PRELIMINARY ANALYSIS

3.1 GENERAL

To aid in the selection of the preferred alignment, two distinct tasks were performed. The first task was the preliminary hydraulic modeling of the basin. The main purpose of hydraulic modeling was to select the areas to be served by the trunk sewer and to provide the preliminary pipe sizes to convey the wastewater from these areas. The results of this task are documented in Technical Memorandum Number 3 (Appendix C). The second task was an alternative alignment analysis. This analysis has taken into account several factors in selecting the preferred alignment. The results of this analysis are documented in Technical Memorandum No. 4 (Appendix D).

These analyses were completed using aerial mapping with two-foot contour elevations provided by the City. Actual pipe lengths and earthwork quantities will be refined during final design utilizing updated mapping.

3.2 HYDRAULICS

3.2.1 Peak flow

In order to determine the proper trunk sewer size, the estimated peak flow from each subbasin was first determined. This was determined using the City's Peak Flow Equation as defined in Technical Memorandum No. 1 (Appendix A). The equation is as follows:

$$Q = 0.01726\ A^{(0.8)} + 0.003\ A$$

Where:

Q = wastewater flow in cfs

A = Area in acres

The City's peak flow equation has a built-in dampening factor that decreases the total flow in the trunk sewer with an increase in cumulative subbasin area. This dampening of peak flow with increasing tributary area correlates with a previous study of the Salt Valley Basin.

3.2.2 Manning's Equation

The Manning's Equation is the most commonly used resistance formula for the analysis of open channel and gravity flow pipe systems. The equation modified to English Units is shown below.

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

Where:

V = Average velocity (ft/sec)

R = Hydraulic radius (ft)

S = Slope of the Energy Grade Line (ft/ft)

'n' = Roughness coefficient

The roughness coefficient varies depending on the type of material. For example, glass would have an 'n' value of 0.010 while earth channels would have an 'n' value of 0.020. There has been much debate about the appropriate 'n' value used for different piping materials in sanitary sewer systems. To complicate the debate, the slime layer that thrives on the wetted portions of the sanitary piping also contributes to and affects the actual value of 'n'.

Due to the unknowns at this time, such as the actual type of the pipe installed, the number of joints in the piping system, and the affect that the slime layer will have on the 'n' value, a conservative value of 0.013 has been adopted for this project. A 'n' value of 0.013 is the most commonly used 'n' value for the evaluation and design of sanitary sewer systems.

3.2.3 Pipe Size

For the preliminary modeling effort, the trunk sewer and subbasin sewers were determined for pipe diameters down to and including 18 inches in diameter. The exception to this criteria is at junction structures where flows from small subbasins enter the trunk sewer. Pipe sizes from these small subbasins were determined for sizes less than 18 inches in diameter.

3.2.4 Pipeline Velocity

For this modeling, the minimum design velocity in the trunk sewer is set at 3 ft/sec during full flow conditions. The maximum design velocity in the trunk sewer system was limited to 10 ft/sec during full flow conditions.

3.2.5 Depth of Flow (d/D)

The depth of flow in (d/D) in the pipe was another consideration included in the hydraulic evaluation. It was desired to maximize the depth of flow in each pipe segment without surcharging the pipe. The preliminary modeling limited the d/D from 0.75 to 0.90 (75% to 90% full).

3.2.6 Structures

Including the effect that manholes and other structures have on the dynamic modeling of the system is also an important consideration. Therefore, the location of manholes as documented in Technical Memorandum No. 2 (Appendix B) was included in the modeling effort.

It is recommended that the actual location of the junction structures and manholes be finalized during final design with input from City staff. Additionally, it is recommended that City staff provide input during final design on the size and location of stub outs on the trunk sewer manholes. These stubouts will allow connection from future developments, eliminating the need to make field connections, which may compromise the trunk sewer or its associated manholes.

3.3 HYDRAULIC MODELING

3.3.1 Methodology

In order to accurately model the Stevens Creek Basin Trunk Sewer system it was necessary that the computer model be able to account for the time wastewater takes to flow from one manhole or structure to the next. For this to be accomplished, the model calculated the flow velocity based on the contributed flows at each input point to determine the time for this flow to reach the next input flow point. Inflows are added at each input point and the total flow is then used to calculate the travel time to the next downstream manhole or structure. The model then determines the water surface elevation at each manhole or junction structure so that the depth of flow and velocity can be determined.

