curves**
The system curves for each pump station were developed as shown in Figures 3-5.

*FIGURE 1*


SYSTEM MAP
Transmission Line
Alignment (Alternate Route)
INTAKE
WTP
CISD
CISD
APEX
JOHNSON RANCH,
DOUBLE J RANCH,
LOST OWL
CORDILLERA RANCH
MURCIA DEVELOPMENT CO.
CISD
BULVERDE HILLS
BOERNE
TAPATIO SPRINGS/
KENDALL CO. UTILITY
SAWS
FAIR OAKS RANCH
SARA
BMWD

# FIGURE 2



Profiles from WTP to SAWS
200 psi Maximum Pressure*
Elevation (ft)
Distance from WTP (ft)
2200
2000
1800
1600
1400
1200
1000
800
0
20000
40000
60000
80000
100000
120000
140000
160000
15 mgd
Limiting Point*
Possible range location for remote PS, dictated by max 200 psi (phased project)
Grnd+200 psi
Grnd+150 psi
Remote PS
10 mgd; min day
10 mgd; intial
10 mgd; ult.
Transmission Line Alignment
SAWS Feed
Boerne Feed
high pt along Ammann Rd
high pt along Cascade Cavern Rd
Limiting Point
WTP PS
Indian Creek
junction to Boerne
* With exception of a single limited area.
Ground
Alt. Ground (Trans.)
10 mgd; 2 PS HGL (Min Day)
Grnd El+150 psi
15 mgd; 2 PS HGL
10mgd(base,ult.)
Grnd El+200 psi
10 mgd; 2 PS HGL (Base Demand)

