REGIONAL BOOSTER PUMP STATION FEASIBILITY STUDY
Water Utility System Master Plan

B&V PROJECT NO. 190376

PREPARED FOR
City of Rapid City, South Dakota
30 JUNE 2021
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1. Introduction

SHEPHERD HILLS OVERVIEW

The East Anamosa Street Water Extension Tax Increment District (TID) consists of a development area between East North Street and Elk Vale Road, north of Omaha Street. The purpose of the TID is to financially assist in the development of commercial, industrial, and residential property through watermain extensions, utility relocations, and grading around East Anamosa Street.

The initial development in this area is referred to as the Shepherd Hills development. Due to existing capacity limitations in the North Rapid pressure zone, a new booster pump station is needed to supply adequate water to the Shepherd Hills development. The Developer’s proposed location of the booster pump station is at the intersection of East Philadelphia Street and East Anamosa Street as shown in Figure 1.

The booster pump station will boost water from the Low Level pressure zone to the North Rapid pressure zone. The Shepherd Hills development will then be incorporated into an expanded North Rapid pressure zone along the East Anamosa corridor. In addition to the booster pump station, watermain extensions are proposed by the Developer along Mickelson Drive (12” pump suction pipe from Low Level pressure zone) and East Anamosa Street (20” pump suction pipe from Low Level pressure zone and 16” pump discharge pipe to future North Rapid pressure zone) to provide adequate suction and discharge piping to the station for the expected flow rates.

Figure 1. Shepherd Hills development

(Figure provided by Dream Design International, Inc)
FEASIBILITY STUDY PURPOSE
A new regional booster pump station (RBS) was originally proposed in Rapid City’s 2008 Utility System Master Plan near the existing Elk Vale reservoir, approximately 1.5 miles east of the proposed Shepherd Hills booster pump station site (see Figure 2). The RBS was intended to serve future development in the North Rapid pressure zone and ultimately supply water to a future North Rapid Elk Vale reservoir.

Instead of the Developer constructing a booster pump station just to serve the Shepherd Hills development, the Developer has proposed to make this a regional facility because of its proximity to the original RBS location. A regional booster station approach in this case is consistent with Section 3.10.1 of the City’s Infrastructure Design Criteria Manual (IDCM) which indicates that these types of facilities should be designed and constructed as regional facilities whenever feasible. The purpose of this feasibility study is to determine if a new RBS is still necessary, evaluate the new location of the RBS proposed by the Developer as part of the Shepherd Hills development, and determine if it can serve in a regional capacity for future development in the North Rapid pressure zone. In the study, the following will be evaluated:

- If the RBS location is operationally feasible and interacts well with other facilities and pressure zones
- If the Shepherd Hills development planned watermain extensions are adequate to support future development
- If the RBS has any impacts which may require additional water distribution system improvements outside the TID
- The necessity of upcoming City CIP projects related to the RBS and Shepherd Hills development

FEASIBILITY STUDY APPROACH
The study is broken up into two parts: Part 1 and Part 2. Each part utilizes 2025 system demands, which are covered in the System Demands section of the report.

Part 1 consists of the Shepherd Hills development buildout through the year 2025 west of Elk Vale Road, including a new RBS and no additional North Rapid Elk Vale storage. The Developer’s proposed watermain layout for Part 1 is displayed in Figure 3. The Shepherd Hills development will be fed by an existing 12” watermain along East Anamosa Street from North Rapid pressure zone until the construction of the new RBS. The extent of the existing system as of June 2021 is also shown in Figure 3.

Part 2 consists of the Shepherd Hills development plus additional demand growth east of Elk Vale Road, a new RBS, and a new North Rapid Elk Vale reservoir. Figure 4 displays a map of the Developer’s proposed watermain layout for Part 2.
Figure 2. New RBS location
Figure 3. Part 1 Developer’s proposed watermain layout
2. Study Preparation

To perform the feasibility study, projected system demands through the year 2025 had to be added in the hydraulic model. In addition, design criteria had to be selected, existing system performance had to be evaluated, and the most recent operations and facilities information had to be populated in the model. The City’s existing model with a physical piping and facilities configuration based on 2018 data and an applied demand from 2015 metered sales data was used as a basis for these updates.

SYSTEM DEMANDS

Through the current water utility system master plan effort, projected system demands for the year 2025 were determined. The 2025 Maximum Day Demand (MDD) of 24.3 million gallons per day (MGD) was used for the feasibility study to coincide with the completion date supplied by the Developer for the Shepherd Hills development. A global multiplier was then applied to the system demands in the model to increase them from the 2015 metered sales data to the 2025 MDD.

Information from the Developer was used to break out demands for the two parts of the study. For Part 1, which is Shepherd Hills development through the year 2025, the projected MDD is 5 MGD. The 5 MGD was included in the total 24.3 MGD from above.
For Part 2, operational and sizing criteria were developed for the RBS serving as a regional facility by supplying demands to not only the Shepherd Hills development but also anticipated un-named development further east in the North Rapid zone. For Part 2 the MDD projection includes 5 MGD from the Shepherd Hills development (Part 1) plus another 3 MGD for additional demand further east in the North Rapid zone. This represents an anticipated 2045 MDD demand of 8 MGD for this portion of the North Rapid zone. The total distribution system demand for Part 2 is thus 27.3 MGD. Other system-wide improvements for 2045 demands will be defined during the system-wide 2045 master plan which is currently under development in parallel with this feasibility study.

For comparison purposes, the 2007 study by Advanced Engineering and Environmental Services, Inc. titled *Elk Vale Low Level Reservoir and Elk Vale High Level Reservoir Preliminary Engineering Report*, projected MDD for this area to be 3.8 MGD, which is less than the projected demands used for this feasibility study. Additionally, the current Utility System Master Plan has projected total future growth of approximately 3 MGD for build out of the North Rapid pressure zone area. The demands used for this analysis are higher than previous studies, which provides a conservative review of the feasibility of the new RBS location.

**DESIGN CRITERIA**

Design criteria were used as a basis, along with engineering judgement, to determine if the RBS was feasible and if additional improvements were needed to meet demands of future development. The selected criteria were based on various water system design guidelines and considered regulations such as the Rapid City Infrastructure Design Criteria Manual (IDCM) and International Fire Code (IFC). Two demand conditions with two different design criteria were evaluated for the feasibility study: (1) peak hour and minimum hour demand on the maximum day and (2) MDD plus fire flow.

