City of Lincoln
Wastewater Collection System Master Plan

Final Report

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Prepared for:
City of Lincoln

Prepared by:
Stantec Consulting Services Inc.
3875 Atherton Road
Rocklin, CA 95765

Stantec

Revision	Description	Author		Quality Check		Independent Review	
1	City Input	BW	2/21	GA	2/22		
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Sign-off Sheet

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Prepared by Breanna Webb
(signature)

Breanna Webb, EIT

Reviewed by Gabe Aronow
(signature)

Gabe Aronow, PE

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Executive Summary

This Wastewater Collection System Master Plan (Master Plan) was developed to provide an evaluation of the wastewater collection systems capacity needs within the current and future boundaries of the City of Lincoln (City), provide servicing options to meet those needs, taking into consideration commitments to regional customers outside the City Limits, and to establish a capital improvement plan that includes improvements to address the existing and future needs of the wastewater collection system.

The City General Plan discusses growth that may occur within the City's Sphere of Influence (SOI). Much of this growth requires the construction of new wastewater collection system infrastructure. Key infrastructure considered in this Wastewater Collection System Master Plan (Master Plan) include those related to the wastewater collection system itself (piping, manholes, pump stations, etc.). Infrastructure improvements related to wastewater treatment, disposal, and reuse facilities will be needed with growth, but were not considered as part of this Master Plan.

Wastewater collection system planning is driven by 1) where the wastewater is generated or collected from, and 2) where it is conveyed to receive treatment and subsequent disposal or reuse of the treated wastewater. For purposes of this Master Plan, it is assumed that 1) the bounds of the City's General Plan will dictate where wastewater will need to be collected from as it relates to infrastructure planning, and 2) wastewater will continue to be conveyed to the City's existing Wastewater Treatment and Reclamation Facility (WWTRF) in the future. The WWTRF and reclamation system will undergo expansions to continue to serve the City through full buildout development, as opposed to the development of new wastewater treatment facilities or satellite treatment plants at alternative locations.

The land uses, outlined in the City's General Plan, were used in conjunction with the City's wastewater generation rates to develop future average dry weather flow (ADWF) estimates. Existing contractual agreements, and flow monitoring data were used to develop regional and existing wastewater flows. Existing, and buildout ADWFs are presented in **Table ES-1**. The City's Design Standard reflects a higher wastewater generation rate than what has been historically observed at the WWTRF. Using higher generation rates, ensures a conservative estimate of wastewater flow that may occur within the collection system. It should be noted that these values may not be considered suitable for wastewater treatment planning, which can be more easily expanded as needed as opposed to the collection system.

Peak Wet Weather Flows (PWWF) within the collection system were used to size new infrastructure and evaluate the capacity existing system. PWWFs were estimated for the existing system and infill development areas using hydraulic model simulations of a 10-year, 24-hour storm event. PWWFs from areas within the SOI, were developed using the "Peaking Factor (PF) Method", as presented in the City's Design Criteria (PWWF = ADWF x PF). A PF of 2.3 was used throughout, corresponding to the large development planning areas. PWWFs estimates for existing and buildout conditions are presented in **Table ES-1**. Data related to the distribution of future wastewater flow estimates within the model are presented in **Appendix A**.

Table ES-1 Wastewater Flow for the City of Lincoln

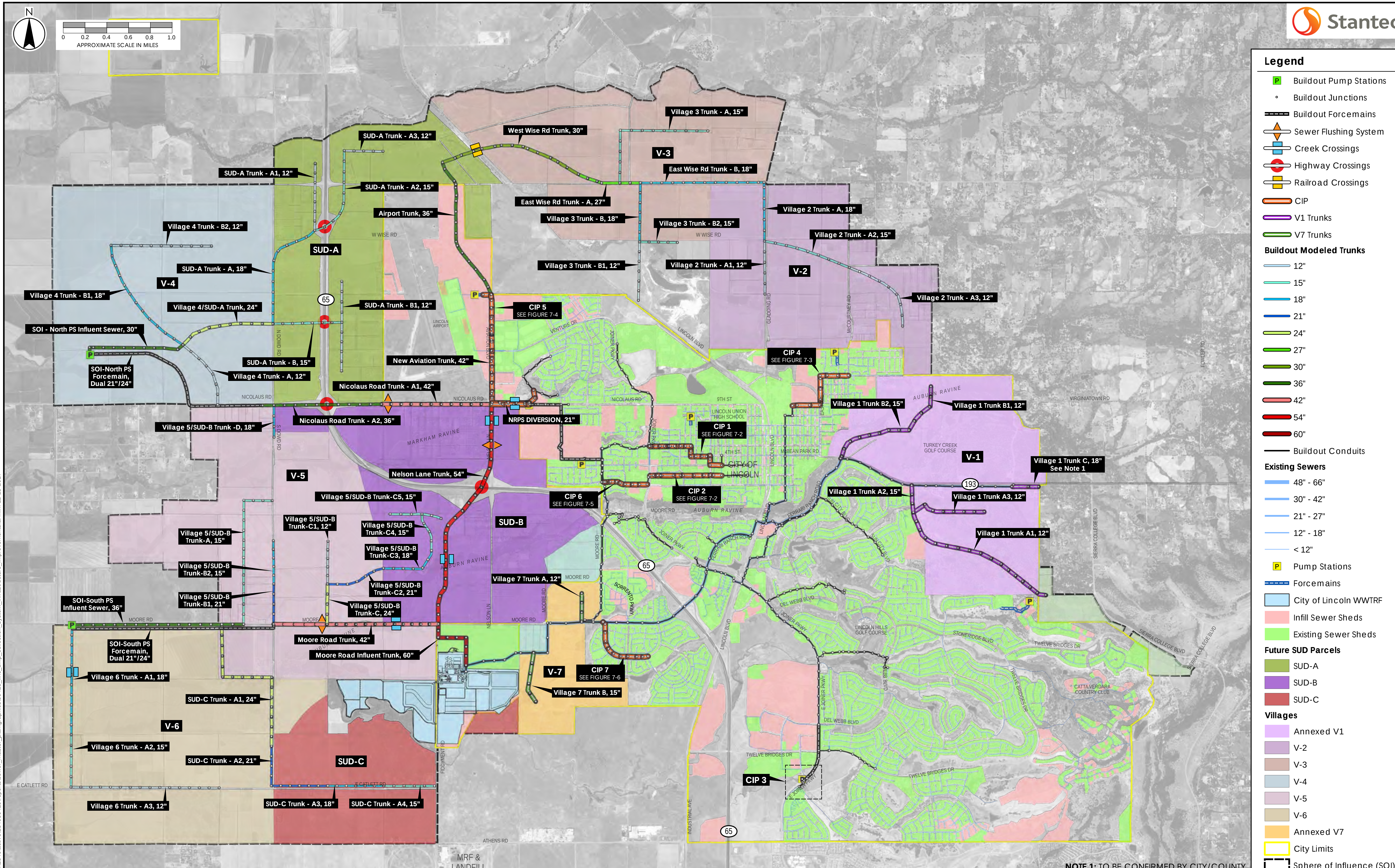
Contributing Area	Existing ADWF (1) (MGD)	Existing PWWF (MGD)	Buildout ADWF (MGD)	Buildout PWWF (MGD)
Existing City	2.8	32.4	5.7	40.3
Sphere of Influence (SOI)	-	-	16.6	38.2
Regional Flow	1.2	11.0	7.1	21.7
WWTRF Total	**4.0**	**43.4**	**29.4**	**100.1**

(1) WWTRF influent flow meter, ADWF observed during July, August, and September 2017.

The hydraulic model of the City's wastewater collection system was developed using PCSWMM software by Computational Hydraulics Inc. The City's existing collection system Geographic Information System (GIS) database was updated and input into the model. Flow monitoring was conducted during the early months of 2017. This data was used to calibrate a model of the existing collection system. In order to evaluate the needs of the collection system under PWWF conditions, a 10-year, 24-hour storm event was simulated within the model. The existing system model was then expanded to incorporate additional flow at varying levels of City development. The following scenarios were evaluated as part of this Master Plan.

Scenario 1 – Existing Dry Weather Flow Model:	Existing ADWF (Winter 2017)
Scenario 2 – Existing Wet Weather Flow Model:	Existing PWWF (10-year, 24-hour Design Storm)
Scenario 3 – Buildout of the Existing Sewer-sheds:	Scenario 2 + Infill of Vacant Parcels
Scenario 4 – Buildout of City Limits:	Scenario 3 + Village 1 & Village 7
Scenario 5 – Buildout of the SOI:	Scenario 4 + Remaining SOI
Scenario 6 – Buildout of the SOI, plus, Regional Flow:	Scenario 5 + Regional Flows

Level of service (LOS) criteria was used to assess model results and identify the capacity limitations of the existing system under existing and future development conditions. The LOS criteria considered the following parameters, the peak modeled depth of flow (d) divided by the pipe diameter (D) (d/D ratio), the peak modeled flow divided by the full pipe capacity derived from Manning's equation (HLR), residual pipeline capacity, and peak simulated flow velocity. Based on the results of the evaluation, seven capital improvement projects (CIPs) were recommended within the existing collection system. These CIPs are identified on **Figure ES-1**.



City of Lincoln
Wastewater Collection System Master Plan

Figure ES-1
Collection System Infrastructure Improvements

CIP 1: Sewer System Overflows (SSOs) are predicted to occur under existing PWWF conditions along the 15-inch sewer trunk that follows 5th Street, Q Street, 4th Street, O Street, and 3rd Street. Two alternative improvement projects have been presented to address this capacity constraint. The sewer could be upsized in place, recommended sizes for each segment are presented in Chapter 7.0. Alternatively, the drop connection at the intersection of Joiner Parkway and 5th Street could be eliminated, and the sewer could be reconstructed at a more suitable pipe slope and size. This alternative may be more attractive to the City because it may allow for Q Street Pump Station to be taken offline.

CIP 2: The 15-inch sewer trunk in 2nd Street (Old Town South Trunk, just south of CIP 1) has been predicted to incur 3-feet of surcharge under existing PWWF conditions. Like CIP 1, two alternative solutions have been presented to address this capacity deficiency. Upsizing the sewer in place or eliminating the drop connection at the intersection of Joiner Parkway and 2nd Street and reconstructing the sewer at an appropriate slope.

CIP 3: The East Lincoln Parkway Pump Station (ELPPS) is in South Lincoln, along Joiner Parkway. The ELPPS is equipped with an emergency storage basin, dual 12-inch forcemains, two 60 horsepower (HP) pumps, and one 45 HP pump. The PWWF simulated under existing conditions exceeds the reliable capacity (2.7 MGD) of the pump station. Although, this PWWF is less than the maximum capacity of the pump station (4.0 MGD), the addition of flow from infill development causes the PWWF to exceed the maximum capacity. Depending on the level of development within the pump stations collection shed, the City may want to increase the reliable capacity of the pump station in the event that one of the 60 HP pumps fails during a PWWF event. No pipeline improvements are recommended as part of this improvement project.

CIP 4: The sewer trunk following 9th Street, East Avenue, and 12th Street, upstream of the E. Street sewer, has been predicted to become surcharged under existing conditions. Surcharging is further exacerbated with the addition of infill flow from upstream developments. This CIP recommends that this sewer trunk be upsized to provide adequate capacity for existing and infill development.

CIP 5: Unlike capacity issues at the ELPPS, both pipelines and reliable pump station capacity fail to meet LOS criteria under infill development conditions at the Nicolaus Road Pump Station (NRPS). Under existing conditions, the NRPS has sufficient reliable pumping capacity to convey flow entering the pump station. Capacity issues exist within the 10-inch sewer in Aviation Boulevard and Nicolaus Road, surcharging is predicted to occur under existing conditions. The addition of wastewater flow from development of vacant areas near the airport exacerbate these pipeline capacity issues and cause the reliable capacity of the NRPS to be exceeded. This improvement project recommends the diversion of this pump station to the proposed trunk sewer in Nelson Lane. Flow from the pump station could be diverted by gravity, by intercepting the existing influent sewers and redirecting flow west on Nicolaus Road to the proposed Nelson Lane Trunk.

The implementation of this CIP is dependent on the phasing and construction of other collection system improvements. Interim solutions for the existing pipeline capacity issues may include on-going inflow and infiltration (I/I) reduction efforts, limiting development in the area, upsizing the 10-inch portion of sewer in Aviation and Nicolaus Road, and/or increasing reliable capacity of the NRPS.

CIP 6: Surcharging is predicted to occur with the addition of flow from infill development in the 18-inch sewer in 1st Street and Chambers Drive, and the downstream 30-inch sewer in Chambers Drive. To reduce surcharging to an acceptable level in these sewers, this improvement project recommends re-routing and upsizing the 18-inch sewer in 1st Street. The Chambers Drive sewer was originally constructed to re-route the collection system from the old Wastewater Treatment Plant (WWTP) location to the new WWTRF on Moore Road. The 30-inch sewer runs parallel to the upstream 18-inch in Chambers Drive. Flow from 1st Street is first routed north in the 18-inch sewer, then loops south in the 30-inch sewer. It is proposed that this "loop" be eliminated by diverting the 18-inch sewer in 1st Street to the Chambers Drive sewer, near the intersection of Douglas Drive and 1st Street. Sewers upstream of this new tie in location should be upsized to 21-inches to provide capacity for flow from infill developments.