***FIGURE 3*** *– System Curve – Raw Water Pump Station.*

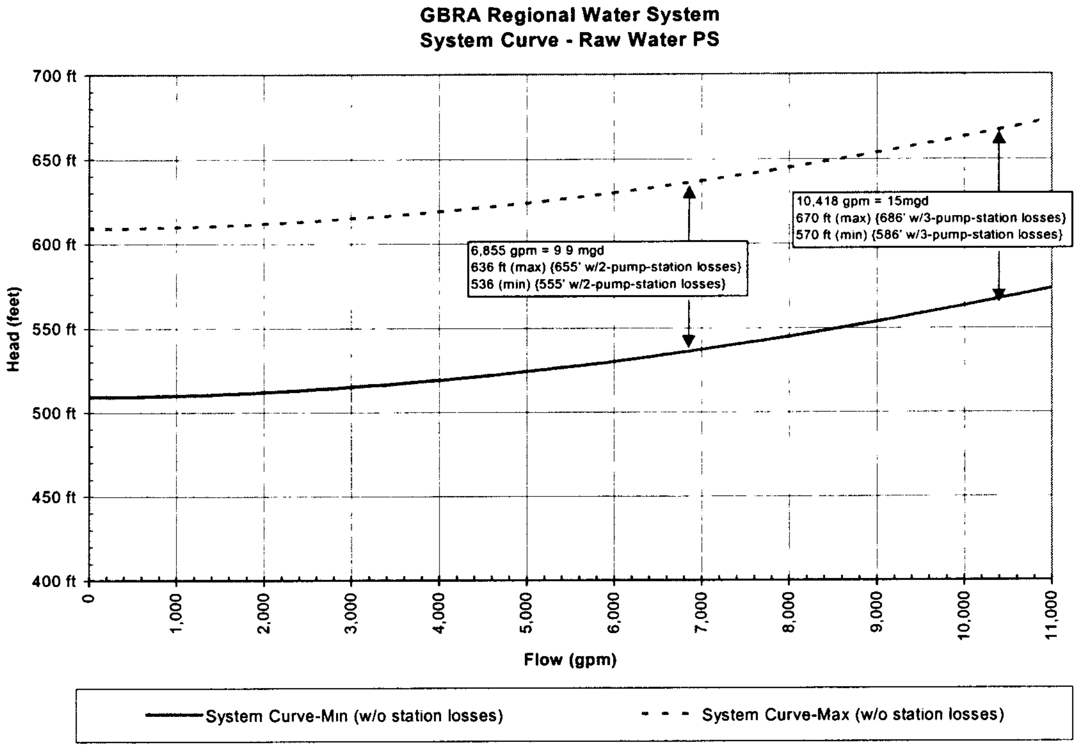



***FIGURE 4*** *– System Curve – Water Treatment Plant Pump Station*

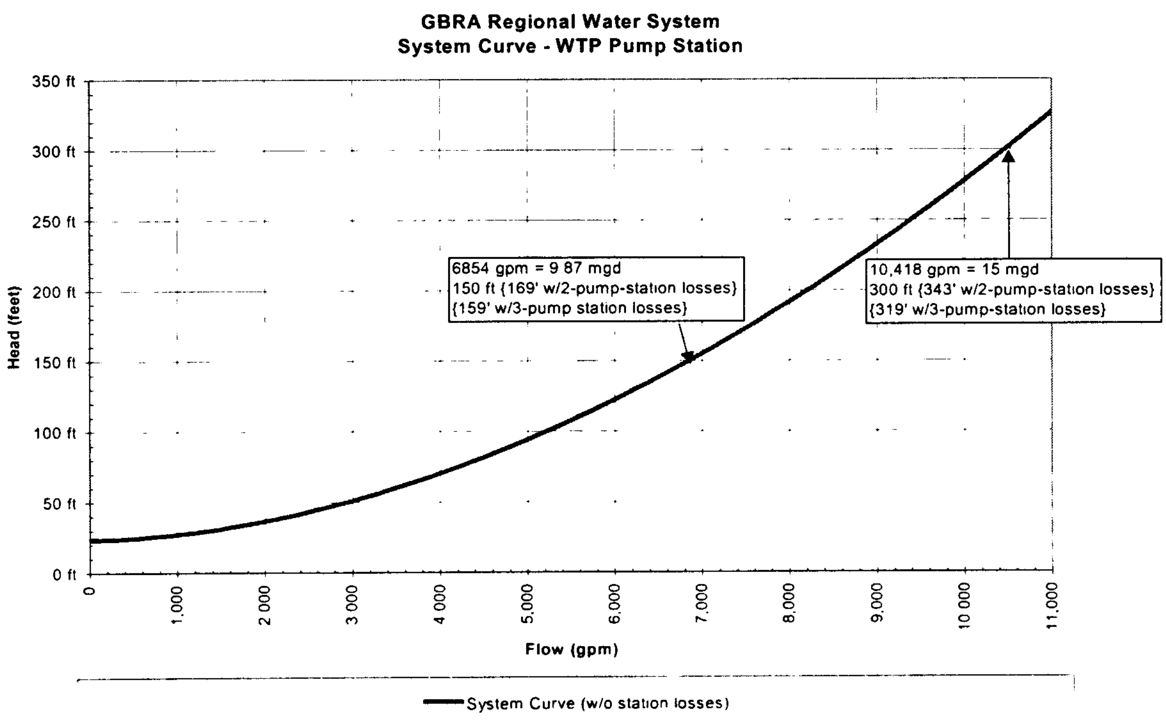
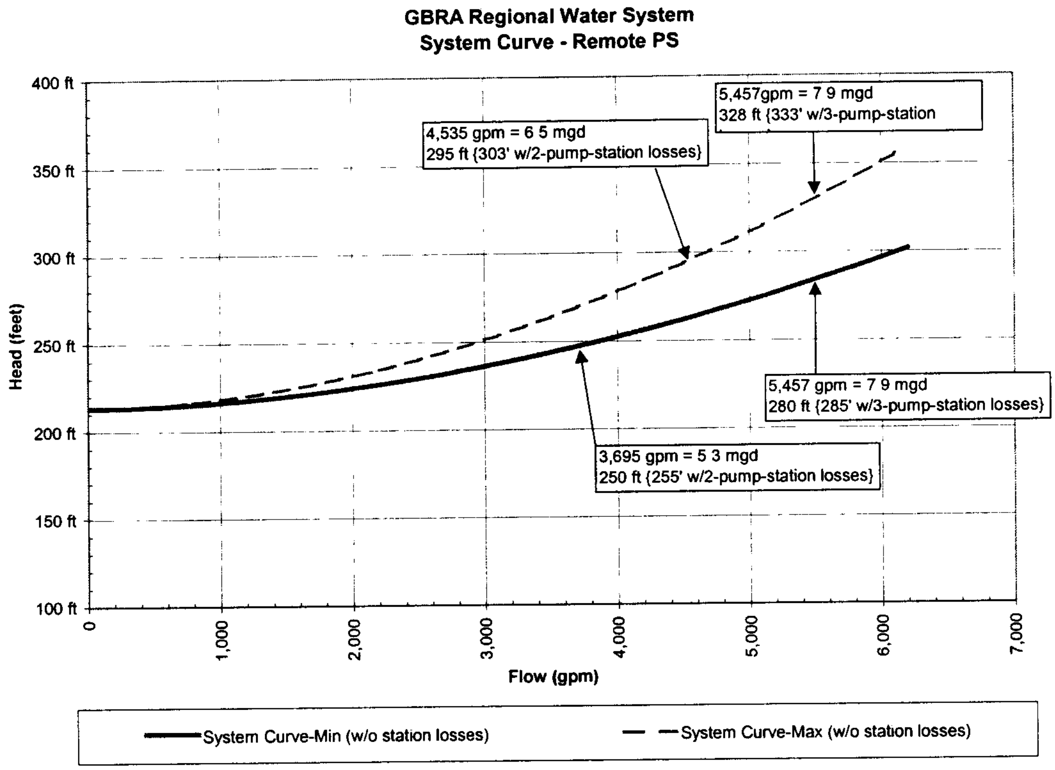