The peak hour and minimum hour criteria on the MDD are as follows:

- Minimum static pressure – 40 psi
- Minimum 1-hour residual pressure – 35 psi
- Maximum static pressure – 135 psi
- Maximum velocity – 10 ft/s

The MDD plus fire flow criteria are as follows:

- Minimum residual pressure – 20 psi
- Maximum velocity – 12 ft/s

In addition to the above criteria, the general interaction of the new RBS (and future North Rapid Elk Vale reservoir for Part 2) with other facilities and pressure zones was observed. Tank levels were monitored to ensure they stayed above ½ full and replenished to initial levels over a 24-hour period. Pump operations were also monitored at surrounding facilities to determine hydraulic interactions between pump stations. Specifically, the North Rapid Booster Pump Station (BPS), North Rapid reservoir, two Signal Hill reservoirs, and Elk Vale reservoir were monitored because of direct hydraulic connections to the elements in the study.
EXISTING SYSTEM PERFORMANCE

Before the analysis of Part 1 and Part 2 of the study, a base scenario was constructed as a control to compare results across other scenarios. In the base scenario, the current system buildout through June 2021 was set in the model, along with the following system setpoints:

- Control valves filling Signal Hill reservoirs were set at 10% open to maintain level at Elk Vale tank (see Study Assumptions section for additional description)
- Bleed valve at the intersection of North Lacrosse Street and East Mall Drive between North Rapid pressure zone and Low Level pressure zone was closed
- Mt. View Water Treatment Plant (WTP) finished water pumping was set to deliver a constant rate of 6.5 MGD for 24 hours/day

Throughout the study, tank levels at Signal Hill, Elk Vale, and North Rapid were compared to determine how the new RBS impacted tank cycling. The results for tank levels in the existing system base scenario are displayed in Figure 5. Over a 72-hour simulation, all four tanks cycled through expected levels and replenished over each diurnal period.

Surrounding the Shepherd Hills development, minimum static pressures of 40 psi were maintained except where near the interface of the North Rapid and Low Level pressure zones or near the Low Level reservoirs. Similarly, maximum pressures remained below the requirement of 135 psi except in the North Rapid pressure zone near the boundary with the Low Level pressure zone. However, these spot high and low pressures are typical according to City staff. Peak hour velocities also met the design criteria of 10 ft/s for the areas surrounding the Shepherd Hills development. Figure 6, Figure 7 and Figure 8 show the results of the base scenario for the criteria above.
Figure 6. Minimum pressures – existing system base scenario

Figure 7. Maximum pressures – existing system base scenario
STUDY ASSUMPTIONS

For the rest of the hydraulic analysis, including Parts 1 and 2, operational assumptions were made to best represent the system with a new RBS in service in the future.

The first assumption was that Mt. View WTP would be operating 24 hours per day for an MDD condition. Full-time production from the Mt. View WTP was critical to keeping tanks full and meeting minimum pressures under each future scenario. For Part 1, Mt. View WTP finished water pumps were set to deliver at 6-12 MGD for much of the day, and for Part 2, it was increased to 12-14 MGD. Jackson Springs WTP was set for a peak of 8 MGD in both parts of the study. Additionally, the wells that were assumed active or inactive are displayed in Table 1. All other facilities not specifically indicated herein were set for typical MDD operations.

Table 1. Active and inactive facilities

<table>
<thead>
<tr>
<th>WELL NO.</th>
<th>PRESSURE ZONE</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low Level</td>
<td>OFF</td>
</tr>
<tr>
<td>4</td>
<td>Low Level</td>
<td>OFF</td>
</tr>
<tr>
<td>5</td>
<td>Low Level</td>
<td>OFF</td>
</tr>
<tr>
<td>9</td>
<td>Low Level</td>
<td>ON</td>
</tr>
<tr>
<td>6</td>
<td>South Canyon Arrowhead</td>
<td>OFF</td>
</tr>
<tr>
<td>10</td>
<td>South Canyon Arrowhead</td>
<td>ON</td>
</tr>
<tr>
<td>8</td>
<td>North Rapid</td>
<td>OFF</td>
</tr>
<tr>
<td>11</td>
<td>Southwest</td>
<td>ON</td>
</tr>
<tr>
<td>12</td>
<td>Red Rocks</td>
<td>ON</td>
</tr>
</tbody>
</table>
As was mentioned in the Existing System Performance section, it was assumed that the flow control valves would be operational to limit flow into the Signal Hill reservoirs and allow Elk Vale reservoir to fill. The bleed valve at the intersection of North Lacrosse Street and East Mall Drive currently used by operations staff to allow water to flow from North Rapid to Low Level pressure zone (to fill Elk Vale reservoir) was also closed in all scenarios.

For Part 2 of the analysis, which includes the future North Rapid Elk Vale reservoir and an additional 3 MGD of demand, the service to the City of Box Elder had to be shut down in the hydraulic model. With a maximum day demand of 2 MGD to Box Elder in place, the Elk Vale reservoir was not able to remain full. It is recommended the City consider shutting down supply to Box Elder prior to the construction of a future North Rapid Elk Vale reservoir. Note, the Ellsworth Air Force Base connection was drawing at the contracted 24-hour flow rate in both parts of the study.

3. Results

STUDY FRAMEWORK

After completing the study preparation, Parts 1 and 2 of the analysis were set-up in the hydraulic model. Multiple solutions were found for both parts of the analysis with final recommendations at the end of the report. For Part 1, three solutions were evaluated:

- Part 1-A. RBS with variable frequency drive (VFD) pumps – No flow control between North Rapid pressure zone and the Shepherd Hills development
- Part 1-B. RBS with VFD pumps – Flow control between North Rapid pressure zone and the Shepherd Hills development
- Part 1-C. RBS with constant speed pumps – No flow control between North Rapid pressure zone and the Shepherd Hills development

The different solutions evaluated for Part 2 will be detailed below.

PART 1

Part 1-A

For Part 1-A, VFD pumps were added in the model at the location of the proposed RBS as shown in the proposed watermain layout map in Figure 9. A total of three watermains were set to serve the suction side of the RBS, including: (1) the Developer proposed 20” watermain along East Anamosa Street, (2) the Developer proposed 12” watermain along Mickelson Drive, and (3) the existing 16” watermain along East Philadelphia Street. One Developer-proposed 16” watermain along East Anamosa Street was set to serve as the main RBS discharge header. The 16” main was connected to a 12” existing North Rapid pressure zone main along East Anamosa Street, allowing for flow to travel between the North Rapid pressure zone and the Shepherd Hills development. The 20” dead
end main along East Anamosa Street east of Mickelson Drive was initially kept out of the model for Part 1 as it did not serve a purpose until it was connected to the existing Low Level watermain.

The RBS was set to a target pressure of 95 psi on the discharge side of the station to maintain a minimum pressure of 40 psi in the development area and balance flow between North Rapid pressure zone and the Shepherd Hills development. Minimum and maximum pressures for Part 1-A are displayed in Figure 10 and Figure 11, respectively.