3.3.2 SewerCAD

SewerCAD, marketed by Haestad Methods, is a steady-state analysis tool and one of the most advanced design, analysis, and planning tools, capable of analyzing both gravity flow and pressurized force main hydraulics. SewerCAD was used to determine the physical constraints and characteristics, such as pipe size and structure locations. This was accomplished using minimum and maximum criteria such as depth of cover, velocity, and pipe slope. The output from SewerCAD was then used as the model input for XP-SWMM.

The basic information used to preliminarily size the sewers using the SewerCAD Program included:

- Ground surface elevation.
- Minimum and maximum cover over the pipe.
- Minimum and maximum allowed pipeline velocities.

- Manning's 'n'.
- Flow input data for each subbasin.
- Physical sewer manholes (nodes) location (located using coordinates).

3.3.3 XP SWMM

XP-SWMM was utilized to model the dynamic hydraulic conditions of the trunk sewer system. XP SWMM, marketed by XP-software, is a dynamic-state analysis tool and is an extremely powerful program for the analysis of flows in pipe networks. The output from SewerCAD was used to define the model input for XP-SWMM. XP-SWMM was utilized to determine the dynamic hydraulic model of the trunk sewer system.

3.3.4 EXTRAN

The gravity flow of wastewater in pipelines is an inherently transient process. Transient waves are created at flow input locations and where the pipelines change direction. These transient waves have been observed to affect the downstream as well as the upstream flow regime. The magnitude of the transient waves depends on many parameters including the distance from the initial wave source, invert, slope, and pipe size. Therefore, even pipelines with a relatively constant slope and pipe size may experience varying velocities, d/D, and q/Q values in the same reach of sewer both upstream and downstream from the initial source of the transient wave. To evaluate the phenomena, the EXTRAN fully dynamic wave model has been utilized to simulate the transient waves in the trunk sewer, and to solve the associated time-dependent flow equations.

The model run outputs presented in Technical Memorandum No. 3 (Appendix C) reflect this varying velocity, d/D, and q/Q related to the transient wave movement in the system. These varying parameters are the primary reasons for the minor differences in the flow for pipe reaches where no additional flow input is being introduced.

3.3.5 Subbasin Flows

The flow from each subbasin was determined using the Subbasin areas as previously established in Section 2.2.3 and the City's flow equation for peak design flow as identified in Section 3.2.1. The inflow to the trunk sewer was determined using the total tributary area to the trunk sewer at each junction structure location. The formula is utilized in such manners that as additional subbasin flows enter the trunk sewer, the area of the subbasins contributing to the flows are combined. Therefore, once the subbasin areas are combined the flows are recalculated and the appropriate pipe size selected.

As previously discussed, the flows from each subbasin will be introduced into the trunk sewer through various junction structures strategically located along the sewer alignment.

There is at least one junction structure associated with each subbasin to collect flow from the subbasin tributaries and release them into the trunk at a single entry point.

3.3.6 Trunk Sewer Modeling

Five hydraulic models were prepared and run to evaluate the Stevens Creek Basin Trunk Sewer. As previously stated the primary purpose of this preliminary modeling was to select the areas that are to be served by this trunk sewer project. The areas to be served by the trunk sewer thereby define the size of the trunk sewer that will eventually be installed. Two primary methods were utilized to accomplish this. The first was to select the model run which serves the areas defined in the Scope of Work (Tier I and Tier II). The second method was to select the trunk sewer size based on the years of service that the trunk sewer will provide regardless of the areas served. Based on the outcome of these analyses Model Run No. 2 was selected. Model Run No. 2 evaluated the flow from the Tier I and Tier II areas on the west side and the lower east side of the basin. See Appendix C for additional information and details relating to the preliminary dynamic hydraulic modeling.

3.3.7 Subbasin E-2 Sewer Model

Included as part of the project a dynamic hydraulic model for Subbasin E-2 (Phase IV) was prepared. The Lower Platte South Natural Resources District (LPSNRD) has indicated that a dam and impoundment will be constructed on the Subbasin E-2 tributary just upstream from Stevens Creek. The actual location and dimensions of the dam and impoundment are unknown at this time. In addition to the dam and impoundment there are plans to develop parts of this subbasin. The unknowns associated with both of these improvements should be further defined prior to an actual alignment being finalized.