***FIGURE 5** – System Curve – Remote Pump Station.*



*Required Pumping Design Conditions*

The required pumping design points are summarized and tabulated for each pump station below in Table 2, *Summary of Pumping Design Conditions*.

***TABLE 2** – Summary of Pumping Design Conditions*

| Design Conditions [1] | | Base Project | | Phased Project | |
|---|---|---|---|---|---|
| | No. of Pumps Operating | 2 | 3 | 2 | 3 |
| **WTP PS** | | | | | |
| | Total Flow, Q (mgd) | 9.87 | 9.87 | 15.00 | 15.00 |
| | Pump Flow, Q (gpm) | 3426 | 2284 | 5209 | 3473 |
| | Head, H (ft) | 169 | 158 | 343 | 319 |
| | Req'd hp | 420 | 390 | 1290 | 1200 |
| **Remote PS** | | | | | |
| | Total Flow, Q (mgd) | 5.32 | - | - | 7.86 |
| | Pump Flow, Q (gpm) | 1847 | - | - | 1819 |
| *(MIN)* | Head, H (ft) | 255 | - | - | 285 |
| | Req'd hp | 340 | - | - | 560 |
| | Total Flow, Q (mgd) | 6.53 | - | - | 7.86 |
| | Pump Flow, Q (gpm) | 2268 | - | - | 1819 |
| *(MAX)* | Head, H (ft) | 303 | - | - | 333 |
| | Req'd hp | 500 | - | - | 660 |
| **RW PS** | | | | | |
| | Total Flow, Q (mgd) | 9.87 | - | - | 15.00 |
| | Pump Flow, Q (gpm) | 3426 | - | - | 3473 |
| *(MIN)* | Head, H (ft) | 555 | - | - | 586 |
| | Req'd hp | 1370 | - | - | 2200 |
| | Total Flow, Q (mgd) | 9.87 | - | - | 15.00 |
| | Pump Flow, Q (gpm) | 3426 | - | - | 3473 |
| *(MAX)* | Head, H (ft) | 655 | - | - | 686 |
| | Req'd hp | 1620 | - | - | 2580 |

[1] Includes allowance for expected station losses.