On the suction side of the RBS in the Low Level pressure zone, more low pressures appeared when the RBS reached high flow rates (> 4,000 gpm); however, most of these nodes stayed above 35 psi in the 1-hour peak flow, which meets the design requirement. For the watermain loops in Figure 12 which did not meet the minimum peak hour pressure requirement of 35 psi, it is recommended they be converted to the North Rapid pressure zone.
Figure 10. Minimum pressures – Part 1-A

Figure 11. Maximum pressures – Part 1-A
To maintain the 95-psi target pressure at the RBS, parallel pumps were automatically triggered in the model. In total, three pumps with a design flow and head of 1,600 gpm and 240 feet each were used over each 24-hour period. The total RBS design flow in this case was thus 4,800 gpm.

The flow between the existing North Rapid pressure zone and Shepherd Hills under this scenario is displayed in Figure 13. Despite optimizing the RBS target pressure, up to 800 gpm of flow was being delivered from the RBS to the North Rapid pressure zone during times of low demand.

Figure 14 displays two plots, one showing the discharge from North Rapid BPS under the base scenario and another showing the North Rapid BPS and RBS discharge flows for Part 1-A. During periods of low demand in Part 1-A, the RBS was unable to maintain head control and shut down. The North Rapid BPS, however, interacted well with the new RBS and operated at an average flow rate of 1,780 gpm compared to 1,100 gpm in the base scenario. As a result of the instability issues at the RBS, flow control between the North Rapid pressure zone and Shepherd Hills area was considered and is discussed in Part 1-B.
As a final check, maximum pipe velocities and tank levels were compared to the base scenario results. Figure 15 shows a map of the maximum velocities. All velocities remained below the design requirement of 10 ft/s with a few watermains increasing in velocity to a range of 5-7 ft/s because of increased capacity requirements (i.e. Mt. View WTP discharge piping, RBS suction piping, Elk Vale reservoir piping, etc.).

Figure 13. Flow between North Rapid pressure zone and Shepherd Hills – Part 1-A

Figure 14. North Rapid BPS and RBS flows for base scenario and Part 1-A
Figure 15. Maximum velocities – Part 1-A

The tanks cycled between expected operating levels for Part 1-A (see Figure 16). Compared to the base scenario, Elk Vale reservoir operated within a range approximately 10% greater in terms of volume for Part 1-A. Similarly, North Rapid reservoir operated between 75-98% full as opposed to 70-90% full in the base scenario. Flow contributions from the RBS to the North Rapid pressure zone likely caused the North Rapid reservoir to operate with a higher depth, and increased flow on the suction side of the RBS likely caused Elk Vale reservoir to cycle within a greater range.
Part 1-B

Part 1-B is the same as Part 1-A except a flow control valve was added on the 16” watermain connecting North Rapid pressure zone to the Shepherd Hills development (see Figure 17 for location). The option of a flow control valve was pursued because the VFD pumps at the RBS in Part 1-A would shut down during periods of low demand, causing instabilities in the hydraulic model. The flow control valve would prevent flow being pumped from the RBS west into the existing North Rapid pressure zone. The same valve however would allow flow from the existing North Rapid zone to flow east into the Shepherd Hills development area when the downstream (east side) pressure drops below a certain setpoint. It was expected the flow control valve would help reduce conflicts between the flow and pressure delivered from the existing North Rapid zone and the discharge of the new RBS.

![Diagram of flow control valve location](image)

**Figure 17. Flow Control Valve Location – Part 1-B**

The flow control valve was initially set at 101 psi in the model (valve opens when downstream/east side pressure is below 101 psi). The resulting flow between the North Rapid pressure zone and the Shepherd Hills development is displayed in Figure 18.

Flow continued to enter the Shepherd Hills development during periods of high demand, but no flow was allowed out to the North Rapid pressure zone because of the flow control valve. Figure 19 displays a comparison of the North Rapid BPS and RBS flows for Part 1-A and 1-B. Instead of shutting down during periods of low demand like in Part 1-A, the RBS now remained operating for the whole simulation period, and the model instabilities were eliminated. The average flow from North Rapid BPS decreased from 1,780 gpm in Part 1-A to 1,520 gpm in Part 1-B.
The minimum pressures, maximum pressures, and maximum velocities remained consistent with the results of Part 1-A. Spot areas of high and low pressure persisted near the interface of the Low Level and North Rapid pressure zones.

The City's IDCM addresses required water storage criteria which is based on the larger of two conditions:

- Operational Storage (25% MDD) + Fire Flow Storage (4 hours at 4,000 gpm)
- Operational Storage (25% MDD) + Emergency Storage (100% Avg Day Demand)

The second criteria governs in the existing North Rapid zone requiring 2.25 MG of storage including 0.75 MG for operational storage plus 1.5 MG for emergency storage. The existing North Rapid Zone has one reservoir with a capacity of 2.0 MG indicating that the existing system is already short of the storage volume required by the IDCM standard.
When the Shepherd Hills development demand (5.0 mgd MDD) is added to the existing North Rapid zone, the IDCM required storage increases to 6.1 MG including 2.0 MG of operational storage plus 4.1 MG of emergency storage.

Tank levels shown in Figures 16 and 20 for the North Rapid Reservoir are similar with a slightly wider fluctuation in Part 1-A (Figure 16) at 75%-98% full versus Part 1-B (Figure 20) at 80-92% full. The narrower operating range for Part 1-B was likely a result of less water flowing from the North Rapid pressure zone into the Shepherd Hills development (1,000 gpm maximum instead of 1,400 gpm), therefore causing the reservoir to drain slower. These hydraulic modeling results indicate that the range of water fluctuation observed in the existing North Rapid Reservoir (i.e. operational storage) ranges from 23% (460,000 gallons) in Part 1-A to 12% (240,000 gallons) in Part 1B.

While these modeled values of operational storage are significantly less than the IDCM criteria requirements of 2.0 MG, the addition of the Shepherd Hills development demands only worsens the storage volume deficiency in the North Rapid zone. As a result, it is recommended that expansion of storage in the North Rapid zone be implemented at the same time as the Shepherd Hills development proceeds. Hydraulic modeling with additional storage is evaluated and discussed below in the Part 2 portion of this feasibility study.
Part 1-C
The last alternative considered in Part 1 was constant speed pumps instead of VFD-driven pumps at the RBS. This was evaluated to match many of the City's existing pump stations that have constant speed pumps with start/stop cycles controlled based on water level in a connected storage tank. In general, pumps run at constant speed have trouble meeting diurnal changes in demand without equalization storage or variation in water source production.