CIP 7: The Lincoln 270 Area lies between Highway 65 and Industrial Avenue. Alternative solutions to provide wastewater collection service to this area have been previously considered. It has been assumed that the City of Lincoln will provide service to this area, through the Lincoln Crossings development. This improvement project recommends that sewers between the point of connection of the 270 Area development and the intersection of Caledon Circle and Ferrari Ranch Road, are upsized to meet LOS requirements. The 12-inch sewer in Caledon Circle would need to be upsized to a 15-inch and the upstream 10-inch sewer, starting at Brentford Circle and continuing to Industrial Avenue, would need to be upsized to a 12-inch to accommodate the additional flow. These sewers have adequate capacity to serve their existing service area under existing and infill development conditions, without the addition of flow from Lincoln 270.

The model predicted ten SSOs within the City's existing collection system under existing and buildout PWWF conditions. A summary of predicted SSOs is provided in **Table ES-2**.

Table ES-2 Predicted SSOs Summary [1]

Manhole ID	Scenario [2]	Invert (ft)	Depth (ft)	Spill Volume (gallons)	Cause of Overflow	Proposed Solution [3]
NW422SS53	2 & 3	136.9	5.2	83,000 – Existing 118,000 – Buildout	Limited Pipeline Capacity	Increase slope/ upsize in place, (CIP 1)
NW456SS03	2 & 3	144.3	6.3	60,000 – Existing 84,000 – Buildout	Limited Pipeline Capacity	Increase slope/ upsize in place, (CIP 1)
SE502SS13	2 & 3	130.3	10.8	15,000 – Existing 373,000 – Buildout	Deficient Pump Station Capacity	Increase reliable pumping capacity of the ELPPS (CIP 3)
NW281SS08	3	118.1	10.3	120,000	Limited Pipeline Capacity	Divert to Nelson Lane Sewer (CIP 5) / upsize 10-inch to 12-inch in interim
NW281SS10	3	116.7	8.9	284,000	Limited Pipeline Capacity	Divert to Nelson Lane Sewer (CIP 5) / upsize 10-inch to 12-inch in interim
NW281SS11	3	115.9	7.9	25,000	Limited Pipeline Capacity	Divert to Nelson Lane Sewer (CIP 5) / upsize 10-inch to 12-inch in interim
NW281SS12	3	115.1	6.9	1,152,000	Limited Pipeline Capacity	Divert to Nelson Lane Sewer (CIP 5) / upsize 10-inch to 12-inch in interim
NW282SS01	3	114.2	7.7	109,000	Limited Pipeline Capacity	Divert to Nelson Lane Sewer (CIP 5) / upsize 10-inch to 12-inch in interim
NW317SS11	3	106.2	9.7	174,000	Deficient Pump Station Capacity	Divert to Nelson Lane Sewer (CIP 5)
NW352SS31	3	106.2	9.8	44,000	Deficient Pump Station Capacity	Divert to Nelson Lane Sewer (CIP 5)

(1) The locations of SSOs are shown on Figure 6-1 and Figure 6-2.
(2) Scenario 2 is Existing PWWF, Scenario 3 is PWWF with infill development.
(3) Additional CIP details are presented in Chapter 7.0.

Opinions of probable capital costs have been developed for each of the existing collection system improvement projects, summarized in **Table ES-3**.

Table ES-3 Opinion of Probable Costs, Existing System Improvements (1)

Item	Description	Construction Cost (4)
1	CIP 1 - Old Town North Sewer Improvements	$1,351,000
2	CIP 2 - Old Town South Sewer Improvements	$992,000
3	CIP 3 - ELPPS Reliable Pumping Capacity Improvements	$500,000
4	CIP 4 - North E Street Sewer Improvements	$1,150,000
5	CIP 5 - NRPS Gravity Sewer Diversion (2)	$1,220,000
6	CIP 6 - Old Town South Sewer Diversion and Improvements	$825,000
7	CIP 7 - Lincoln Crossing Sewer Improvements (3)	$1,198,000
	CIP Subtotal:	**$7,236,000**
8	Estimating Contingency (35%)	$2,533,000
	Total Construction Costs:	**$9,769,000**
9	Engineering and Environmental Documentation (25%)	$2,443,000
	Total Project Costs:	**$12,212,000**

(1) ENRCCI = 11,013, April 2018.

(2) Costs associated with the construction of the 54-inch Nelson Lane Trunk & 42-inch Aviation Trunk are not included within CIP 5.

(3) Costs only include those to upsize the 12-inch sewer in Caledon Lane to a 15-inch, upstream improvements are not included.

(4) The breakdown of construction costs for each pipeline improvement is presented in **Appendix B**.

The improvement projects to address existing deficiencies, identified in **Table ES-3**, do not include general repair and replacement (R&R) of City facilities. The City's R&R program includes an annual expenditure for the replacement of older, aging wastewater collection system infrastructure.

The existing collection system models were expanded to include flow and infrastructure from the Villages and Special Use Districts (SUDs) within the City's General Plan area. This Master Plan has identified locations for future trunk sewers consistent with the City's General Plan Circulation Diagram. Future trunks sewers are generally planned within future arterial roadways.

Village 1 and Village 7 have recently been annexed into the City's existing boundary (City Limits). The full extent of the infrastructure needed to provide service to these areas has been developed in each of the Village Specific Plans, only sewers greater than or equal to 12-inches in diameter have been identified for purposes of this Master Plan. Flow from these Villages will be routed through the Regional Sewer Trunk (along Hwy 193 and Ferrari Ranch Road, extending to the WWRTF) and the Moore Road Sewer Trunk. These existing trunks have sufficient residual capacity to accept the projected wastewater flow from these areas.

Three new trunk sewers will be needed to provide service to Village 1, equating to approximately 3.9 miles of 12-inch to 18-inch sewer. The location of Village 7 allows it to connect small collector sewers to existing sewer trunks near the WWTRF. Two new trunk sewers are needed to provide service to Village 7, including approximately 1,330 feet of 12-inch sewer and 2,500 feet of 15-inch sewer.

The remaining portions of the City's SOI include Villages 2, 3, 4, 5, and 6 and SUD-A, SUD-B, and SUD-C. These areas will be served by new trunk sewers that bypass the existing collection system and carry flow directly to the WWTRF. A new 60-inch influent sewer will extend from WWTRF to the intersection of Moore Road and Fiddyment Road.

A new 54-inch trunk in Nelson Lane will serve as the main trunk sewer servicing the northern portion of the SOI and the NRPS collection shed, through CIP 5. The 42-inch Moore Road Trunk will provide service to Village 5/SUD-B, Village 6, and SUD-C. The new Nicolaus Road Trunk will provide service to Village 4 and SUD-A, and a small portion of Village 5/SUD-B. A total of 50 new trunk sewers are proposed with this Master Plan to serve the City's Villages and SUD areas. These trunk sewers are shown on **Figure ES-1**. Overall recommendations for collection system planning are summarized within **Table ES-4**.

The ground elevation within the SOI ranges from approximately 208 feet above sea level in the northeast, to 77 feet above sea level in the southwest. The relatively high elevation in the northeast allows the slope of trunks serving Village 2 and Village 3, to exceed minimum slope requirements. The remaining trunks serving the western portion of the SOI will require minimum slopes. **Pipe slopes of less than 0.0008 ft/ft** will be needed along the Moore Road Influent Trunk, Moore Road Trunk, Nelson Lane Trunk, and Nicolaus Road Trunk. Minimum slopes that allow flow velocity to reach 2 ft/s under full pipe flow conditions were assumed for these trunks.

Future trunk sewers have been designed to serve a large development area but will initially only have sewer connections serving a portion of the area. Low flow velocity under initial conditions may result in solids deposition along shallow sloped sewers, requiring regular cleaning to prevent solids accumulation and possible odor issues. To mitigate solids deposition, ovoid shaped pipes or pipes with dry weather flow channels shall be included in the design of these large shallow sloped sewers. As an additional precaution, flushing systems using manhole chambers and gates have been identified at key locations in the proposed collection system. These systems allow for detention of sewage with a quick release to flush solids deposited on the sewer invert during low velocity conditions. Flushing systems can be very effective and may not be needed once development produces adequate base flow.

Two new pump stations will be required to provide service to the western portion of the SOI. The northern pump station will collect wastewater from Villages 4 and SUD-A and require a peak pumping capacity of 8.5 MGD. The southern pump station will collect wastewater from Village 6, SUD-C, and a portion of Village 5/SUD-B and require a peak pumping capacity of approximately 7.1 MGD. Each pump station will require 15 to 18-inch dual forcemains to route flow to the gravity portion of the collection system.

Table ES-4 Collection System Master Plan Recommendations Summary

Item	Recommendations	Details
Hydraulic Modeling	• Continuously update the model with physical system improvements and recalibrate to additional flow monitoring, to serve as a "living tool" for City use.	Section 4.5
Maintenance	• Ongoing I/I Reduction Program • Regular Repair and Replacement program	Section 7.4 Section 8.4
Additional Flow Monitoring	• To further isolate areas of the system with high localized I/I contributions • To further plan for CIPs 1 through 3, specifically upstream of Flow Monitor 3. • To provide updates to the hydraulic model • Evaluate GWI in each sewer-shed by monitoring flow during times of ADWF	Section 7.4 Section 8.3 Section 8.4

Existing System CIPs	• **CIP 1** – Currently at risk of SSO
	• **CIP 2** – Combine with CIP 1
	• **CIP 3** – Increase reliable pumping capacity of the ELPPS and raise upstream manhole lids to an elevation higher than the emergency overflow elevation
	• **CIP 4** – Warrants additional flow study/ monitoring within area of recommended improvements
	• **CIP 5** – Dependent on construction of the Nelson Lane Trunk and those downstream
	Interim Improvements:
	  • upsizing the 10-inch sewer in Aviation Blvd.
	  • Increasing NRPS pumping capacity.
	  • Limiting development
	  • Reduce I/I, inspect for direct stormwater inflow paths (Airport Area)
	• **CIP 6** – City may elect to accept a lower LOS for this sewer, freeboard remains 10-feet below the ground surface. Surcharging further reduced after implementing CIP 5.
	• **CIP 7** – Improvements are not needed unless wastewater service is provided to the Lincoln 270 Area.
		Section 6.2
		Section 6.3
		Chapter 7.0
		Section 8.3
		Section 8.4

Future System CIPs	• Prioritize new trunk sewers by vicinity to the WWTRF, and near-term developments. • **Ensure that large shallow sloped sewers (<0.0008 ft/ft) are designed with consideration of solids deposition and associated maintenance activities. Requiring that flushing systems, odor control facilities, low flow channel/ovoid pipe shapes, and pipe materials with low roughness coefficients are used (T-lock, lined concrete, PVC, etc.).**	Section 6.3 Chapter 8.0 Chapter 9.0
Planning Principals & System Design	• **Minimize Pump Stations** – permit temporary pump stations contingent on the collection system being compatible with being converted to gravity in the future (once more development occurs, and new trunks/ large pump stations have been constructed). • **Maximize Gravity Flow Sewers** – consider alternative gravity servicing strategies in areas currently planned to flow to large pump stations (SUD-A and SUD-C). Extend the trunk sewers in Nicolaus Road and Moore Rd as far west as minimum slope and cover will permit. • **Solids Deposition** – require flushing systems, pipe materials with low manning's n coefficients (roughness), and pipes with low flow channels or ovoid shapes where specified. To be approved by the City Engineer. • **Odor Control** – should be included on shallow sloped sewers, flushing systems, and pump stations • **Forcemains** – dual forcemains are recommended to accommodate varying levels of flow. • **Aging Infrastructure** – The City's design guidelines were used to estimate PWWF from SOI areas, using a peaking factor of 2.3. Smaller areas of development warrant the use of a larger peaking factor. Assessing new sewers using RDII parameters developed for the existing system warrants larger pipe sizes for those upstream sewers currently sized between 12 and 24 inches in diameter. Upsizing these sewers by one pipe size would allow capacity for increasing levels of I/I as the system ages.	Section 8.4

Flow from regional wastewater entities was added to the hydraulic model to assess the impact on the existing system. Regional wastewater flow will be routed through the Regional Sewer Trunk to the WWTRF. No capacity restrictions were identified within the Regional Sewer Trunk assuming these flows do not exceed those outlined within existing Agreements.

Opinions of probable cost were developed for wastewater collection system infrastructure needed to provide service to the City's Villages and SUDs. These costs are summarized in **Table ES-5**.

Table ES-5 Opinion of Probable Cost, SOI Infrastructure (1)

Item	Description	Total Project Cost (2)
1	Village 1 & Village 7 Pipelines	$12,540,000
2	SOI Pipelines	$218,145,000 (3)
3	SOI Pump Stations	$12,460,000
	Total Costs:	**$243,145,000**

(1) ENRCCI = 11,013 (April 2018)

(2) Individual project costs include a 35% contingency and 25% allowance for engineering and environmental documentation.

(3) The breakdown of construction costs for each pipeline improvement is presented in **Appendix B**.

All the improvements recommended within this Master Plan are shown on **Figure ES-1**.