**Pump Selections**
Each proposed pump station was evaluated for use of both horizontal split case (centrifugal) and vertical turbine pumps. The general advantages and disadvantages of each type of pump are listed in Table 3, *Advantages and Disadvantages of Pump Type.*

*TABLE 3 – Advantages and Disadvantages of Pump Type*

| HORIZONTAL SPLIT CASE PUMPS |
|---|
| ***Advantages*** |
| Pumps and motors can be removed separately for repair. |
| Pump repair can usually be performed in place without removing the entire pump. |
| Piping may be installed exposed. |
| ***Disadvantages*** |
| Pumps require more floor space and a larger building. |
| **VERTICAL TURBINE PUMPS** |
| ***Advantages*** |
| Pumps are more easily modified for future pumping conditions. |
| Small footprint, requiring less floor space. |
| ***Disadvantages*** |
| Removing a pump for repair requires more labor. |
| Suction piping is buried under the floor slab. |

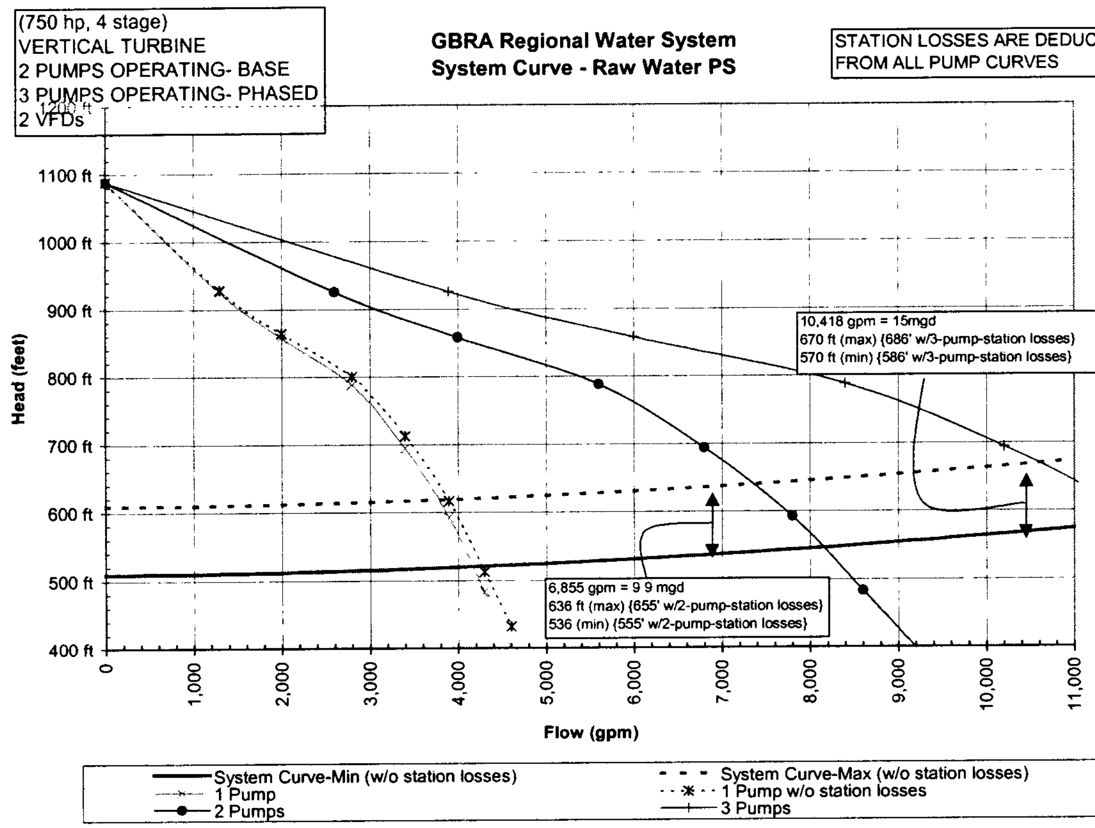
The advantages and disadvantages of each type of pump for use at the pump stations proposed for the GBRA system have been investigated. The pump selections and associated characteristics applicable to the GBRA system were developed with the assistance of pump manufacturers, as noted.