Part 1-C required the same model set-up as Part 1-A, but two constant speed pumps were added at the new RBS instead of VFD pumps. One 1,500 gpm pump was set to run the whole day and another 3,600 gpm pump was set to operate based on the North Rapid reservoir level.

In addition, for the constant speed pumps to be effective, a 16” parallel watermain was necessary for hydraulic connectivity between the North Rapid pressure zone and Shepherd Hills along East Anamosa Street from East Philadelphia Street to Luna Ave (See Figure 21). With just the existing 12” watermain connecting the two areas, flow was limited to 1,000 gpm in either direction as is shown in Figure 22. With the 16” parallel watermain in place, the flow increased to a maximum of 1,400 gpm as shown in Figure 23, and pressures improved in the Shepherd Hills development.

Changes in flow direction in the North Rapid/Shepherd Hills connecting pipeline were more prominent when the pumps were operated at constant speed versus on VFDs. When the second constant speed pump was on at the RBS, water tended to travel north because the RBS discharge pressure was greater than the flow and pressure coming from the North Rapid pressure zone. When the second pump was off, flow was either negligible or towards the south.
The discharge flows from North Rapid BPS and the RBS for the base scenario and Part 1-C are displayed in Figure 24. The average flow from North Rapid BPS was approximately the same between the base and Part 1-C scenarios. A comparison of the average flows from North Rapid BPS for all the Part 1 alternatives and base scenario is available in Table 2. Like the other alternatives, the tanks cycled within their expected ranges for Part 1-C, and a graph of their levels over a 72-hour simulation is displayed in Figure 25.
Figure 24. North Rapid BPS and RBS flows for existing system base scenario and Part 1-C

Table 2. Flow from North Rapid BPS

<table>
<thead>
<tr>
<th>PART</th>
<th>AVERAGE FLOW FROM NORTH RAPID BPS (GPM)</th>
</tr>
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<tbody>
<tr>
<td>Existing system base scenario</td>
<td>1,100</td>
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<tr>
<td>Part 1-A. VFD pumps</td>
<td>1,780</td>
</tr>
<tr>
<td>Part 1-B. VFD pumps with flow control</td>
<td>1,520</td>
</tr>
<tr>
<td>Part 1-C. Constant speed pumps</td>
<td>1,000</td>
</tr>
</tbody>
</table>
Minimum pressures, maximum pressures, and maximum pipe velocities for Part 1-C are available in Figure 26, Figure 27 and Figure 28. Overall, pressures and velocities remained comparable to Parts 1-A and 1-B (i.e. spot high and low pressures, higher velocities near facilities, etc.) with no additional hydraulic limitations identified.
PART 2

Part 2 of the study focused on the Shepherd Hills development plus additional development that could occur in the future further east in the North Rapid zone (both west and east of Elk Vale Road) through the year 2045. The Developer's proposed watermain and facilities layout shown in Figure 29 was used as a basis for the analysis, which includes two watermain improvements: (1) the proposed 20” Low Level watermain terminated short of the intersection of Concourse Drive and East Anamosa Street in Part 1 connecting to the existing 16” Low Level watermain at the same
By 2045, an additional 3 MGD of demand is projected east of Shepherd Hills development in the North Rapid zone. Demand varies significantly over the course of the day, and to meet these variations, adjustments of water source production, variable booster station pumping rates, or equalization storage are required. For these 2045 demand conditions, equalization storage would enable the new RBS pumps to operate at a constant speed similar to the City’s other facilities. Additionally, it is desirable to size pumping facilities to meet MDD and provide equalization storage to handle peak hour demands because storage reservoirs are generally less expensive than high service pumps. To accommodate future growth and development; provide operational, fire, and
emergency storage volume; ensure greater system reliability; and facilitate improved operations, a new North Rapid Elk Vale reservoir is recommended.

Based on Rapid City IDCM criteria, 3.85 million gallons (MG) of storage is necessary to meet the specific needs of the Shepherd Hills development. In the hydraulic model, a 3.5 MG North Rapid Elk Vale reservoir was added at the location shown in Figure 30 near the existing Elk Vale reservoir. A 3.5 MG reservoir was initially suggested by the Developer.

IDCM criteria for water storage volumes was presented previously under the Part 1-B evaluation. The total North Rapid zone storage volumes required by the IDCM criteria are:

- 6.1 MG when the Shepherd Hills development demands (5.0 mgd MDD) are included, and
- 8.3 MG when projected additional un-named development occurs in the North Rapid zone east of the Shepherd Hills development (3.0 mgd MDD additional).

With the existing North Rapid Reservoir volume of 2.0 MG, this evaluation indicates that an additional 4.0 MG of storage should be implemented along with the Shepherd Hills development in order to eliminate the North Rapid zone storage deficiency.

In addition to the reservoir, a looped 16” watermain was added along future East Philadelphia Street, Elk Vale Road, and East Anamosa Street to tie the future storage facility into the Shepherd Hills development planned pipeline as shown in Figure 30. The three RBS pumps from Part 1 were used as a basis for the Part 2 analysis. The pumps operate at 100% full-speed and were set to start/stop based on level at the North Rapid Elk Vale reservoir.
The results for the first simulation of Part 2 with the above physical and operational settings showed that the Low Level reservoirs (Elk Vale and Signal Hills) were not able to stay full (see Figure 31). The higher demand drawn from the Low Level pressure zone to the Shepherd Hills development drained the reservoirs faster than in Part 1.

To meet minimum pressure requirements and tank level requirements, the City of Box Elder demand (2 MGD) on Cheyenne Boulevard had to be removed from the model, and flow control had to be added on the 16” watermain connecting to the existing North Rapid pressure zone. Like Part 1-B, a flow control valve restricting water from flowing into the existing North Rapid pressure zone from the RBS assisted with the hydraulic performance in the proposed development. See Figure 32 for a comparison of the flow between North Rapid pressure zone and the Shepherd Hills development with and without flow control. At times, a maximum of 1,400 gpm was flowing into North Rapid pressure zone from Shepherd Hills development, thereby limiting the amount of water available to replenish the North Rapid Elk Vale reservoir. An updated plot of tank levels with the flow control added and Box Elder demands eliminated is available in Figure 33.

Figure 31. Tank levels – Part 2 simulation one
Figure 32. Flow between North Rapid pressure zone and Shepherd Hills development

NOTE: Positive flow is flow into North Rapid pressure zone from Shepherd Hills and negative flow is flow from North Rapid pressure zone into Shepherd Hills.