Abbreviations

ADWF	Average Dry Weather Flow (observed during the dry season)
BMP	Best Management Practice
CIP	Capital Improvement Project
DWF	Dry Weather Flow (Observed during the flow monitoring period, used in model simulations)
DU	Dwelling Unit
EDU	Equivalent Dwelling Unit
ELPPS	East Lincoln Parkway Pump Station
GIS	Geographic Information System
gpd, gal/d	Gallons per Day
gpcd	Gallons per Capita Per Day
GWI	Ground Water Infiltration
HGL	Hydraulic Grade Line
HLR	Hydraulic Loading Ratio
IDM	Inch-diameter-mile
IDW	Inverse Distance Weighting
I/I	Inflow and Infiltration
LiDAR	Light Detection and Ranging
LOS	Level of Service
MG	Million Gallons
MGD	Million Gallons per Day
NRPS	Nicolaus Road Pump Station
PCSWMM	Personal Computer Storm Water Management Model

PS	Pump Station
PWWF	Peak Wet Weather Flow
RDI	Rainfall Dependent Infiltration
RDII	Rainfall Dependent Inflow and Infiltration
ROW	Right of Way
SMD1	Placer County's Sewer Maintenance District No. 1
SOI	Sphere of Influence
SRTC	Sensitivity-based Radio Tuning Calibration
SUD	Special Use District
V&A	V&A Consulting Engineers, Inc.
Water Year	October to September (i.e. Water Year 2017 = 10/16 – 11/17)
WWTRF	Wastewater Treatment and Reclamation Facility
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

The City of Lincoln (City) currently collects and treats wastewater from an area of approximately 11,200 acres within the City Limits, serving a population of more than 45,000 residents as well as a number of industrial and commercial users. The City's Wastewater Treatment and Reclamation Facility (WWTRF) also accepts wastewater flow from Placer County's Sewer Maintenance District No. 1 (SMD1) subject to a Joint Exercise of Powers Agreement established for this purpose. This Wastewater Collection System Master Plan (Master Plan) was developed to provide an evaluation of collection system capacity needs within the current and future boundaries of the City as defined by the City's General Plan, servicing options to meet those needs taking into consideration commitments to regional customers outside the City Limits, and to establish, a capital improvement plan that includes improvements to address existing and future needs.

The area to which the City currently provides sewer service is identified in **Figure 1-1**.

1.1 OBJECTIVES

The City has established the following objectives for this Master Plan:

- Summarize previous studies and reports.
- Develop and calibrate a hydrodynamic computer model.
- Evaluate the level of service of the existing sewer system using the calibrated model.
- Identify hydraulic deficiencies (if any) within the existing sewer system.
- Extend the hydraulic model by including wastewater flow from existing City infill growth potential, and adding entitled developments and annexation areas to predict dry and wet weather deficiencies that would be incurred under future growth scenarios, predicted by General Plan land uses.
- Develop a conceptual servicing strategy to upgrade and expand the existing collection system network to service annexed lands, simulating future growth scenario conditions using the calibrated model.
- Prepare a formalized document that describes a trunk sewer network to serve the extent of the City's current General Plan Sphere of Influence (SOI), including the new Villages, and Special Use Districts (SUDs) identified in the General Plan Land Use and Circulation Diagram, shown in **Figure 1-2**.
- Identify necessary capital improvements to correct existing system deficiencies as well as serve future development within the seven Villages and three SUDs and develop associated costs to serve as a basis for recommendations for adjustments in sewer enterprise fund revenues, including ongoing sewer charges (e.g. monthly rates) and one-time development impact fees.

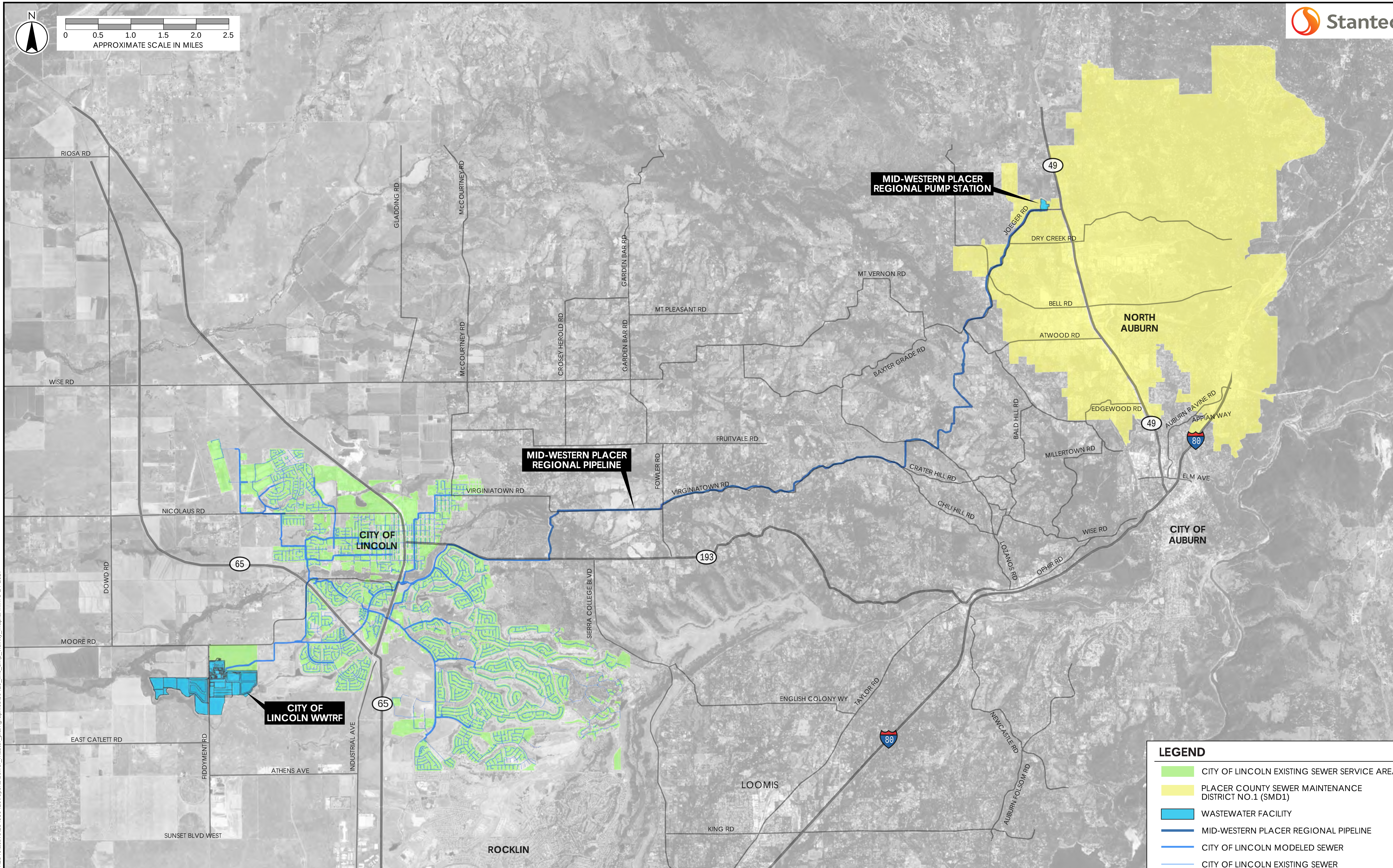
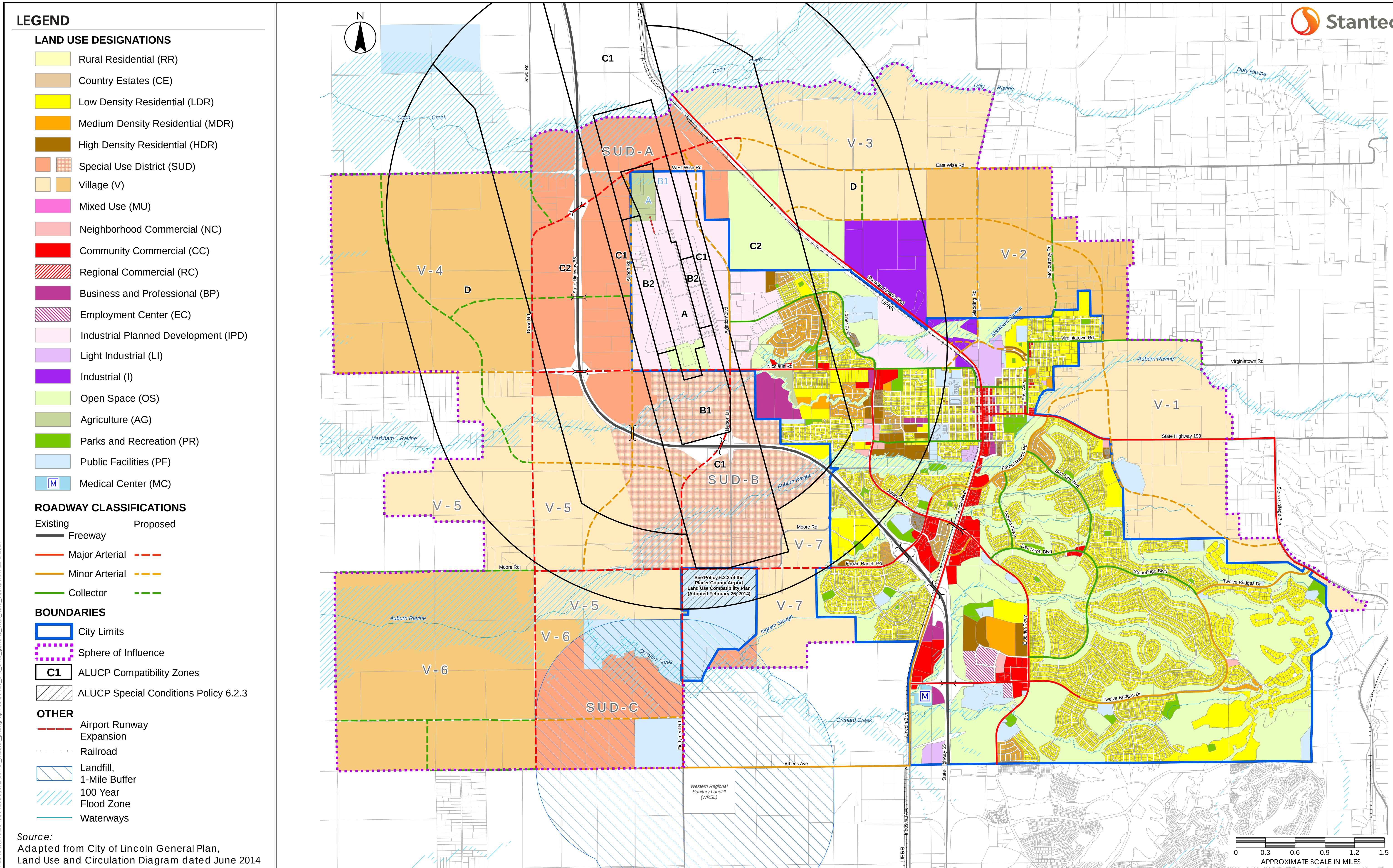


Figure 1-1
City of Lincoln Collection System Vicinity Map



City of Lincoln
Wastewater Collection System Master Plan

Figure 1-2
City of Lincoln General Plan Land Use

2.0 EXISTING COLLECTION SYSTEM

2.1 PURPOSE

The purpose of this chapter is to present an overview of the City's existing wastewater collection system.

This chapter is divided into the following sections:

- Regulatory Framework
- Overview of the Existing Collection System
- Existing Wastewater Flows
- Relevant Studies & Agreements
- Existing Capital Improvement Plans

2.2 REGULATORY FRAMEWORK

The City's collection system is permitted to operate under State Water Board Water Quality Order No. 2006-0003. "Statewide General Waste Discharge Requirements for Sanitary Sewer Systems" (General Order). The City has developed a Sewer System Management Plan (SSMP) that describes how the City operates and maintains the collection system in compliance with General Order requirements. See **Appendix E**.