***Raw Water Pump Station***
A floating barge is currently proposed for the raw water intake at Canyon Lake. Hence, the raw water pump station will require vertical turbine pumps due to the requirement for pumps operating with suction lift.

The established design criteria encompasses the range of pump head possible for each base and phased-design condition as a result of the low and normal pool elevations of the Canyon Lake reservoir. To meet the base project maximum design point of 9.9 mgd at a head of 655 ft, 2 pumps operating would require 750 brake horse power (bhp) each at an efficiency above 84% (1770 rpm). All pumps should be operated in lead/lag sequence based on filling of the raw water reservoir to account for the fluctuations in lake elevation. For the phased design condition, addition of a third pump operating provides the required head of 686 ft at 15 mgd.

An additional pump is recommended as standby for each the base and phased project conditions. The pump curve is plotted with the system curve below in Figure 6. The layout of the raw water pump station is included in Appendix, Conceptual Pump Station Layouts.

***FIGURE 6*** *– Pump Curve – Raw Water Pump Station.*




## *WTP Pump Station*

As shown in Figure 4, the system curve for the WTP pump station is quite steep, requiring an addition of 150 feet (89% increase in head) for a 51% increase in flow to expand the system to phased project conditions. As a result, there are a few alternative options available. Those options are described for each different pump type evaluated as follows:

*Horizontal Split Case (Centrifugal) Pumps*

- Simple addition of a pump for expansion is not feasible due to the typical flatness characteristics of horizontal split-case pump curves and the steep characteristic curvature required of the system. Since finding a pump that can meet both base and phased project conditions (requiring only minor modifications) is difficult if not impossible, interchanging the pumps with totally new pumps upon expansion is likely.

  Therefore, 4 pumps total would be required (3 operating; 1 standby) for both the base project and phased project. The pumps would be interchanged once expansion of the system is required. Three pumps operating at a head of 159 feet for a flow of 9.9 mgd requires 200 bhp each at an efficiency of 83% (1770 rpm). For expansion, the pumps and motors can be upgraded to operate at 319 ft for a flow of 15 mgd (1780 rpm) for an efficiency of 84%, requiring 400 hp motors.

To exemplify the difficulty in using horizontal split case pumps for this application, the pump curves are plotted on the system curve in Figure 7.

*Vertical Turbine Pumps*

- Provide 3 pumps (2 operating; 1 standby) to meet the base project design conditions.
- Provide an additional pump (3 operating; 1 standby) for phased project conditions. Add additional stages required to the existing 3 pumps.
- The pump barrel must be configured to account for the additional stages that are to be added in the future.

Two pumps operating at a head of 169 feet and flow of 9.9 mgd requires a 2-stage pump with 200 hp motor for an efficiency of 78% (1770 rpm). The same pumps, altered for a total of 4-stages, with a third pump added operating at a total head of 319 ft and flow of 15 mgd requires 400 hp motors for an efficiency of 84% (1770 rpm).