Figure 33. Tank levels – Part 2 simulation two
With the above changes, North Rapid BPS operated at an average flow rate of 1,380 gpm as opposed to the base scenario of 1,100 gpm. Additionally, the pumps at RBS were able to function at a decreased design flow of 1,600 gpm each to match the recommended pump sizes from Parts 1-A and 1-B. The total pump station design flow for Part 2 was thus 4,800 gpm (three pumps rated at 1600 gpm and 240 ft head). During peak system demands the total pump station flow produces 6,700 gpm with the same pumps operating at 2,233 gpm and 165 ft head each. A comparison between the base scenario and Part 2 for North Rapid BPS and RBS flows is available in Figure 34.

Maps of the minimum pressures, maximum pressures, and maximum pipeline velocities in the system are available in Figure 35, Figure 36 and Figure 37. In general, pressures and maximum velocities remained comparable to the results of Part 1 with high and low pressures encountered near the interface of two pressure zones and high pipeline velocities encountered near major facilities. No additional areas of deficiency were identified than already identified in Part 1.

**FIRE FLOW**

Steady-state available fire flow simulations for both Parts 1 and 2 were performed to check against the MDD plus fire flow criteria. The minimum required residual pressure and maximum water main velocity during a fire flow are 20 psi and 12 ft/s, respectively.

Per the IDCM, the minimum fire flow for residences less than 3,600 in square footage should be 1,000 gpm, which was used as a basis for the single-family homes in the Shepherd Hills development. For large commercial lots, a requirement of 3,000 gpm was selected based on information from the IFC.

The results from Part 1 for available fire flow are displayed in Figure 38. The simulation showed that available flows in the development were above 3,000 gpm with exception to 8” dead end watermains which are flow restricted by the 12 ft/s velocity criteria. According to the Developer’s proposed land use map, no large commercial lots or multi-family residential buildings are planned along these 8” watermains.
Results for the Part 2 available fire flow analysis were very similar to Part 1. The same 8” dead end watermains are flow restricted by the velocity constraint of 12 ft/s. The rest of the system maintains minimum flows of 3,000 gpm, with many locations showing an increase in flow due to the addition of the new North Rapid Elk Vale Reservoir.

Figure 35. Minimum pressures – Part 2

Figure 36. Maximum pressures – Part 2
REDUNDANCY

System redundancy was briefly reviewed as part of the feasibility study. The ability of the new RBS to provide supply to the existing North Rapid pressure zone and well as the ability of the North Rapid pressure zone (pump station and tank) to provide supply to the Shepherd Hills area was reviewed. An in-depth analysis and recommendations for projects that support system redundancy will be provided as part of the Utility System Master Plan. Results of the brief analysis included in the feasibility study are provided below.
Currently, one 16-inch watermain is planned along East Anamosa Street to connect the existing North Rapid pressure zone to the new Shepherd Hills area of the North Rapid pressure zone. The model runs documented below used the proposed 16-inch pipeline connection with no flow control.

**Supply from the new RBS to the existing North Rapid Zone:** Initial hydraulic analysis indicates that supply can be provided from the new RBS to the North Rapid Zone during low and average demand periods. Providing supply during max day demand periods results in excessive head loss through the proposed 16-inch pipeline connecting the two zones.

**Supply from existing North Rapid Zone to new Shepherd Hills development area under Part 1 demands (5 MGD):** Initial hydraulic analysis indicates that supplemental supply can be provided from the existing North Rapid zone to the new Shepherd Hills area. The existing North Rapid pressure zone is not capable of supplying total system demand to the new Shepherd Hills area during average or maximum day demand conditions, the RBS is necessary to provide adequate flow/pressure. Pipeline improvement may be a possibility to increase the amount of flow available from the existing North Rapid pressure zone.

North Rapid pressure zone redundancy will be evaluated under differing demand conditions and planning years as part of the Utility System Master Plan. Capital improvements will be generated from the master plan analysis.

### 4. Proposed Plan

**PART 1 RECOMMENDATION**

For Part 1 of the study, including the Shepherd Hills development buildout through the year 2025, the solution in Part 1-B is recommended. The solution includes VFD pumps at the RBS as well as flow control between the existing North Rapid pressure zone and Shepherd Hills development. A map of the proposed pipeline plan is displayed in Figure 39.

The VFD pump solution, as opposed to the constant speed pump solution, is recommended because VFD pumps offer flexibility for varying service without the need for equalization storage. The VFD pumps can be set to operate based on target discharge pressure and flow control can be provided to prevent excess flow from the RBS to the North Rapid pressure zone. A pump station with a final design capacity of 4,800 gpm and total dynamic head of 240 feet will be sufficient to meet the maximum day development demands through 2025. Design criteria for the initial phase of the RBS pumps is summarized as follows:

- **Part 1**
  - Flow control valve station with bypass included
  - Pump Control based on discharge pressure setpoint with VFDs if new reservoir not in service
  - 4 pumps total; 3 duty pumps plus one standby pump
  - Pump rated point – 1600 gpm at 240 ft head
  - North Rapid Elk Vale Reservoir included in Part 1 improvements
The feasibility study focused on sizing the pump station for maximum day demands and did not focus on minimum expected flows. Having pumps that meet low demands as the development is constructed and during winter months will be just as critical as meeting peak forecasted buildout demands. During the design phase of the RBS, special consideration should be made for low flows. The use of jockey pumps or small equalization tanks should be considered, and pump construction phasing shall be set to meet changing demands. Alternately, the proposed flow control valve can be used to supply water from existing North Rapid pressure zone to the Shepherd Hills development during seasonal low demand periods.

With the construction of the new RBS, re-zoning of the Low Level pressure zone may be necessary because of low pressures. On Camden Drive, Lando Lane, and Century Road as indicated in Figure
12, pressures drop below 35 psi during the 1-hour peak flow. The water mains along these roads are located adjacent to the existing 12”/16” North Rapid pressure zone water main along East Anamosa Street. The recommendation to convert this area to the North Rapid pressure zone will be reviewed in the Utility System Master Plan.

Modeling of additional storage in the North Rapid zone was completed in the Part 2 evaluation. With the existing North Rapid Reservoir volume of 2.0 MG, this evaluation indicates that an additional 4.0 MG of storage should be installed along with the Shepherd Hills development in order to eliminate the North Rapid zone storage deficiency and conform to the City’s IDCM criteria for water storage volume. Construction of additional storage could be phased with two 2.0 MG elevated storage tanks being commissioned sequentially as the Shepherd Hills development continues.