For the purpose of selecting a preliminary pipe size a hydraulic dynamic model was prepared. The sewer will generally follow the tributary from near 98th Street and “O” Street to Junction Structure E-2. For the purpose of sizing the proposed Subbasin E-2 sewer, thirteen sub-subbasins were delineated. The sub-subbasin areas ranged between 23 and 455 acres. The total area of Subbasin E-2 is approximately 1,817 acres. The pipe sizes for this tributary sewer ranged from 18 to 24-inches in diameter. Four Junction Structures A, B, C, D and E were located along the sewer at each point where a secondary tributary sewer intersected the subbasin sewer. Like the trunk sewer, the details of this model can be found in Appendix C.

3.4 ALTERNATIVE ALIGNMENT EVALUATION

With the preliminary pipe size identified, various alternative alignments for the trunk sewer routing were analyzed as documented in Technical Memorandum No. 4 (Appendix D) and summarized below.

3.4.1 Evaluation Criteria

Alternative alignment evaluation criteria was developed with input from the Wastewater, Engineering, and Planning Departments of the City of Lincoln, as well as the Lower Platte South Natural Resources District (LPSNRD), public participants, and others. The criteria, as listed below, was used as the primary method of selecting the preferred alignment.

Ease of Construction - Items such as topographic features (hills, stream crossings, etc.) are considered in this category. Open areas that avoid these more difficult construction areas are ranked higher than those that do not.

Accessibility for Maintenance - Accessibility to critical locations such as junction structures, siphons structures, metering manholes and other appurtenances is very important. These locations require sewer maintenance and operating staff to access the trunk sewer for cleaning and inspection. Sewer cleaning equipment is very large and is generally mounted on trucks. Locating these special structures near roads or other areas that allow vehicular access, during all weather conditions is very important. The preliminary location of the junction structures has been located such that access will be similar for all of the alternatives evaluated. Therefore, accessibility for maintenance will not be discussed separately for each phase.

Conflicts with Existing Utilities - Over 20 different utilities and governmental agencies have been contacted and informed of this project. Maps showing the alternative alignments were distributed to these utilities and agencies. All utilities and agencies have responded to our request for utility location along the affected areas. The location of major utilities including electrical transmission lines, major water distribution lines, fiber optic cable, and high-pressure gas transmission lines have been preliminarily identified.

Environmental Factors - Emphasis was placed on minimizing the removal of remnant native vegetation and habitat along the pipeline route and within the riparian setback. The team has strived to locate the alignments in such a manner to avoid areas that have been identified as having environmental significance. If these areas are crossed, it is recommended that during the final design methods to minimize the impacts of the project be addressed. These areas include: wetlands, declared parks, areas of remnant vegetation, areas of botanical and zoological significance, riparian setbacks, and native grasslands.

Stream Geomorphology - The effects that the project has on the bank stability of the stream and its tributaries is included in the evaluation. The information to evaluate these concerns has been provided to us by the City's Watershed Study Team that is currently performing a watershed master plan for Stevens Creek basin. During final design, stream geomorphology including bioremediation, bank stability, pipe protection, and other stream stability issues should be addressed.

Impact on Potential Development - This factor relates to future land planning and zoning, and what effect the location of the trunk sewer will have on future development. For

example an alignment located in the floodway, where development will not be allowed is more desirable than an alignment located in prime development land.

Traffic Disruption/Inconvenience to Public - Alignments that minimize construction inconvenience are more desirable than those alignments that will cause additional traffic disruption and inconvenience to the public. For this study is has been assumed that all street crossings will be accomplished using trenchless technologies. During Final Design the actual crossing details should be determined jointly with City staff and the road, street or highway agency.

Right - of - Way Acquisition - The cost of right of way acquisition has been included in the estimated project costs. In addition to right of way costs, as part of the evaluation, the alternative alignments have been selected to minimize passing through existing farm buildings, residential acreages, commercial development, and similar areas. Where possible, the alignments were located in the floodway and floodplain. Disrupting existing residential, commercial, and industrial improvements was avoided to the greatest extent possible. Due to the inclusion of Right-of Way costs in the cost estimate, it will not be addressed separately for each phase.