2.3 OVERVIEW OF THE EXISTING COLLECTION SYSTEM

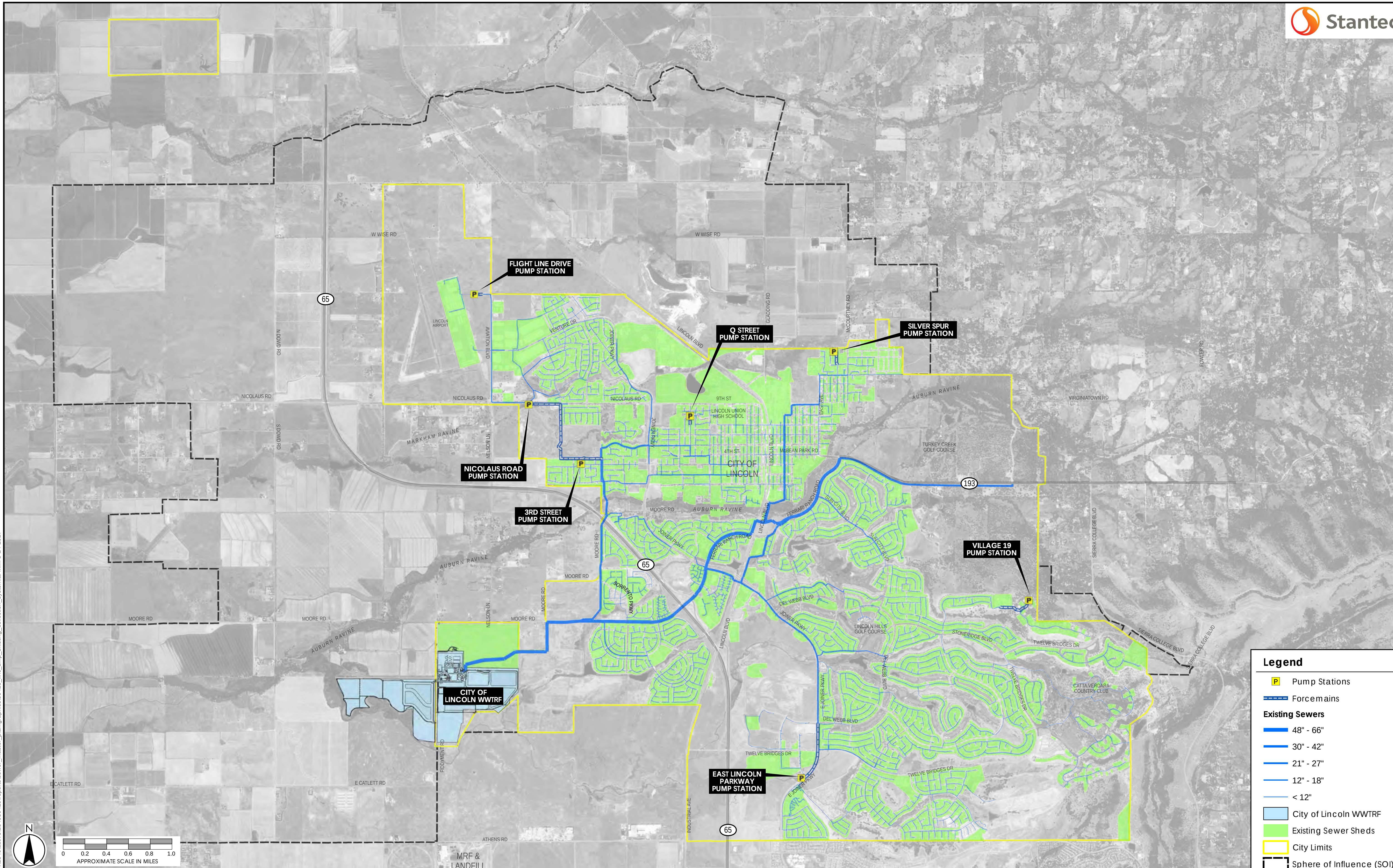
The City currently provides sanitary sewer service within its City Limits (excluding areas annexed in 2017) and collects and treats flow from regional wastewater contributors (SMD1) at the WWTRF. The City's existing collection system covers an area of approximately 5,800 acres and provides service to over 20,000 equivalent dwelling units (EDUs), which include residential, commercial, and industrial users. The wastewater generated from these users is collected and conveyed to the City's WWTRF by a network of sewer pipes, forcemains, and pump stations. **Figure 2-1** shows the City's existing sanitary sewer collection system network including pump stations and forcemains.

The sanitary collection system consists of approximately 195 miles of sanitary sewers (local sewers, trunk sewers, and forcemains) and seven sewage pump stations. Pipeline material within the collection system consists of approximately, 95% VCP, 2% PVC, and 1% RCP, by length. The majority of the collection system consists of sewers 10-inch in diameter and smaller. The hydraulic model and Master Plan described in the subsequent chapters of this report focus on the sewer trunks (existing and new), 12-inch in diameter and larger.

Regional wastewater flows are received from outside of the City's boundaries. Flow from Placer County's Sewer Maintenance District No. 1 (SMD1) is pumped from the Mid-Western Placer Regional Pump Station on Joeger Road in North Auburn through a 13.5 mile forcemain (Mid-Western Placer Regional Pipeline) before discharging into the City's collection system near the intersection of Highway 193 and Sierra College Boulevard. The WWTRF began receiving flow from SMD1 in May of 2016. The Regional Sewer Pipeline and location of the SMD1 collection system are identified on **Figure 1-1**. The City of Auburn has contributed funding to the Mid-Western Placer Regional Pipeline Project, and while sewer service is not currently provided to the City of Auburn, flows from this potential regional entity are included in this collection system Master Plan.

In July of 2004, the City commenced operation of the Wastewater Treatment and Reclamation Facility (WWTRF). The facility was built to comply with new water quality regulations promulgated by the State of California and to provide capacity for growth within the City's Sphere of Influence (SOI). The facility produces Title 22 compliant effluent suitable for unrestricted use and reclamation.

The City's original wastewater treatment plant was located south of Nicolaus Road between Nelson Lane and Waverly Drive. Planning for the new WWTRF required portions of the existing collection system to be re-routed to the new facility location, near the intersection of Fiddyment Road and Moore Road. Diverting flow from collection system to the new WWTRF required the construction of the Douglas Road, Chambers Drive, Moore Road, E Street, and Regional Sewer trunks. The location of the old wastewater treatment plant, new WWTRF, and major sewer trunks are identified on **Figure 2-2**.



City of Lincoln
Wastewater Collection System Master Plan

Figure 2-1
Existing Sewer Collection System

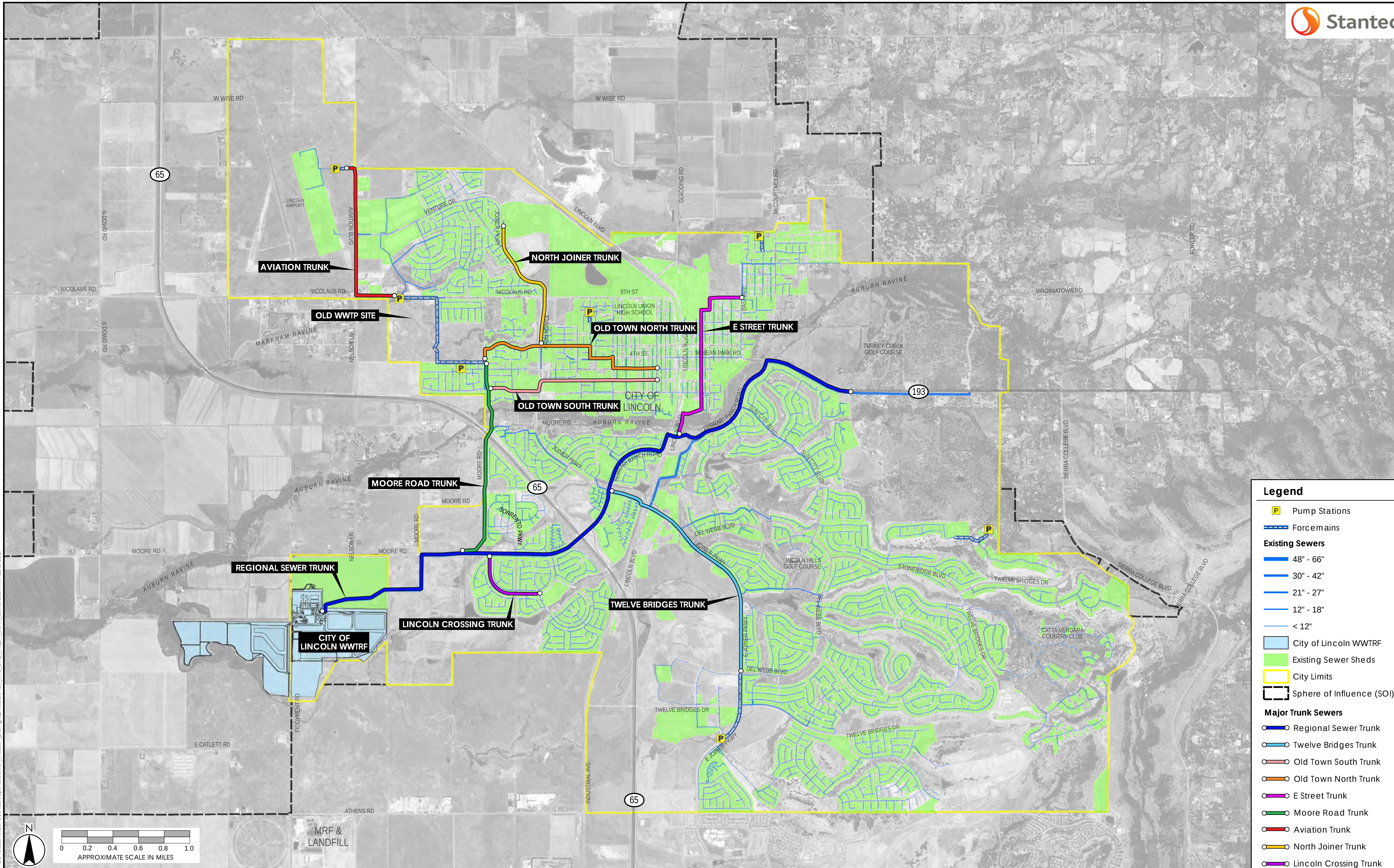


Figure 2-2
Major Trunk Sewers

2.4 EXISTING WASTEWATER FLOWS

2.4.1 Wastewater Flow Characterization

Wastewater collection systems are designed to convey PWWFs. PWWFs are generally comprised of three elements: base sanitary flow, groundwater infiltration (GWI), and rainfall dependent inflow and infiltration (RDII). Each component is described in more detail below.

Base Sanitary Flow

Sanitary flow or base flow is the component of wastewater generated directly by public, residential, commercial, and industrial users.

Groundwater Infiltration (GWI)

GWI is groundwater that enters the collection system through cracks in sewer pipes and manholes, leaky joints, and damaged sewer lateral connections. GWI tends to vary seasonally depending on groundwater depth in relation to the depth of sewer pipelines. GWI is more significant during the wet season when groundwater elevations are high. GWI is also more significant in sewers built in low lying areas near creeks and drainage course where groundwater elevations may be high due to surface water conditions.

Rainfall Dependent Inflow and Infiltration (RDII)

RDII is flow that enters the collection system due to precipitation events. Inflow enters the sewer system directly often through leaky manhole covers, improperly connected roof leaders, and clean-outs. Infiltration is an indirect introduction of rainfall into the collection system through cracked sewer pipes, leaky joints, and manhole walls.

Diurnal Patterns

A diurnal flow pattern describes the variation in wastewater flow occurring over the course of a full day. In a 24-hour period, wastewater flow varies significantly with maximum flow typically occurring in the morning and early evening. During the flow monitoring study conducted by the City in January through March of 2017 (further described in **Section 2.4.3**), flow was measured every 15 minutes. This monitoring provided detailed data allowing the City to evaluate these daily patterns throughout its service area. Each area of the City has its own unique pattern, which also varies between weekdays and weekends.

2.4.2 Historical WWTRF Influent Flows

Average daily influent flow at the City's WWTRF from August 2004 through July 2017 is presented in **Figure 2-3**. The greatest peak wastewater flows have been observed at the facility during wet weather conditions in water year 2017. It should be noted that the SMD1 service area began contributing flow to the facility on May 23, 2016; influent flow shown in the figure after this date reflects consolidation of flow conditions from both communities.

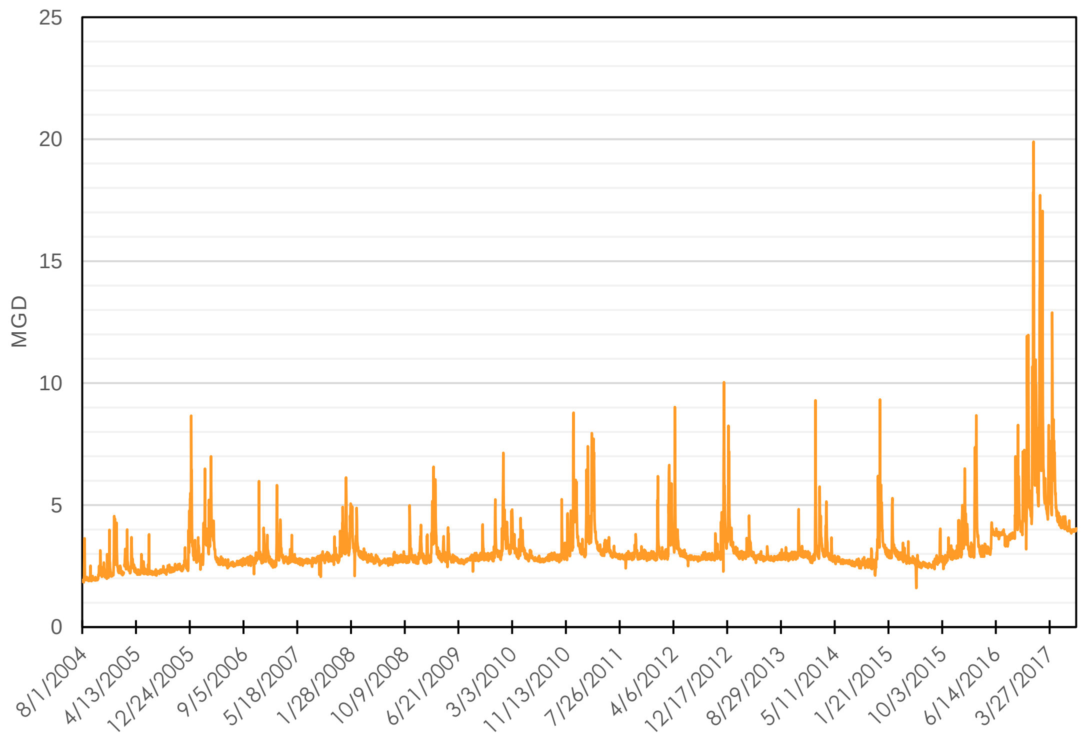


Figure 2-3 Lincoln WWTRF Flow Data

2.4.3 Wastewater Flow Per Equivalent Dwelling Unit (EDU)

An evaluation of the wastewater generation rate per Equivalent Dwelling Unit (EDU) was performed using historical wastewater flows and EDU counts provided by the City. The evaluation considered data prior to the introduction of flow from SMD1. Results of the evaluation are presented in **Table 2-1**.