PART 2 RECOMMENDATION

For Part 2, equalization, fire, and emergency storage will be provided in the form of a new North Rapid Elk Vale reservoir east of Elk Vale Road. The additional equalization storage will be able to meet diurnal variations in demand and therefore the RBS pumps can then be operated at a set rate with start/stop pump control based on tank level. Figure 40 displays a map of the proposed watermain diameters and new reservoir location. The same pumps from Part 1 were able to meet Part 2 demands when a flow control valve was in place to limit excess flow from the RBS to the North Rapid pressure zone. As a result, design criteria for the RBS pumps is summarized as follows:

- **Part 1**
  - Flow control valve station with bypass included
  - Pump Control based on Discharge Pressure Setpoint with VFDs if new reservoir not in service
  - 4 pumps total; 3 duty pumps plus one standby pump
  - Pump rated point – 1600 gpm at 240 ft head
  - North Rapid Elk Vale Reservoir included in Part 1 improvements

- **Part 2**
  - Flow control valve station with bypass included
  - North Rapid Elk Vale Reservoir included
  - Pump control based on North Rapid Elk Vale Reservoir water level
  - 4 pumps total; 3 duty pumps plus one standby pump
  - Pump rate points: 1600 gpm at 240 ft head (average pumping) and 2250 gpm at 165 ft head (peak hour pumping)

A new 3.5 MG reservoir was added in the hydraulic model for the Part 2 simulations based on initial suggestions by the Developer. However, it was determined that 3.85 MG of storage would be necessary based on the specific Shepherd Hills development demand and IDCM storage criteria. When IDCM criteria is applied to the entirety of the North Rapid zone, this evaluation indicates that an additional 4.0 MG of storage should be installed along with the Shepherd Hills development in
order to eliminate the North Rapid zone storage deficiency and conform to the City’s IDCM criteria for water storage volume. Construction of additional storage could be phased with two 2.0 MG elevated storage tanks being commissioned sequentially as the Shepherd Hills development continues.

SUMMARY

The results of this study indicate that locating a new RBS at the proposed location to serve both the Shepherd Hills development as well as future un-named development further east in the North Rapid zone is feasible and the City can proceed with implementation of design and construction for the new RBS. Table 3 provides a summary of the improvements addressed in Part 1 and Part 2 of
this study. The table categorizes improvements into one of three groups: assumed improvements, developer improvements and hydraulic improvements.

**Assumed Improvements** – these are the improvements that are assumed to be in place for this study. These improvements are necessary, but not associated with the Shepherd Hills development.

**Developer Improvements** – these improvements are part of the developers currently proposed plan.

**Hydraulic Improvements** – these improvements are improvements were identified as part of the feasibility study and will be necessary in the future. They are not currently part of the developer’s plan.

There are a few recommended projects that are referenced as “details to be determined”. The current developers pipe diameter plan is feasible, however there may changes to the pipe plan that would be beneficial. The follow-up analysis, East Anamosa Street and Mickelson Drive Pipe Assessment, in Section 5 below reviews potential changes to the pipe plan. It is recommended that the follow-up analysis be reviewed and integrated as appropriate when selecting final system pipe diameters.
### Table 3. Improvement summary table

<table>
<thead>
<tr>
<th>PHASE</th>
<th>IMPROVEMENT TYPE</th>
<th>PROJECT</th>
</tr>
</thead>
</table>
| **Part 1** | **Assumed** | Signal Hill Valve Flow Control  
• Assumed in place for both Part 1 and Part 2 |
| **Developer** | Shepherd Hills Development Pipe (Figure 39)  
• 8-inch and 12-inch Shepherd Hills distribution pipe  
• 16-inch North Rapid transmission main along E. Anamosa from RBS to Concourse Dr.  
• 20-inch Low Level transmission main along E. Anamosa from E. North St. to Mickelson Dr. |
| **Developer** | Low Level Pipe (Figure 39) – Details to Be Determined (see Section 5)  
• Potential Mickelson Dr. pipeline connection  
• Potential Low Level E. Anamosa St. pipeline from Mickelson Dr to existing 16-inch on Concourse Dr. |
| **Developer** | RBS  
• 4 VFD Pumps 4,800 gpm firm capacity  
• Pump Rated Points: 1,600 gpm at 240 ft & 2,250 gpm at 165 ft  
• North Rapid Zone flow control valving integrated into the RBS building and provided with a manual bypass to allow pumping from the RBS north and west into the North Rapid pressure zone. |
| **Hydraulic** | North Rapid Elk Vale Storage Reservoir  
• 3.85 to 4.0 MG reservoir and associated piping to connect the reservoir to the planned 16-inch pipe in Elk Vale Rd.  
• Implement in phases with two 2.0 MG reservoirs as development continues |
| **Hydraulic** | Highway 44 Parallel Piping – Details to Be Determined (see Section 5)  
• Potential parallel pipe along Highway 44 from Campbell St. to Mickelson Dr. |
| **Part 2** | **Developer** | North Rapid Transmission (Figure 40)  
• 16-inch North Rapid transmission main along E. Anamosa from Concourse Dr to Elk Vale Rd then North along Elk Vale Rd to the location of the new elevated storage tank |
| **Hydraulic** | North Rapid Transmission (Figure 40)  
• 16-inch loop connection from N. Elk Vale Rd to Shepherd Hills pipeline |
| **Hydraulic** | RBS  
• Constant speed pump conversion with tank level controls  
• North Rapid Zone flow control valving integrated into the RBS building and provided with a manual bypass to allow pumping from the RBS north and west into the North Rapid pressure zone. |
5. Follow-up Hydraulic Model Scenarios

The follow-up hydraulic modeling scenarios focus on optimizing pipeline diameters/pipeline projects in and around the Shepherd Hills area. The feasibility analysis documented above shows that the plan with the currently proposed pipeline diameters is feasible, however there may be alternate pipeline diameters that are more favorable. The follow-up hydraulic model evaluations assess differing pipeline diameters and their effect on system pressure, available fire flow and filling of the Existing Elk Vale Reservoir. The results from the follow-up hydraulic modeling scenarios should be reviewed to support final decisions on the pipeline diameters to be constructed as part of the RBS and Shepherd Hills development.

The follow-up evaluations are summarized below:

Shepherd Hills Transmission Pipe Assessment
This analysis assesses the adequacy of the developer proposed 16-inch diameter pipeline along East Anamosa Street within the Shepherd Hills development.

East Anamosa Street and Mickelson Drive Pipe Assessment
This analysis assesses the adequacy of the proposed 20-inch diameter pipeline along East Anamosa Street and the proposed 12-inch diameter pipeline along Mickelson Drive.

SHEPHERD HILLS TRANSMISSION PIPE ASSESSMENT

The Shepherd Hills transmission pipe assessment reviews the adequacy of the Part 1 proposed 16-inch pipeline that provides near term transmission within the Shepherd Hills area, and the Part 2 proposed 16-inch looped pipeline that provides ultimate transmission for this area. The Part 1 and Part 2 proposed pipelines are shown in Figure 41. These pipelines are for service in the North Rapid zone.