Geotechnical Factors - Due to this similarity in geotechnical features throughout the alignment, geotechnical issues will not be discussed in each of the following alternative analysis since they all generally posses the same features. The alignments lie in the loess mantled, glaciated region of Nebraska. A generalized subsurface profile for this region consists of wind deposited soils (Peoria and Loveland age Loess deposits) overlying Kansas Age Glacial deposits which in turn overly bedrock formations. Erosion of the loess mantle has created the surface topography common to this area of Nebraska. This erosion of the surface soils has created alluvial (water transported) deposits at the lowest elevations of the stream channels and colluvial (gravity transported) deposits along the edges of the stream channels. Typically, the alluvial soils are very recent deposits with very little strength that develops over time due to consolidation and surcharging. Bedrock in the area of this phase is generally Dakota Sandstone or Shale. These Dakota formations would be expected at a depth of 50 feet or greater and most likely closest to the surface near stream channels.

Estimated Overall Project Costs - Preliminary cost estimates, as detailed in Technical Memorandum 4 (Appendix D), were developed and used as a comparison tool in evaluating alignment alternatives. All of the preliminary costs were based on 2004 first quarter values. Projected costs for boring, tunneling, and utility protection were also included in the costs. These costs are considered order of magnitude costs. Alignments that are direct from point to point, cross open areas and avoid construction difficulties such as hills, streams, railroads, and other obstacles will have the lower costs associated with them. The following allowances were incorporated into the cost estimates:

- Twenty (20) percent estimating contingency.
- Ten (10) percent for engineering and administrative fees.
- Eight (8) percent for general conditions.
- Right of way and easements.
- Roads and stream crossings were assumed to be constructed using tunneling methods.

3.4.2 Alternative Alignment Analysis

Several sewer alignments were evaluated for each phase of the trunk sewer project using the aforementioned criteria. The outcome of this analysis presented in Technical Memorandum No. 4 (Appendix D) revealed the preferred alignment as shown in Figure 3.1 and summarized below.

Phase I Three alternative alignments were identified for Phase I of the trunk sewer which begins at an existing manhole upstream of the NE WWTP and continues to Junction Structure E-6 near Fletcher Avenue. After an evaluation of the three alternatives, the alignment referred to as Alignment 1C was selected for its cost-effectiveness and constructability. The other alternatives evaluated presented numerous conflicts with existing utilities.

Phase II Three alternative alignments were also evaluated for Phase II of the trunk sewer, which picks up at Junction Structure E-6 and continues just south of Havelock Avenue to Junction Structure E-1. Of the three alignments, Alignment 2C was preferred for its cost-effectiveness, minimal impact on traffic disruption, fewer utility conflicts, and least impact on future development.

Phase III Two alternative alignments were evaluated for Phase III. The Phase III alignment starts at Junction Structure E-1 and continues to Junction Structure E-2 near Holdrege Avenue. Though the construction of either alternative would yield a fair amount of tunneling and utility crossings, Alignment 3A presents the least impact on future development and is more “friendly” to environmental and geomorphologic factors. This selection is also anticipated to be the least expensive to construct.

Phase IV Phase IV consists solely of the tributary sewer for Subbasin E-2. The two alignments evaluated for this phase runs from Junction Structure E-2 southwest through the middle of the subbasin to collect drainage from various branch sewers. Both alignments are constructed in open areas, yet the location of Alignment 4B is such that it avoids the proximity of potential future development.

Phase V This phase starts at Junction Structure E-2 and ends at Junction Structure E-3A near “A” Street. Of the two alternatives, Alignment 5A was selected for its lower costs, and lack of geomorphologic and environmental implications.

Phase VI The trunk sewer for Phase VI proceeds from Junction Structure E-3A to Junction Structure E-4. Due to a major utility crossing and geomorphologic concerns, only one viable option was identified for this phase.

Phase VII Based on estimated project costs, constructability and environmental concerns, Alignment 7A was the selected alternative for Phase VII of the trunk sewer which runs from Junction Structure E-4 to Junction Structure E-5G.

Phase VIII Two alternatives from Junction Structure E-5G to Junction Structure E-5D were evaluated. The selected Alignment 8A is a continuation of Alignment 7A and is preferred for its lower project costs, ease of construction, and clearance of the riparian corridor.