Table 2-1 Lincoln Historical Wastewater Generation Rates

Year	Total EDUs	ADWF (MGD)	Generation Rate (gpd/EDU)
2005	12,986	2.28	175
2006	15,505	2.58	166
2007	16,368	2.69	164
2008	16,633	2.70	162
2009	16,795	2.73	163
2010	16,968	2.78	164
2011	17,068	2.94	172
2012	17,275	2.83	164
2013	17,701	2.83	160
2014	18,006	2.65	147
2015	18,243	2.53	138
		Average:	**161**

The average wastewater generation rate per EDU from 2005 to 2015 was 161 gpd/EDU, under dry weather conditions. Drought conditions and water use restrictions were in effect from 2011 to 2015, producing a declining trend in wastewater generation rates during this period. For purposes of wastewater treatment planning, a value of 215 gpd/EDU has been established. However, for purposes of this Collection System Master Plan, the City's Design Standard of 250 gpd/EDU was used to estimate flow from new developments. While use of the City Standard 250 gpd/EDU may appear conservative in the establishment of the base flow rate for new communities, this Master Plan also uses PWWF factors from the City's Design Standards, which appear low when compared to observed peaks, especially as facilities age. Together, the City Design Criteria for the average wastewater generation rate and peaking factors appear to represent realistic PWWFs (when compared to flow monitoring data) that the collection system should plan for. Further, as wastewater treatment facilities can be expanded or flow equalization added as needed, this is much more difficult for collection systems, warranting a higher level of conservatism.

2.4.4 Collection System Flow Monitoring

The City monitored flow within the collection system from January 4, 2017 to March 7, 2017. This work was conducted by V&A Consulting Engineers (V&A) and summarized in a technical report dated May 2017. Open channel flow monitoring was performed at nine sites and volumetric-time flow monitoring was performed at two pump stations with state-loggers. Flow monitoring was performed to provide data from specific locations within the collection system to allow calibration of the hydraulic model. Calibration allows the actual distribution of dry weather flows to be assessed as well as allowing a system specific distribution of wet weather flow. The flow monitoring report and inflow and infiltration study provided by V&A is included in **Appendix G** (*City of Lincoln 2017 Flow Monitoring and Inflow/Infiltration Study, May 2017, V&A Consulting Engineers*).

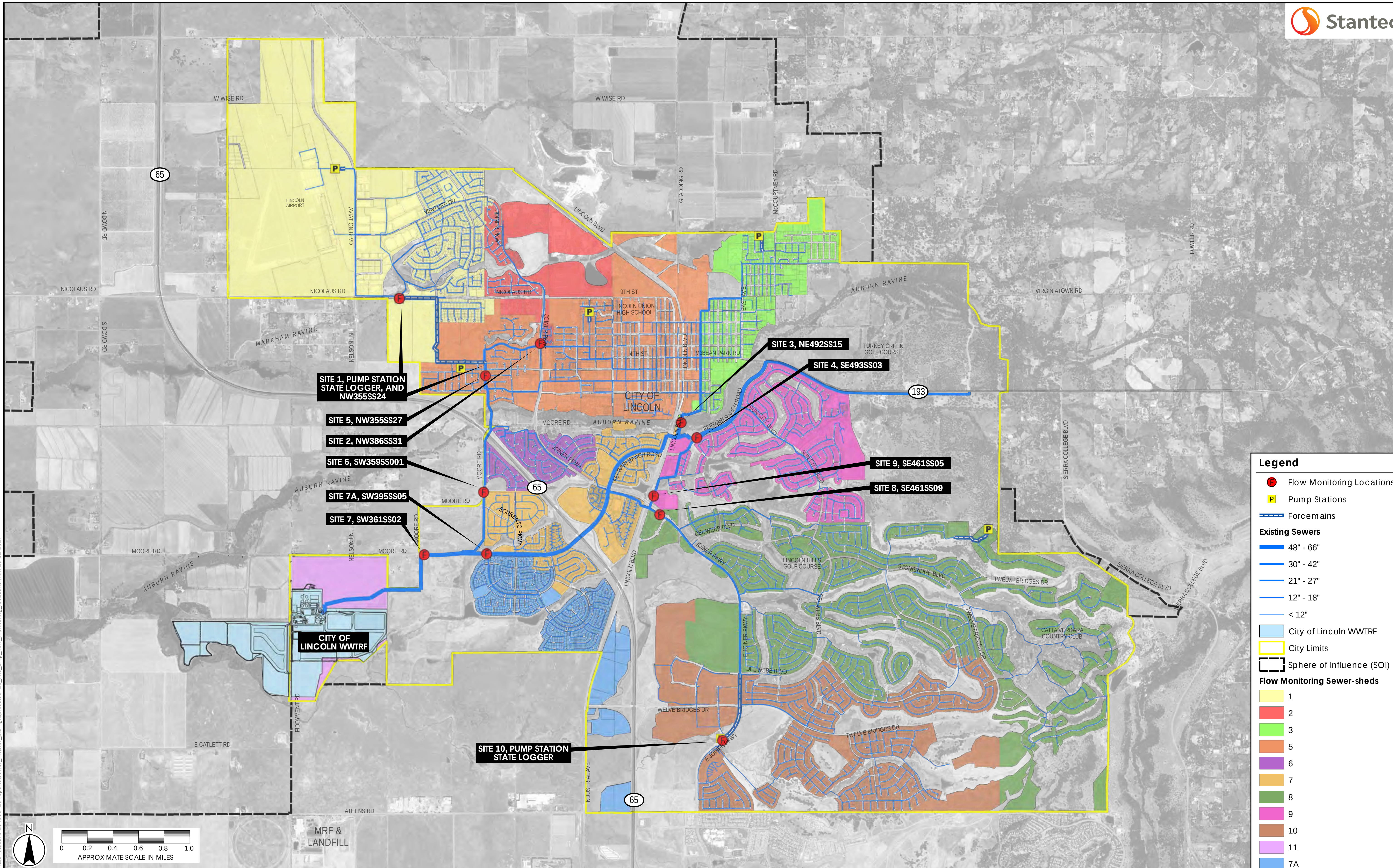
To distribute flow within the hydraulic model, flows from flow monitoring sheds in series are estimated by subtracting flow from upstream sheds. There are inherent errors introduced when subtracting flow monitors in series due to variations in data quality, and travel time between monitors. The highest error in the flow monitoring study can be associated with the most downstream sewer-shed, Shed 7 in the 2017 flow monitoring study. The City also monitored flow from a portion of Shed 7 during a 2016 study, providing a basis for correcting error from the 2017 data. The hydraulic model was further refined using data from the City's 2016 flow monitoring study. V&A monitored flow from Shed 7A, the Lincoln Crossing collection shed from February 26, 2016 to April 3, 2016. The flow monitor used for calibration of Shed 7A was located on a 12-inch sewer up stream of the intersection of Calden Circle and Ferrari Ranch Road. This flow monitor was referred to as Flow Monitor 6 in the technical report provide by V&A, but will be referred to herein as Flow Monitor 7A.

Data from the 2016 study was also used to distribute dry weather flow within the Nicolaus Road Pump Station collection shed, Shed 1. This data was not used for calibration because more recent data had been provided with the 2017 study. The 2016 Flow Monitoring Report by V&A can be found in **Appendix G** (*City of Lincoln 2016 Flow Monitoring and Inflow/Infiltration Study, June 2016, V&A Consulting Engineers).*

A total of 11 flow monitoring sites were used for model development and calibration. The location of these flow monitors and associated sewer-sheds (flow monitoring sheds) are presented in **Figure 2-4**. **Table 2-2** summarizes the characteristics of the 11 sewer-sheds established for use in this Master Plan.

Table 2-2 Flow Monitoring Shed Characteristics

Flow Monitor/ Sewer-shed	MH ID	Pipe Diameter (in)	Existing Area (Acres)	Shed Description
1	NW355SS24 and (Pump Station State-Logger)	30	1,044	Nicolaus Road Pump Station collection shed
2	NW386SS31	18	297	Joiner Parkway north of 5th Street
3	NE492SS15	30	291	E Street Sewer North of Gateway Drive
4	SE493SS03	48	NA	Regional Sewer, SMD1 collection shed
5	NW355SS27	30	791	Chambers Drive, Old Part of Town collection shed
6	SW359SS001	36.75	134	Moore Road, North Lincoln Crossing collection shed
7	SW361SS02	66	337	Hwy 65 Crossing, Regional Sewer collection shed
7A	SW395SS05	12	242	Calden Circle and Ferrari Ranch Road, Lincoln Crossing collection shed
8	SE461SS09	24	1,114	Joiner Parkway south of Sterling Parkway, Twelve Bridges collection shed
9	SE461SS05	30	411	Lincoln Boulevard north of Joiner Parkway, SCLH Villages collection shed
10	NA (Pump Station State-Logger)	NA	724	East Lincoln Parkway Pump Station collection shed



City of Lincoln
Wastewater Collection System Master Plan

Figure 2-4
Flow Monitoring Locations

Higher than average rainfall was experienced throughout Northern California in the 2017 Water Year (October – September), particularly in January 2017. V&A installed rain gauges at the Nicolaus Road Pump Station and the East Lincoln Parkway Pump Station to collect rainfall data during the 2017 monitoring period. There were four main rainfall events totaling 15.7 inches (average of both rain gauges) of rain. The 2016 flow monitoring study occurred during drought conditions, which persisted for five years in Northern California from approximately 2011 to 2016. Water use restrictions were in effect and very little rain fell during the study; limiting wet weather flow response in the collection system. A total of 5.01 inches of rain fell during the 2016 flow monitoring period.

V&A provided an analysis of inflow and infiltration (I/I) within the collection system. A summary of the results is provided in **Table 2-3**. V&A differentiated I/I flow from ADWFs to determine which components of I/I were more prevalent in each shed. After separating flow components, the I/I analysis metrics were normalized for an "apples-to-apples" comparison of each flow monitoring shed. Flows were normalized per-ADWF and per-IDM (inch-diameter-mile). The per-IDM method was weighted 60 percent in the overall ranking of the sheds because I/I rehabilitation and reduction efforts are typically budgeted per unit length of pipe. More information is provided in V&A's full Technical Report included in **Appendix G**.

V&A noted that Sheds 3, 5, and 7 had high normalized inflow. Sheds 1, 4, and 6 had high normalized Rainfall Dependent Infiltration (RDI). Site 3, 5, 6, 9, and 10 had high rates of GWI. Site 9 had a particularly high GWI component when compared to typical values. Sheds 3, 4, and 6 had the highest normalized total I/I contributions.

Table 2-3 V&A Flow Monitoring and I/I Analysis Summary

Flow Monitoring Site	V&A's ADWF (1) (2) (MGD)	Peak Measured Flow (MGD)	Peaking Factor	Max depth/ Diameter Ratio	High Ground Water Infiltration	I/I Ranking (3)
1	0.56	2.75	4.9	0.97	-	5
2	0.10	0.62	6.1	1.23	-	9
3	0.41	3.16	7.7	0.49	Yes	2
4	1.65	11.47	6.9	0.29	-	3
5	1.12	8.17	7.3	0.87	Yes	4
6	1.30	8.78	6.8	0.38	Yes	1
7	5.68	39.76	7.0	1.56	-	8
8	0.98	5.21	5.3	0.36	-	6
9	0.78	2.18	2.8	0.19	Yes	7
10	0.50	2.08	4.1	NA	Yes	10

(1) ADWF values are those observed at each flow monitoring site and have not been adjusted to remove flow from upstream flow monitors.

(2) ADWFs measured during the flow monitoring study are not representative of annual dry weather flows. Flow monitoring occurred during the wet weather season, ADWFs have a higher than normal groundwater infiltration

component and the values presented here represent the “low” flows between peak events. Flows measured during July, August, or September are significantly lower.

(3) A ranking of “1” represents the most observed I/I after normalization.

2.5 RELEVANT STUDIES & AGREEMENTS

Several studies of the collection system have been undertaken since the development of the development of *Technical Memorandum No. 1: The General Plan Update, Sewer Constraints Analysis and Sewer Facilities Cost Estimate* by Stantec (formerly ECO:LOGIC) in 2006. This Technical Memorandum (TM) presents the results of a wastewater flow analysis intended to identify potential constraints associated with sewage collection and treatment for the City. The focus of the TM was the development of a future servicing strategy for buildout of the General Plan update. New trunk sewers were recommended to serve the majority of development outside of the existing collection system. This proposed servicing strategy would impose little impact on the existing collection system.

There are currently no formal planning documents that assess the capacity of the existing collection system or present recommended improvement projects, aside from the City’s capital improvement plan which has identified projects based on field observations. Despite the lack of a formal planning document, several studies and improvement projects within the existing collection system have occurred since 2006. The following studies and improvement projects were considered during the development of this Master Plan:

- 2010 Placer County SMD1 WWTP Preliminary Design
- 2012 SMD1 Pump Station Preliminary Design
- 2015 Flow Monitoring Study
- 2015 Nicolaus Road Pump Station Evaluation
- 2016 Flow Monitoring Study
- 2017 Placer County Sewer Service Analysis for the Area Surrounding Athens Avenue

In March of 2012 Placer County accepted the City of Lincoln’s offer to complete the Mid-Western Regional Sewer Project, intended to provide regional wastewater treatment for the City of Auburn and Placer County’s SMD1, and Bickford Ranch Development. The terms of the Construction, Operations, and Joint Exercise of Powers Agreement (COJA) outline the projected wastewater flows from these regional wastewater flow contributors. These include PWWFs to Lincoln (equalized at the source) of 14.7 MGD from SMD1; 5.2 MGD from the City of Auburn; and 1.75 MGD from Bickford Ranch.