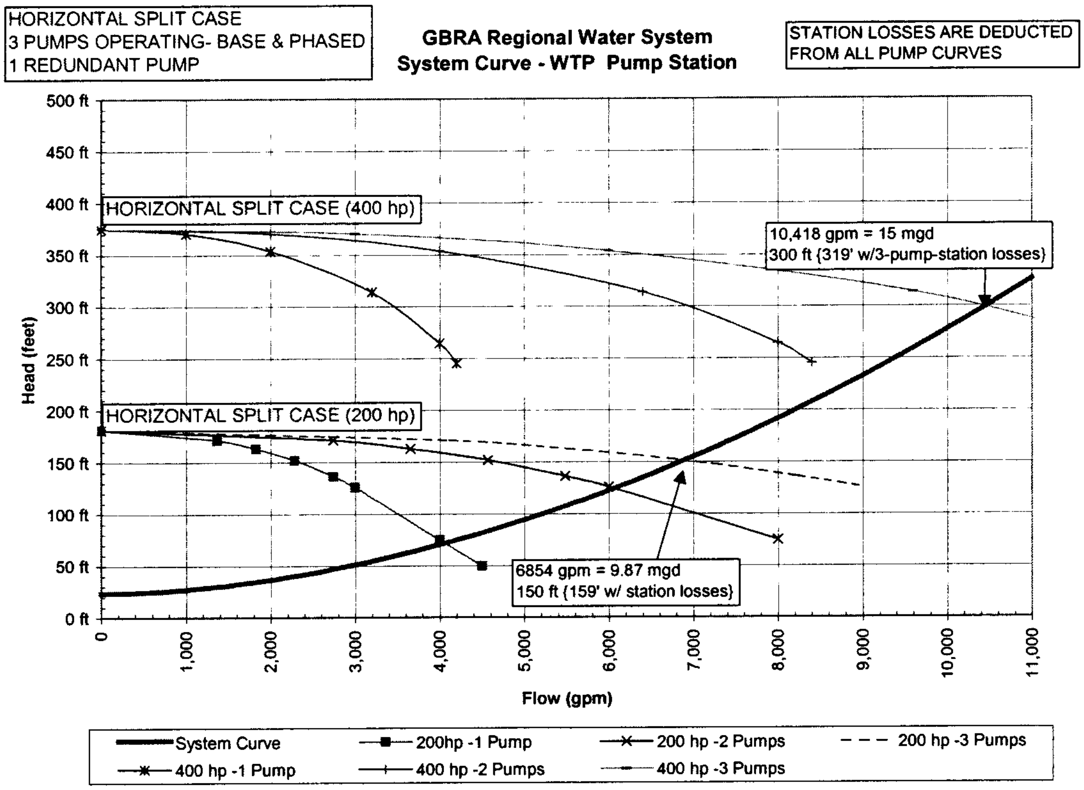
Provision of pumping systems designed for phased project conditions initially, operated on VFDs to run the pumps at reduced speeds for base project demands, was evaluated briefly. As expected, this option involves a significant annual cost for energy and proves not to be feasible unless the project would be expanded within the first two years of operation. Since that is not the intent of the project, the option has not been considered further.

The vertical turbine (VT) pump curves are plotted with the system curve below in Figure 8. The layouts of the WTP pump station facility, for both vertical turbine and horizontal split case pumps, are included in Appendix, Conceptual Pump Station Layouts.