Phase IX The final phase of the project, Phase IX, starts at Junction Structure E-5G and continues uphill toward Junction Structure E-5A. The only alignment identified for this phase, Alignment 9A, satisfies the evaluation criteria listed in Section 4.2.2.

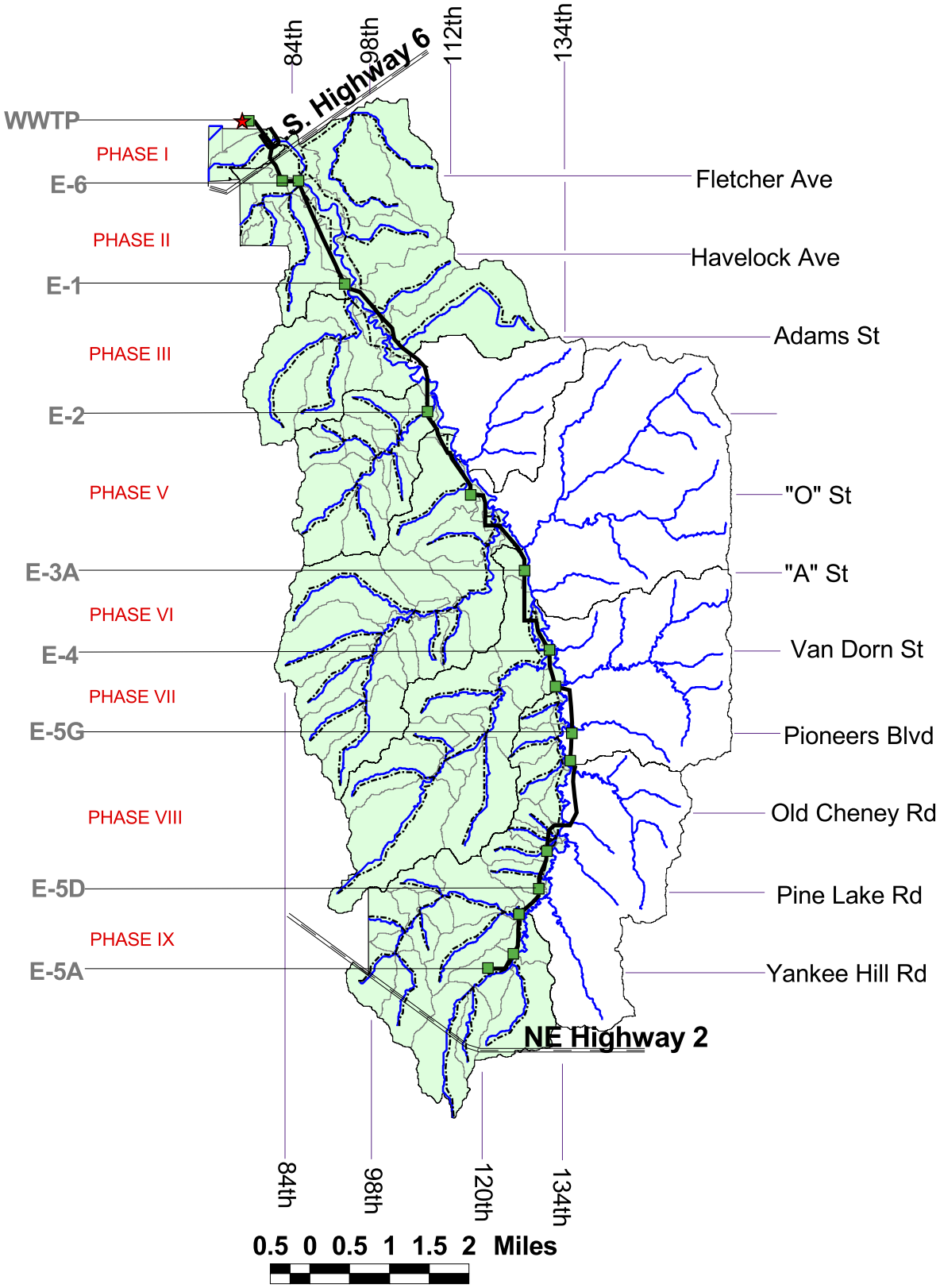

Figure 3.1
Preferred Alignment
STEVENS CREEK BASIN TRUNK SEWER
CITY OF LINCOLN, NEBRASKA