2.6 EXISTING CAPITAL IMPROVEMENT PLANS

The City has a Public Facilities Element (PFE) list of sewer projects and infrastructure values (cost estimates) that include some existing sewer assets within the wastewater collection system, as well as other facilities needed to support the development of the expanded City sphere and the establishment of sewer connection fees. These PFE documents were derived from the 2006 Sewer Constraints Analysis, which was used to support the development and adoption of the City's Updated General Plan. Sewers not included within the PFE list are considered local sewer projects and are not included in the establishment of the City sewer connection fee as common and shared infrastructure. Local projects must be built as part of local development projects. Once built, all sewers within the public right of way are maintained by the City of Lincoln and are funded by monthly user fees.

The PFE list (last updated in 2014) and the 2006 Sewer Constraints Analysis are included in **Appendix F**. The PFE list consists of a City map with sewer projects identified by number and a table with opinions of cost for each project.

The PFE improvements were based on steady-state spreadsheet models and are being revisited as part of the development of this Master Plan, which presents conclusions and makes recommendations of needed capital improvements in **Chapter 7.0**.

Project details for wastewater collection system projects included within the City's Fiscal Year 2017-2018 Budget are included in **Appendix F** and are summarized below:

- CIP 395 – Nicolaus Road Pump Station Upgrades

  Ongoing project that increases the reliable capacity of the NRPS.

- CIP 396 – Markham Ravine Sewer Rehabilitation

  Reduces I/I of sewers in and around Markham Ravine that impact the capacity of the NRPS.

- CIP 302 – Sewer Collection System Rehabilitation

  This is the City's existing Repair and Replacement (R&R) budget for SSMP compliance, which will be absorbed primarily by CIP 395 and CIP 396.

- CIP 425 – Silver Spur Sanitary Sewer Lift Station

  This project is an R&R project to improve aging infrastructure at the Silver Spur Pump Station.

- CIP 427 – Aviation & Venture Sewer Line Rehabilitation

  The goal of this project is to reduce operation and maintenance costs associated with this clogging in this portion of the collection system.

3.0 STUDY AREA INVENTORY

3.1 PURPOSE

The purpose of this chapter is to present the data and assumptions used to approximate future wastewater flow and distribution from areas within the planning horizon of the City's General Plan. These flows and distributions were used as a basis for the development of the hydraulic models of the existing and future collection system. Hydraulic models were used to evaluate existing infrastructure and to determine infrastructure needed to provide service to future planning areas.

This chapter is divided into the following sections:

- Population Projections
- Land Use Data
- Wastewater Generation
- Wastewater Flow Estimates
- Regional Flow Contributors
- Wastewater Flow Distribution

3.2 POPULATION PROJECTIONS

The City of Lincoln's population grew 282 percent from 11,205 in 2000, to 42,819 in 2010, making it the fastest growing place in the United States during this time. Annual residential population data, estimated by the United States Census Bureau from 2010 to 2016 is presented in **Table 3-1**.

Table 3-1 City of Lincoln Population Data

Year	Population
2010	42,819
2011	43,684
2012	44,191
2013	45,006
2014	45,747
2015	46,344
2016	47,030

Growth has slowed since the early 2000's, but the City is still expected to see significant growth in the future. The *City of Lincoln Housing Element Background Report* predicts a population of 92,350 by 2035. Population projections are presented in **Table 3-2**.

Table 3-2 City of Lincoln Population Projections

Year	Population Projection (1)	Data Source
2016	47,030	United States Census Bureau (2016)
2035	92,350	City of Lincoln Housing Element Background Report (2007)
2050	132,000	General Plan/ Municipal Service Review, City of Lincoln, Placer County, CA (2010)

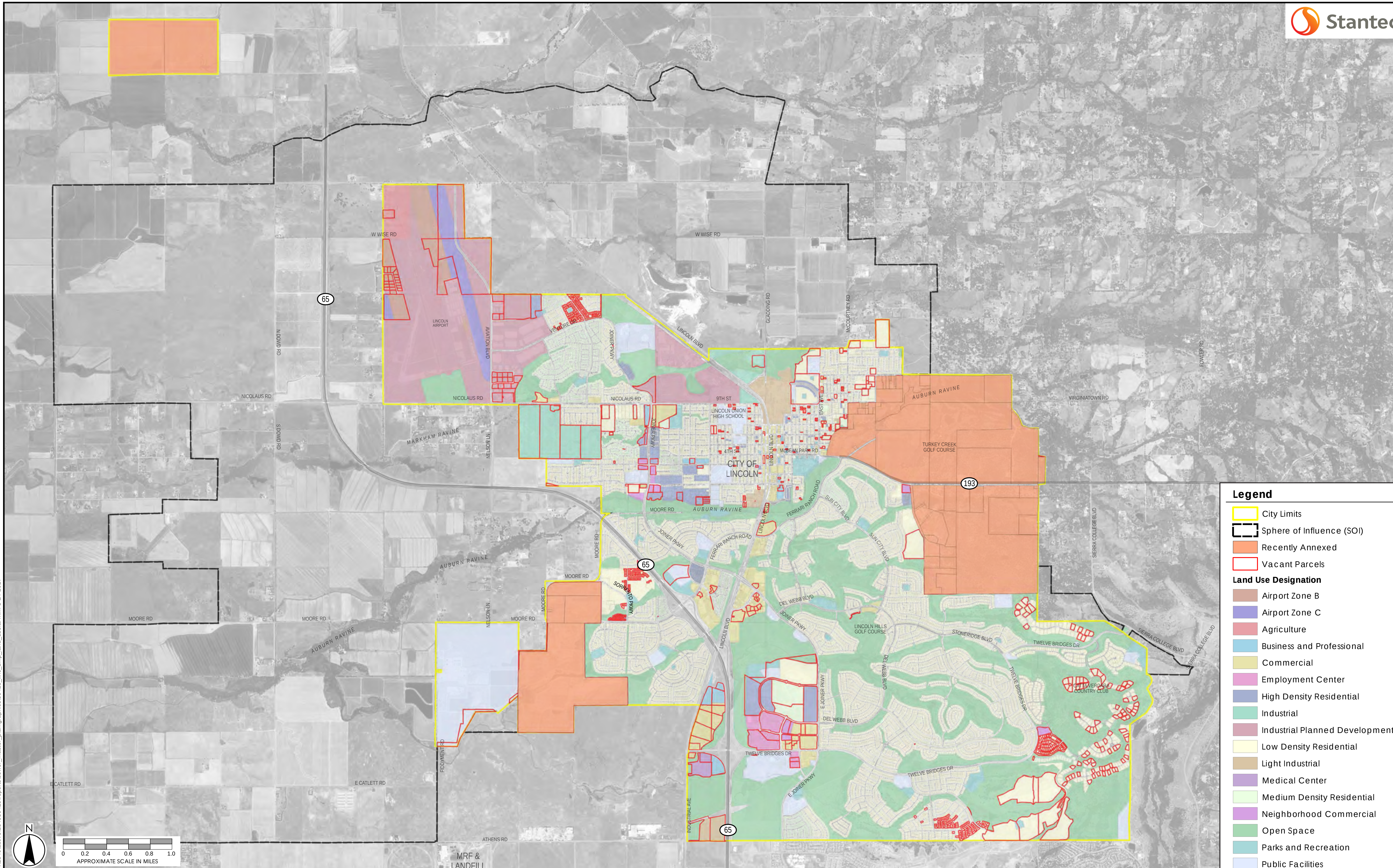
(1) Land uses from the General Plan were used to project future wastewater flows from areas within the City's SOI as opposed to the population projections presented here.

3.3 LAND USE DATA

Land uses within City Limits and within the SOI are established in the City's General Plan and serve as the basis to estimate future wastewater flow rates for each planning scenario evaluated during the development of this Master Plan.

3.3.1 Existing Land Use

Land use parcel data used in this Master Plan was obtained from the City in the form of GIS shapefiles. The land uses and vacant developable areas within the City Limits are shown on **Figure 3-1**. It was assumed that existing developments would not be rezoned or intensified, and existing wastewater flows are representative of ultimate land uses defined in the General Plan. Any such rezoning or redevelopment should be subject to review, requiring specific evaluation of its impact on the collection system prior to approval by the City. Properties currently identified as vacant were considered undeveloped and land use data from GIS parcel data was used to develop estimates of infill flows for buildout development planning scenarios. The total acreage, sorted by land use designation, within the existing City service area is presented in **Table 3-3**. Land use data presented in **Table 3-3** excludes public right of ways and does not include the SMD1 service area or those of other regional entities.



City of Lincoln
Wastewater Collection System Master Plan

Figure 3-1
City Limits Land Use

Table 3-3 Land Uses within City Limits

Land Use Designation		Gross Total Area (Acres) (1) (2)	Vacant Area (Acres) (3)
Low Density Residential	LDR	3,614.7	558.1
Medium Density Residential	MDR	413.7	70.5
High Density Residential	HDR	233.8	117.4
Neighborhood Commercial	NC	37.9	30.9
Business and Professional	BP	59.3	41.1
Employment Center	EC	68.0	55.1
Commercial	C	360.3	157.0
Light Industrial	LI	129.8	32.6
Industrial Planned Development	IPD	1,138.0	223.0
Industrial	I	242.3	200.6
Parks and Recreation	P	194.8	28.0
Public Facilities	PUB	798.6	52.6
Medical Center	MC	21.7	21.7
Open Space	OS	3,499.2	15.5
Agriculture	AG	80.7	5.0
Airport Zone B	AB	156.6	99.5
Airport Zone C	AC	152.4	141.1
Total		**11,201.7**	**1,849.7**

(1) City of Lincoln General Plan Land Use and Circulation Diagram GIS Data.
(2) Existing public right of ways were excluded from gross area calculations.
(3) City of Lincoln Tentative Parcel Map GIS Data. Vacant area is a subset of the Gross Area.

3.3.2 Future Land Use

To provide flexibility while ensuring new developments meet the quality and mix of land uses desired by the City, the General Plan applies two land use designations, Village and Special Use District (SUD) for larger undeveloped portions of the General Plan Sphere of Influence (SOI). These two designations do not dictate specific land use patterns on the areas to which they are applied but do require the development and approval of a detailed Specific Plan that will ensure a mixed-use concept consistent with the General Plan guidelines. The Villages and SUDs lie within the City’s SOI, between City Limits and the SOI boundary and are also referred to in this Master Plan as SOI Areas. There are seven Villages (identified as V-1 through V-7), three SUDs (identified as SUD-A, SUD-B, and SUD- C) and 942 acres of “Additional Areas” which collectively are considered SOI Areas in the context of this Master Plan. Land Uses within the City’s SOI are shown on **Figure 3-2**. Village 1 and Village 7 were annexed into the City in 2017.

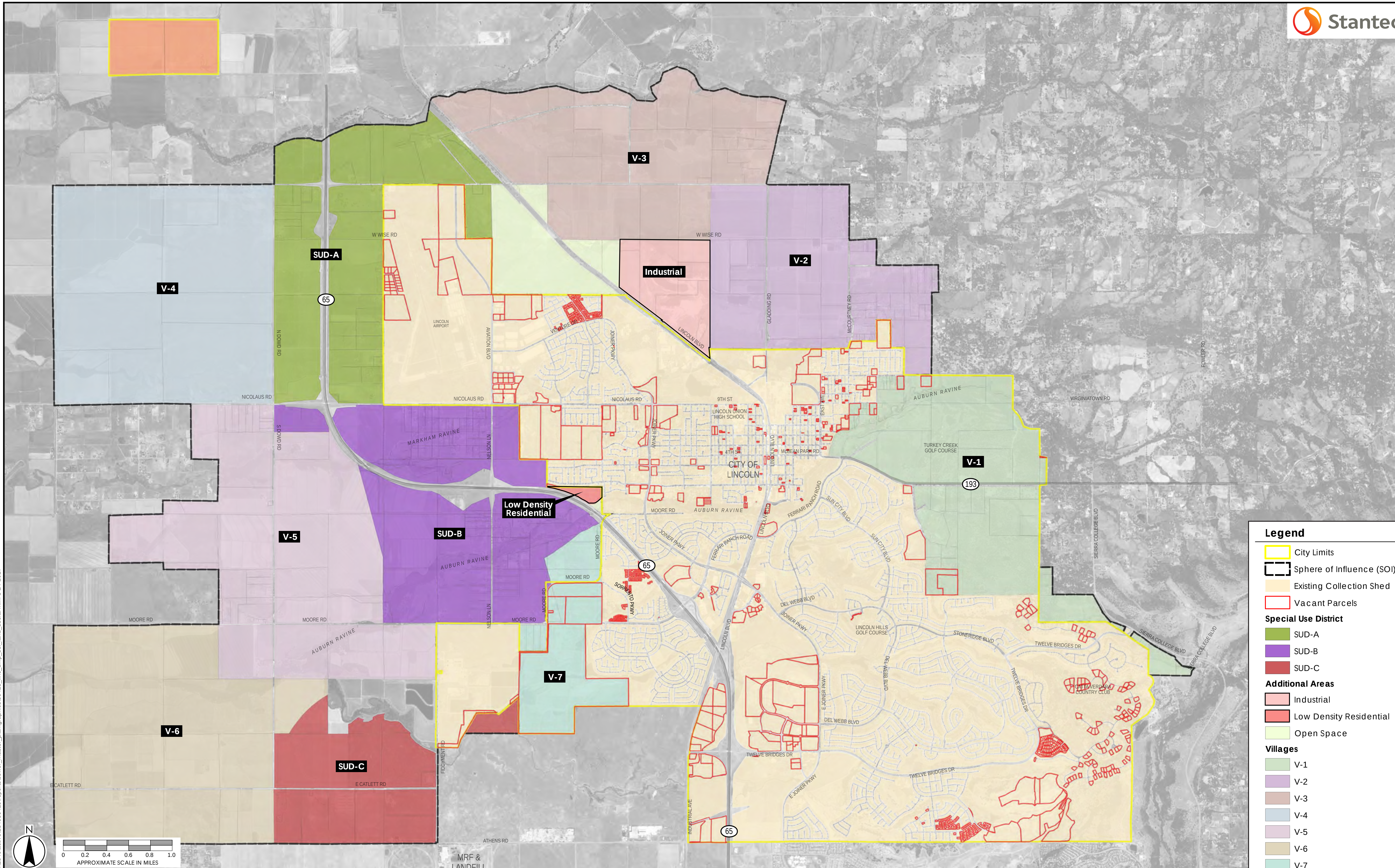


Figure 3-2
Sphere of Influence (SOI) Land Use

SOI Villages

The City's General Plan land use designation of "Village" is intended result in development that promotes mixed-use residential projects focused around a Village core containing a mix of high-density residential and neighborhood commercial uses. These areas are to be developed with smart growth principals and sustainability in mind to provide livable communities.