There are areas of the Shepherd Hills development that are expected to experience pressures between 40 to 60 psi under peak demand conditions, and there are areas of the Shepherd Hills development that have simulated fire flow availability below 2000 gpm. This analysis was completed to determine if a larger transmission pipeline would boost system pressure or provide additional fire flow.

A 20-inch pipeline was simulated in place of the proposed 16-inch pipeline under both the Part 1 and Part 2 demand scenarios. The findings are as follows:

System Pressure: There is a negligible (1 to 3 psi) increase in system pressures when the proposed 16-inch pipeline is replaced with a 20-inch pipeline. Low pressures are occurring in areas of high elevation. There is minor head loss in the proposed 16-inch pipeline and increasing the diameter to 20-inch does little to support the high elevation areas. System pressure remains above the 40 psi minimum criteria with the 16-inch pipeline.

Available Fire Flow: There was no change in available fire flow at the model nodes with available fire flow less than 2,000 gpm. These nodes are flow restricted by the 12 ft/s velocity criteria in the 8-inch diameter pipelines. The remaining nodes are above the flow...
criteria of 3,000 gpm for commercial areas. Minimal benefit is gained by increasing the diameter of the proposed 16-inch pipeline to 20-inches.

Increasing the diameter of the 16-inch to a 20-inch provides limited benefits and is not recommended.

![Figure 41. Shepherd Hills transmission pipe assessment](image)

**EAST ANAMOSA STREET AND MICKELSON DRIVE PIPE ASSESSMENT**

The East Anamosa Street and Mickelson Drive pipe assessment reviews the 20-inch Low Level pressure zone pipeline that is planned to be built as part of the Shepherd Hills project. This analysis looked at the function of the 20-inch pipeline and adjacent pipelines such as the proposed 12-inch diameter pipeline along Mickelson Drive.

**20-inch East Anamosa Pipeline History**

The planned 20-inch pipeline along East Anamosa Street was intended to facilitate transmission of water from Low Level supply sources to the east side of the zone to support filling of the Low Level Elk Vale Reservoir and the planned RBS in its original location (adjacent to Low Level Elk Vale Reservoir). As part of the feasibility study the RBS was moved to a new location and the function of the planned 20-inch diameter pipeline needed to be reviewed.

**Initial Hydraulic Modeling of the 20-inch East Anamosa Pipeline**

In the Initial Part 2 feasibility study modeling the proposed 20-inch pipeline was connected and modeled. Simulation results indicated that the new RBS used the 20-inch diameter pipeline as a primary suction line, drawing water from the Elk Vale Reservoir and draining it over the course of
the extended period simulation. The Elk Vale Reservoir was not able to recover to an acceptable level, and the 20-inch pipeline was removed from the analysis. With the 20-inch diameter pipeline removed from the simulation the new RBS suction was provided by supply sources from the west in the Low Level pressure zone. The flow balance between the new RBS and the existing North Rapid pressure zone was then reviewed and it was determined that excess flow was being provided from the RBS to the North Rapid pressure zone. A flow control valve was then added between the two portions of the North Rapid zone to limit the amount of flow being pumped from the RBS north and west to the North Rapid pressure zone. After the flow control valve was inserted in the model, the 20-inch pipeline along East Anamosa Street was added back into the simulation to determine if controlling the excess flow at the RBS improved filling conditions at the Elk Vale Reservoir. Filling conditions at the Low Level Elk Vale Reservoir improved and it was determined that a follow-up hydraulic analysis should be completed to determine if the 20-inch pipeline along East Anamosa Street should be built.

**Pipeline Assessment**

The East Anamosa Street and Mickelson Drive Pipe Assessment looks at variations in pipeline diameters for the developer proposed 20-inch E. Anamosa St. pipeline and the 12-inch Mickelson Drive pipeline. The assessment also reviews the benefit of large diameter parallel pipe improvements along Highway 44 to support Low Level pressure zone water transmission.

The following assumptions were made for pipeline segments:

- **East Anamosa Street** – This pipeline is part of the Low Level pressure zone and runs along East Anamosa Street from the intersection of Mickelson Drive to the intersection of Concourse Drive where it connects to the existing 16-inch pipeline.

- **Mickelson Drive** – The proposed 12-inch diameter pipeline will run from the intersection of East Anamosa Street, connecting to the existing 8-inch pipeline on Mickelson Drive. When using alternate diameters, the pipeline is proposed to run from the intersection of East Anamosa Street to the intersection of Highway 44.

- **Highway 44** – The Highway 44 pipeline improvements extend from the existing 24-inch pipeline on Campbell Street, running parallel to the existing 12-inch pipeline in Highway 44 (E. Omaha St) to the intersection of Mickelson Drive.

Figure 42 shows the locations of these pipeline segments.

Table 4 lists the diameter combinations which were reviewed as part of this analysis. The five diameter combinations in bold were selected for result comparisons and details of these runs are provided below.
### Table 4. Model Scenario Pipeline Combinations

<table>
<thead>
<tr>
<th>EAST ANAMOSA STREET IMPROVEMENT</th>
<th>MICKELSON DRIVE IMPROVEMENT</th>
<th>HIGHWAY 44 IMPROVEMENT</th>
<th>SELECTED COMPARISON SCENARIOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pipe</td>
<td>12-inch</td>
<td>No pipe</td>
<td>Base Scenario</td>
</tr>
<tr>
<td>No pipe</td>
<td>16-inch</td>
<td>No pipe</td>
<td>n/a</td>
</tr>
<tr>
<td>No pipe</td>
<td>16-inch</td>
<td>24-inch</td>
<td>n/a</td>
</tr>
<tr>
<td>No pipe</td>
<td>16-inch</td>
<td>30-inch</td>
<td>Scenario 1</td>
</tr>
<tr>
<td>20-inch</td>
<td>16-inch</td>
<td>No pipe</td>
<td>n/a</td>
</tr>
<tr>
<td>20-inch</td>
<td>16-inch</td>
<td>24-inch</td>
<td>n/a</td>
</tr>
<tr>
<td>24-inch</td>
<td>16-inch</td>
<td>30-inch</td>
<td>Scenario 2</td>
</tr>
<tr>
<td>12-inch</td>
<td>24-inch</td>
<td>24-inch</td>
<td>n/a</td>
</tr>
<tr>
<td>12-inch</td>
<td>16-inch</td>
<td>No Pipe</td>
<td>Scenario 3</td>
</tr>
<tr>
<td>12-inch</td>
<td>16-inch</td>
<td>30-inch</td>
<td>Scenario 4</td>
</tr>
</tbody>
</table>
Low system pressures and cycling of the existing Low Level Elk Vale Reservoir were the data points used to compare scenarios. The base scenario includes the proposed 12-inch Mickelson Drive pipeline connected to the existing 8-inch pipeline on Mickelson Drive. The base scenario does not include pipeline improvements on East Anamosa Street or Highway 44. Figure 43 shows the minimum pressure results from the base scenario run.