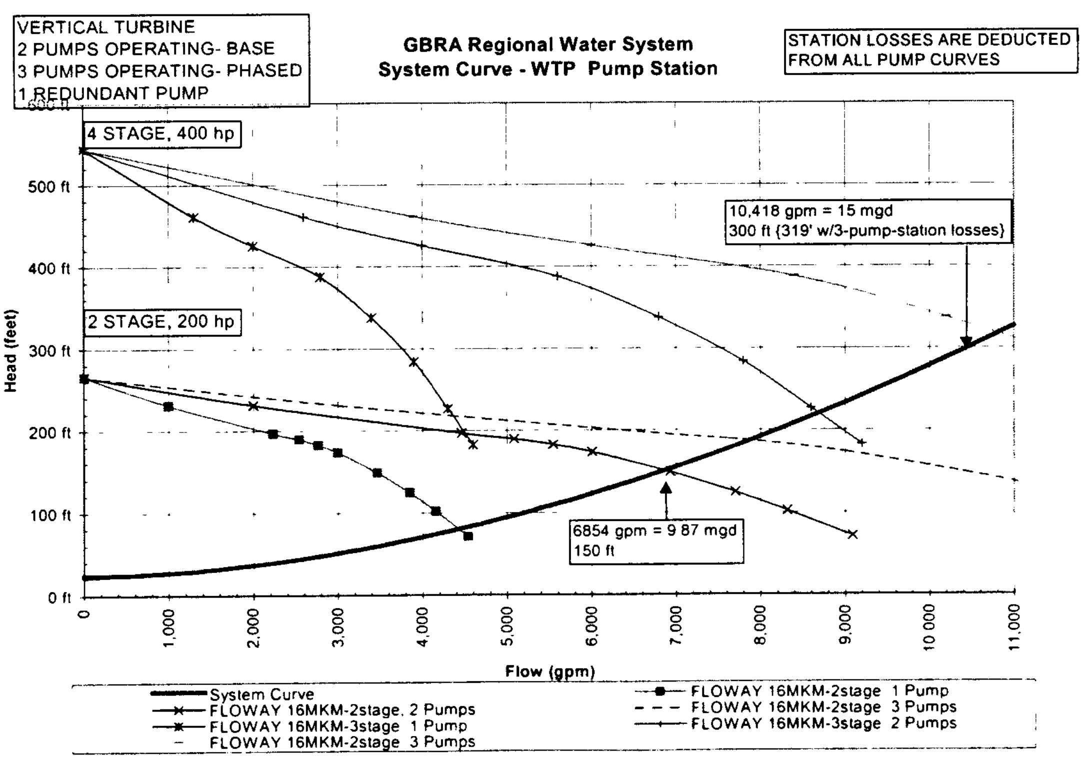
As indicated in the pump curves in Figures 7 and 8, the pumps cannot cover the steep range of heads required by the system at the WTP without use of a VFD. The VFD would allow one pump to operate without cavitating. A redundant VFD is recommended.

Based on the developed WTP system curve, use of vertical turbine pumps is preferable for the WTP pump station. The vertical turbine pumps inherently produce a steeper pump curve, which is conducive to the larger increase in head with relatively low increase in flow expected to occur within the system. In addition, the vertical turbine pumps require minimal layout area and are more easily modified to provide for future expansion of the system.

## FIGURE 7 – HSC Pump Curve – Water Treatment Plant Pump Station




## FIGURE 8 – VT Pump Curve – Water Treatment Plant Pump Station



***Remote Pump Station***
As in the case of the WTP pump station, both centrifugal and vertical turbine pumps have been evaluated. As shown in Figure 5, Remote Pump Station System Curve, use of a VFD is needed to account for the expected variation in flow and corresponding pump head required.

*Horizontal Split Case (Centrifugal) Pumps*

- Provide 3 pumps (2 operating; 1 standby) to meet the base project condition – a maximum 303 ft head for a flow of 2,268 gpm and efficiency of 75%. These pumps require 250 hp motors and operate at a maximum speed of 1800 rpm.

- Provide an additional pump (3 operating; 1 standby) to meet the phased project condition – a maximum of 333 ft at 15 mgd.

*Vertical Turbine Pumps*

- Provide 3 pumps (2 operating; 1 standby) to meet the base project design condition – a maximum 303 ft head for a flow of 2,268 gpm and efficiency of 83.5%. These pumps require 250 hp motors, operating at a maximum speed of 1800 rpm.

- Provide an additional pump (3 pumps operating; 1 standby) to meet the phased project condition – a maximum of 333 ft at 15 mgd.

Given that the vertical turbine pump efficiencies are significantly better than those of the horizontal split case pump, use of vertical turbine pumps is recommended. The vertical turbine (VT) pump curves are plotted with the system curve in Figure 9. The layout of the remote pump station facility for both vertical turbine and horizontal split case pumps are included in Appendix, Conceptual Pump Station Layouts. The layout area required is significantly less for vertical turbine pumps than horizontal split case pumps, requiring overall less construction costs for required facilities.

***FIGURE 9** – Remote Pump Station Pump Curves*