The mix of land uses within a Village is determined by a set of performance standards specified in the General Plan. For example, there is a percentage range used to prescribe the mix of housing that each Village must obtain. Specific Plans have been adopted for Village 1 and Village 7 and these areas have since been annexed by the City. A draft Specific Plan for the combination of SUD-B and V-5 is currently in development. The City provided updated GIS data reflecting the SUD-B and V-5 boundaries as a result of the draft Specific Plan, compared to the General Plan. This Master Plan uses the updated boundaries and land use proposed in the draft SUD-B/V-5 Specific Plan.

These adopted and draft Specific Plans provide land use designations from which an estimate of wastewater flow (generation) can be developed. For Villages and SUDs where no specific plan has been developed, assumed EDU counts, and land use information was provided by the City. Village land use information and source data used in the analyses conducted in support of this Master Plan is presented in **Table 3-4**. Land Use information for SUD-B/V-5 is presented in **Table 3-5**.

Table 3-4 Village Land Use Data

Village	EDU (1)	Commercial Area (Acres)	Industrial Area (Acres)	Public Area (Acres)	Park Area (Acres)	Data Source	Total Area (Acres) (2)
V-1	5,641	0	0	12	321	Village Specific Plan	1,866
V-2	4,209	7	44	34	0	Provided by City	1,626
V-3	4,843	70	0	0	0	Provided by City	2,021
V-4	5,421	12	0	0	0	Provided by City	2,567
V-6	5,083	12	0	0	0	Provided by City	2,514
V-7	3,285	12	0	12	59	Village Specific Plan	681
Total:	28,482	113	44	58	380	-	13,955

(1) EDU = Equivalent Dwelling Unit. Residential service is represented as EDU data, residential acres are not listed.

(2) Source: City of Lincoln General Plan Land Use and Circulation Diagram GIS Data.

SOI Special Use Districts (SUDs)

The difference between Villages and SUDs is how allowed land uses are prescribed. For SUDs, land uses are limited by restrictions established by the County's Airport Land Use Compatibility Plan and the proximity to the SR 65 Bypass. These areas have been provided with a designated use consistent with these limitations and compatible with surrounding land uses. Like Villages, a detailed Specific Plan is required prior to development of these areas. The City of Lincoln provided EDU counts and land use information for SUDs, this information is provided in **Table 3-5**.

Table 3-5 Special Use District Land Use Data

Special Use District	EDU (1)	Commercial Area (Acres)	Industrial Area (Acres)	Public Area (Acres)	Park Area (Acres)	Data Source	Total Area (Acres) (2)
SUD-A	1,623	1,170	142	0	0	Provided by City	1,809
SUD-B/ V-5	8,231	373	0	138	145	Draft Specific Plan	4,725
SUD-C	0	644	0	0	0	Provided by City	1,080
Total:	9,941	2,370	142	280	149	-	4,934

(1) EDU = Equivalent Dwelling Unit

(2) Source: City of Lincoln General Plan Land Use and Circulation Diagram GIS Data.

Additional Areas

The General Plan includes two small areas of land that fall within the City's SOI but are not included within any SUD or Village. One of the areas consists of thirteen parcels north of North Joiner Parkway and east of the Lincoln Regional Airport, below V-3 and SUD-A (See **Figure 3-2**). The General Plan assigns land use designations to these parcels. Parcels to the east are designated industrial and those to the west are planned to be open space.

There are also three parcels north of Highway 65 across from SUD-B, near Moore Rd that fall outside City limits but are not included in any Village or SUD. Two of these parcels are designated to be Open Space, and the remaining 27-acre parcel is designated as low density residential. Land Use information is provided in **Table 3-6** for these two "Additional Areas", designated as "Other" in the table.

Table 3-6 Additional Areas (Other) Land Use Data

Area	EDU (1)	Commercial Area (Acres)	Industrial Area (Acres)	Public Area (Acres)	Data Source	Total Area (Acres) (2)
"Other"	122	0	403	0	Land Use GIS Data	942

(1) EDU = Equivalent Dwelling Unit

(2) Source: City of Lincoln General Plan Land Use and Circulation Diagram GIS Data.

3.4 WASTEWATER GENERATION

Land use data is correlated with wastewater generation unit rates to project average wastewater flows for future developments where specific estimates were not provided. The information presented in this Section was used to model future wastewater flows from infill within City Limits and from SOI Areas for each planning scenario. Specific wastewater flow estimates were provided for regional flow contributors and for Village 5/SUD-B. PWWFs identified in the City's existing agreements with regional flow entities are used in this Master Plan (SMD1, City of Auburn, and Bickford Ranch). The draft specific plan for Village 5/SUD-B presented a higher flow that what would have been calculated with the following methodology due to higher planned residential densities and commercial wastewater generation rates. The specific plan flow estimates are used in the Master Plan as opposed estimates derived using land use and generations rates.

Average wastewater flows were estimated by multiplying each land use acreage by unit flow generation factors. Unit flow generation factors are outlined in the *City of Lincoln Department of Public Works Design Criteria and Procedures Manual (City Design Criteria, June 2004)*, with the exception of the Airport Zone B, Airport Zone C, and Parks land uses. The Airport wastewater unit flow factors were developed based on information outlined in the *Placer County Airport Land Use Compatibility Plan (Mead & Hunt, February 2014).* The unit flow generation factor of 20 gpd/acre applied to Parks is a typical value used in similar planning studies in the Central Valley. Unit flow factors used in this Master Plan are summarized in **Table 3-7**.

Neighborhood Commercial, Community Commercial, Regional Commercial, Business and Professional and Employment Center land use designations correlated to the Commercial unit flow generation factor from the City's Design Criteria. Light Industrial, Industrial Planned Development, and Industrial land use designations are correlated with the Industrial unit flow generation factor. Public Facilities and Medical Center land use designations are correlated to the Public unit flow generation factor.

For residential land uses, the density of development is a major variable in the estimation of per acre wastewater generation. Unit density used for residential land uses, based on direction from City staff, is the midpoint of the density range presented in the City's General Plan. It is assumed that Open Space and Agricultural land uses will not contribute flow to the collection system or will contribute only negligible flow not material to sizing sewers for this Master Plan.

Table 3-7 Unit Flow Generation Factors

Land Use Designations	Label	Category	Unit Density & Wastewater Generation Rate	
Rural Residential	RR	Residential	0.5 EDU/Acre	250 gpd/EDU
Country Estates	CE		2.00 EDU/Acre	
Low Density Residential	LDR		4.45 EDU/Acre	
Medium Density Residential	MDR		9.45 EDU/Acre	
High Density Residential	HDR		16.50 EDU/Acre	
Special Use District	SUD	SUD	Refer to SUD Land Use Information	
Village	V	Village	Refer to Village Land Use Information	
Mixed Use	MU	NA	NA	
Neighborhood Commercial	NC	Commercial	1,600 gpd/Acre	
Community Commercial	CC			
Regional Commercial	RC			
Business and Professional	BP			
Employment Center	EC			
Light Industrial	LI	Industrial	2,500 gpd/Acre	
Industrial Planned Development	IPD			
Industrial	I			
Airport Zone B	AB	Airport	25 gpd/Acre	
Airport Zone C	AC	Airport	125 gpd/Acre	
Parks and Recreation	PR	Parks	20 gpd/Acre	
Public Facilities	PF	Public	1,000 gpd/Acre	
Medical Center	MC			
Open Space	OS	No Flow Contribution	NA	
Agriculture	AG			

3.5 WASTEWATER FLOW ESTIMATES

3.5.1 Dry Weather Flow

The existing collection system was delineated and the total sewer-shed area of collector sewers (10-inch sewers and smaller) were assigned to manholes along each trunk sewer (12-inch sewers and larger). Dry weather flows from existing developments were then distributed along each trunk proportionally based on the total contributing area within each flow monitoring shed.

Dry Weather Flow (DWF) estimates for infill and future developments are based on the unit flow generation factors presented in **Table 3-7** and the total development areas presented in **Table 3-3** through **Table 3-6**, with the exception of Village 5/SUD-B and regional wastewater flows, where specific plan flow estimates were greater than flow estimates determined by land use and unit flow factors. It should be noted the acreage calculations do not include public right of ways.

As previously noted, Village 1 and Village 7 were recently annexed into the City Limits. In this Master Plan, because no units have yet been developed and these planning areas remain separate and distinct, Village 1 and Village 7 are presented as imposing a future wastewater demand on the collection system, as opposed to being included as infill within the existing service area. Wastewater flow estimates are presented in **Table 3-8**.

Table 3-8 Future Wastewater Flow Estimates

AREA	EDU (MGD)	Commercial (MGD)	Industrial (MGD)	Public (MGD)	Park (MGD)	Airport Zones (MGD)	ADWF (MGD)	PWWF (1) (MGD)
Infill within City Limits	1.27	0.46	1.14	0.07	0.00	0.02	2.96	7.80
Village 1	1.41	0.00	0.00	0.01	0.01	0.00	1.43	3.30
Village 2	1.05	0.01	0.11	0.03	0.00	0.00	1.21	2.80
Village 3	1.21	0.11	0.00	0.00	0.00	0.00	1.32	3.00
Village 4	1.36	0.02	0.00	0.00	0.00	0.00	1.37	3.20
Village 5/SUD-B	2.06	0.60	0.00	0.14	0.00	0.00	3.85 (2)	8.90
Village 6	1.27	0.02	0.00	0.00	0.00	0.00	1.29	3.00
Village 7	0.82	0.02	0.00	0.01	0.00	0.00	0.85	2.00
SUDA	0.41	1.87	0.36	0.00	0.00	0.00	2.63	6.00
SUDC	0.00	0.00	1.61	0.00	0.00	0.00	1.61	3.70
Other Spaces	0.03	0.00	1.01	0.00	0.00	0.00	1.04	2.40
SMD1	-	-	-	-	-	-	4.20	14.70
City of Auburn	-	-	-	-	-	-	2.50	5.20
Bickford Ranch	-	-	-	-	-	-	0.40	1.80
Total							26.70	67.80

(1) Peak Wet Weather Flow (PWWF) has been included here for completeness and is further described in the following section

(2) Total wastewater flow estimate from draft specific plan.

3.5.2 Peak Wet Weather Flow (PWWF)

PWWFs simulated in the hydraulic model are used to evaluate the level of service (LOS) of the collection system and provide recommendations for future servicing and improvement strategies. PWWFs are determined by computational models by simulating design rainfall events representing a reasonable worst-case condition. During rainfall conditions considered more severe than the input design storm, exceedances of LOS criteria would be expected to occur, which may result in sanitary sewer overflows (SSOs). The design storm selected for many Central Valley collection systems has a statistical 10-year return frequency and 24-hour duration. PWWFs in the collection system, originating from within the existing collection shed were evaluated using a 10-year, 24-hour design storm with a Huff Distribution (distributing rainfall by hour), as shown in **Figure 3-3**.