There are two areas of low system pressures. Pressure Area 1 is located off East Anamosa Street on Camden Drive; there are 10 nodes with minimum pressures below 35 psi in this location and 63 nodes with minimum pressures between 35 and 40 psi in this area. Pressure Area 2 is located off East North Street along Century Road; there are 26 nodes with minimum pressures below 35 psi in this location and 15 nodes with pressures between 35 and 40 psi in this location. The model scenario pipeline combinations were run with the goal of improving pressures in Pressure Area 1 and Pressure Area 2. Results of pressure changes for the selected comparison scenarios are provided below.

In addition to improving system pressures, the pipeline assessment focused on improving transmission to the existing Low Level Elk Vale Reservoir. The minimum tank percent full during the 72-hour model simulation was used as the comparison point. Results of tank cycling (Tank % full) for the base scenario (12-inch Mickelson Dr. pipeline connected to existing 8-inch pipeline) are shown in Figure 44. The Low Level Elk Vale Reservoir hits a minimum percent full of 51% over the 72-hour model simulation. The minimum percent full of Low Level Elk Vale Reservoir for each of the selected comparison scenarios is provided below in Table 5.

![Figure 43. Base scenario (Mickelson Drive 12-inch) minimum pressures](image-url)
Hydraulic model results indicate that increasing the diameter in Mickelson Drive from a 12-inch to a 16-inch connected along Hwy 44 raises system pressure for some areas. Adding a new parallel 30-inch pipeline along Highway 44 supports both system pressures and Low Level Elk Vale Reservoir filling. With the addition of the 20-inch pipeline on East Anamosa Street, system pressures are further increased, however the RBS does suction from the existing Low Level Elk Vale Reservoir somewhat decreasing the minimum percent full. Decreasing the diameter of the proposed pipeline in East Anamosa Street from a 20-inch to a 12-inch helps keep Low Level Elk Vale Reservoir full, but also slightly reduces system pressure.

All pipeline combinations reviewed are feasible; some provide more support for system pressures and other provide more support for the existing Elk Vale Reservoir. The consulting team has selected Scenario 2 as the best-fit balanced approach. It is recommended that these improvements be reviewed by the Developer and City Staff to determine the appropriate installation diameters for the pipelines on Mickelson, Anamosa and Highway 44. The City’s updated Utility System Master Plan is currently in progress. The master plan will assess the ability of existing and proposed system pipeline to adequately serve regional system demand for the 2045 and 2115 planning periods. A new water treatment plan location is also being assessed. Pipeline diameter recommendations may change following completion of the master plan.

**16-inch Pipeline improvement along Mickelson Drive** – This improvement supports system pressures and provides a redundant supply pipeline for the RBS. The two other supply lines for the RBS are the planned 20-inch pipeline on E. Anamosa St., north of E. Philadelphia St., and the planned 16-inch pipeline on E. Philadelphia St. It is possible that a larger pipeline may be required for regional service. The master plan will assess and
recommend the appropriate diameter based on future regional demand for 2045 and 2115 as well as the new water treatment plant location.

**20-inch Pipeline on E. Anamosa St.** – This improvement serves an important role as a Low Level transmission main supporting the existing Elk Vale reservoir. It is possible that a reduced diameter pipeline may be adequate to convey future regional system demand, however a 20-inch diameter pipeline is recommended at this time. The master plan will assess and recommend the appropriate diameter based on future regional demand for 2045 and 2115 as well as the new water treatment plant location.

**30-inch Pipeline on Highway 44** – This recommendation will be reviewed as part of the Utility System Master Plan. It is likely that the existing 30-inch pipeline which currently ends at the intersection of 5th St will be recommended for extension. The master plan will determine the appropriate diameter for the Highway 44 improvement.

### Table 5. Modeled pipeline combinations: pressure and tank level results

<table>
<thead>
<tr>
<th>COMPARISON SCENARIO</th>
<th>PRESSURE AREA 1</th>
<th>PRESSURE AREA 2</th>
<th>LOW LEVEL ELK VALE RESERVOIR CYCLING MINIMUM % FULL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># NODES &lt; 35 PSI</td>
<td># NODES 35 - 40 PSI</td>
<td># NODES &lt; 35 PSI</td>
</tr>
<tr>
<td><strong>Base Scenario</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mickelson 12”</td>
<td>10 nodes &lt; 35 psi</td>
<td>26 nodes &lt; 35 psi</td>
<td>51 %</td>
</tr>
<tr>
<td></td>
<td>63 nodes 35 – 40 psi</td>
<td>15 nodes 35 – 40 psi</td>
<td></td>
</tr>
<tr>
<td><strong>Scenario 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mickelson 16”</td>
<td>0 nodes &lt; 35 psi</td>
<td>16 nodes &lt; 35 psi</td>
<td>58.5 %</td>
</tr>
<tr>
<td>Hwy 44 30”</td>
<td>64 nodes 35 – 40 psi</td>
<td>23 nodes 35 – 40 psi</td>
<td></td>
</tr>
<tr>
<td><strong>Scenario 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anamosa 20”</td>
<td>0 nodes &lt; 35 psi</td>
<td>8 nodes &lt; 35 psi</td>
<td>54.5 %</td>
</tr>
<tr>
<td>Mickelson 16”</td>
<td>33 nodes 35 – 40 psi</td>
<td>29 nodes 35 – 40 psi</td>
<td></td>
</tr>
<tr>
<td>Hwy 44 30”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scenario 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anamosa 12”</td>
<td>0 nodes &lt; 35 psi</td>
<td>9 nodes &lt; 35 psi</td>
<td>46.6 %</td>
</tr>
<tr>
<td>Mickelson 16”</td>
<td>58 nodes 35 – 40 psi</td>
<td>28 nodes 35 – 40 psi</td>
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</tr>
<tr>
<td><strong>Scenario 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anamosa 12”</td>
<td>0 nodes &lt; 35 psi</td>
<td>9 nodes &lt; 35 psi</td>
<td>56.6 %</td>
</tr>
<tr>
<td>Mickelson 16”</td>
<td>47 nodes 35 – 40 psi</td>
<td>28 nodes 35 – 40 psi</td>
<td></td>
</tr>
<tr>
<td>Hwy 44 30”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>