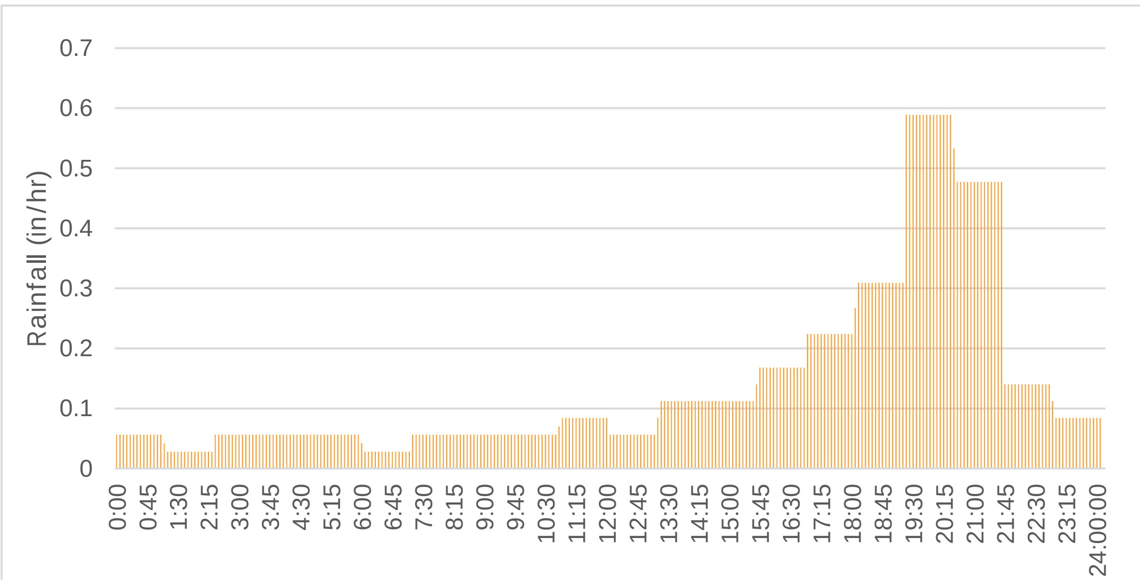


Figure 3-3 10-year, 24-hour Design Storm

Storms in Water Year 2017 were used to establish the formula for predicting PWWFs in the hydraulic model of the City's collection system trunk network. The 2017 events represented return frequencies from 5 to 100 years and were considered an appropriate basis on which to distribute "design storm" flow (including GWI and RDII) throughout the existing portions of the collection system in order to conduct collection system level of service analyses. I/I flow contributions were estimated using the RTK Unit Hydrograph Method, further discussed in **Section 4.5** and **Appendix H**.

The existing dry weather flows distributed throughout the model have a high groundwater infiltration component and are considered to represent peak dry weather flow conditions. Historical data was used in the EDU assessment described in **Section 3.4,** from which it was confirmed that the wastewater flow generation rate per EDU (250 gpd/EDU) is a reliable, conservative approach to estimate wastewater flow from future development.

PWWF from future development was estimated using the peaking factor method outlined in the City's Design Criteria. A peaking factor of 2.3 was applied to flows from SOI areas to estimate a PWWF under buildout conditions.

It should be pointed out, although based on storm events and recorded (flow monitoring) conditions at the time, the concept of a design storm does not directly affect predicted future flows to the City's collection system model with the peaking factor approach applied (a peaking factor of 2.3 per City Standards). The design storm approach is based on flow monitoring and precipitation data gathered at the time of model development and remains the basis for distribution of flow within the existing portions of the City's collection system. Applying the peaking factor of 2.3 to all future flows represents a more steady-state approach which eliminates the need to apply design storm conditions to simulate future flow conditions.

The approach of establishing design storm conditions to distribute flow within the existing collection system, and application of a peaking factor of 2.3 to estimate future flows from future development (to size future infrastructure) is considered by the City to be an acceptable and conservative approach to meeting State Water Board requirements. Peak wastewater flow estimates from regional entities were provided by the City and are fixed based on pump station capacity and service Agreements. **Table 3-9** presents a summary of the PWWF estimating methods used in this Master Plan.

Table 3-9 PWWF Development Methods

Contributing Area	PWWF Simulation Method	Description
Existing Sewer-sheds	RTK Unit Hydrograph and 10-year, 24-hour Design Storm	Calibrated based on flow monitoring data
SMD1 Collection Shed	Fixed Flow, Peak Pump Station Capacity	PWWF outlined in existing agreements, for all levels of development
Future Infill	RTK Unit Hydrograph and 10-year, 24-hour Design Storm	Assigned based the location of infill
SOI Areas	Fixed Flow, Peaking Factor	Design criteria prescribed
Regional Flows	Fixed Flow	PWWF outlined in existing agreements

3.6 REGIONAL FLOW CONTRIBUTORS

The City of Lincoln's collection system and WWTRF currently accepts regional flows from Placer County's SMD1 service area and is expected to accept flow from other entities east of the City in the future. Estimates of regional wastewater flows were provided in existing service Agreements and are presented in **Table 3-10**. These estimates are considered maximum buildout PWWFs under future development conditions. The existing system capacity will need to be reevaluated if these estimates of regional flow increase under future planning conditions.

Table 3-10 Regional Wastewater Flow Estimates

Regional Entity	ADWF (MGD)	PWWF (MGD)
SMD1	4.20	14.70
Bickford Ranch	0.40	1.75
Auburn	2.50	5.20

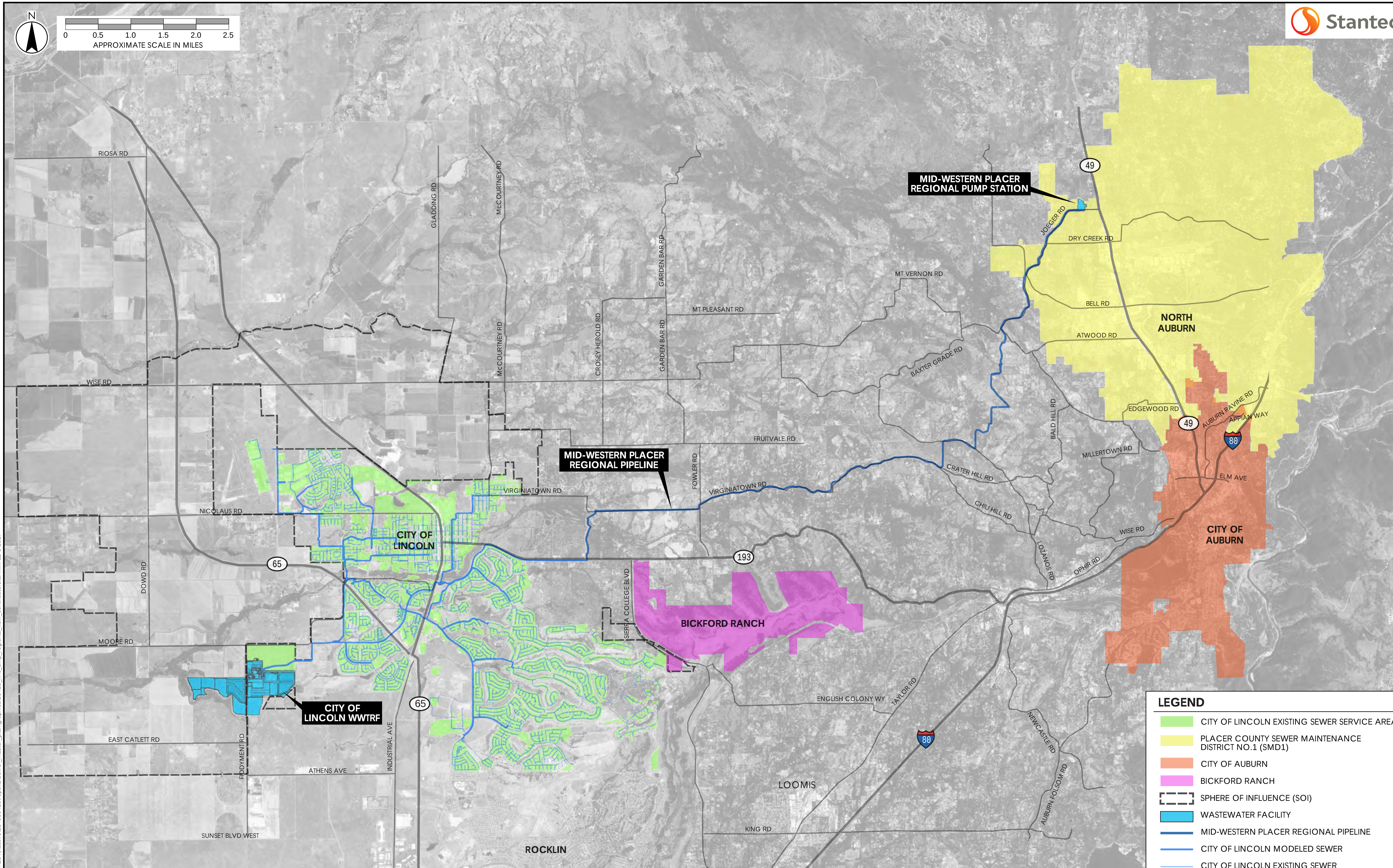
(1) ADWF and PWWF flows as outlined in the City's existing service agreements.

A vicinity map showing the location of regional entities is included as **Figure 3-4**.

3.7 WASTEWATER FLOW DISTRIBUTION

Wastewater flow contributions were distributed to manholes within the existing sewer-sheds based on the flow monitoring data and the proportion of the sewer-shed area contributing to each manhole. The existing collection system was delineated as part of the flow monitoring study; upstream sewer-shed areas were assigned to manholes along sewers 12-inches and larger. For example, 32 acres of sewer-shed 8 contribute to a 10-inch collector sewer which ties into a 12-inch in the existing system at manhole SW343SS05. Therefore, manhole SW343SS05 is assigned 32 acres within sewer-shed 8. If the total area of sewer-shed 8 equals 320 acres, manhole SW343SS05 contributes ten (10) percent (32/320) of the total flow monitored at flow monitor 8.

Flow estimates from future service areas was distributed in a similar manner. After laying out the ideal future collection system configuration, flow was assigned to existing parcels within the City's SOI areas (Villages & SUDs). Existing parcels consist of large swaths of land and were grouped based on location and proximity to the future system. Flow from parcel groups was assigned to the most upstream manhole closest to the parcel. City provided flow estimates for each of the SOI areas were distributed to parcel groups proportionally to the parcel group area. Further information and flow distribution data is presented in **Appendix A**. **Table A-1** presents a summary of future pipeline properties, corresponding upstream manholes and downstream manhole properties, and contributing sewer-shed area information for the upstream manhole.



V:\1840\active\184030429\reports\sewer_master_plan\graphics\30429_linc_smp_regional_flow_contributors.ai mlm 11-3-2017

Figure 3-4
Regional Flow Contributors

4.0 HYDRAULIC MODEL DEVELOPMENT

4.1 PURPOSE

The purpose of this chapter is to outline details of the sewer collection system model construction and approach.

This chapter is divided into the following sections:

- Hydraulic Model Approach
- Modeling Software
- Review of Geodatabase
- Hydraulic Model Calibration
- Design Criteria

4.2 HYDRAULIC MODEL APPROACH

The City of Lincoln's hydraulic modeling needs were assessed to help define the software and approach needed in the development of the hydraulic model. The preferred approach was to develop a dynamic trunk model that includes all pipes greater than or equal to 12-inches in diameter within the existing collection system. A trunk model is a skeletal model which is less detailed than a full pipe model. These types of hydraulic models are used for high level decision-making and system planning. This approach was selected based on the level of detail and analysis required for this Master Plan.

4.3 MODELING SOFTWARE

Based on hydraulic needs, PCSWMM software, developed by Computational Hydraulics Inc., was selected for use in developing a collection system computer model for the City. This software package has been developed using the EPA SWMM 5.0 engine as its basis. This software was selected for its ability to meet the following objectives:

- To determine the existing hydraulic capacity of the City of Lincoln's wastewater collection system and components.
- To identify system limitations such as bottlenecks and infrastructure incapable of accommodating future growth.
- To provide preliminary estimates of the infrastructure required to service future development of the General Plan.
- To evaluate future phasing strategies for the construction of future infrastructure.

Some of the advantages that PCSWMM holds over other similar hydrodynamic modeling packages are:

- Proven ability to efficiently and accurately model municipal wastewater collection systems for both dry weather flow and wet weather flow regimes.
- Extensive model input tools, visualization, and analysis features.
- GIS-integration and CAD format support.
- Developer's history of consistent and reliable technical and customer support.
- Overall inexpensive investment required by the City of Lincoln to purchase and maintain this software, if they so choose.

4.4 REVIEW OF GEODATABASE

During model development, the physical network of sewers, manholes, and pump stations was established based on the City's GIS database, specifically the physical information contained therein for the existing collection system. This physical network becomes the underlying framework for the model. Therefore, it is crucial that the infrastructure is reviewed for completeness and proper connectivity. A review of the existing collection system, parcel, and land use information in the GIS database was completed prior to model development which provides quality enhancements to the sanitary GIS data. The data review was undertaken in GIS in both ESRI ArcMap and hydraulic modeling software utilizing built-in PCSWMM analysis tools.

Missing and inconsistent data identified in the physical network included manhole inverts and rim elevations, sewer diameters, and slopes. In addition, a review was conducted of the hydraulic continuity and suitability of physical sewer data in terms of profile connectivity.

A data verification program was developed to obtain missing or inconsistent data in an efficient manner, through the use of drawing review, field verification, and inference. As a final resort data was inferred based on the surrounding network.

The following physical asset data was received from the City:

- Manholes – **ssmh.shp**
- Pipes – **sspipe.shp**
- Pump Stations – **sspump.shp**

4.4.1 Manholes

The City's manhole shapefile contains a number of attribute fields used to define physical parameters and provide additional relevant information. Based on the data provided, there are 3,565 manholes, and 1,029 cleanouts, plugs, and nodes in the City's sanitary geodatabase. A summary of the relevant attribute fields for manholes and initial gap assessment is provided in **Table 4-1**.

Table 4-1 Manhole Data Gap Assessment

Field Name	Description	Input Notes	Gap Assessment
STRUCT_ID	Unique Identifier	Letter/Numeric ID	813 Left Blank (~23%), 52 duplicates found
THRU_INV	Manhole Invert Elevation	Numeric Entry	1,216 Blanks (~34%)
RIM_INV	Manhole Rim Elevation	Numeric Entry	1,611 Blanks (~45%)

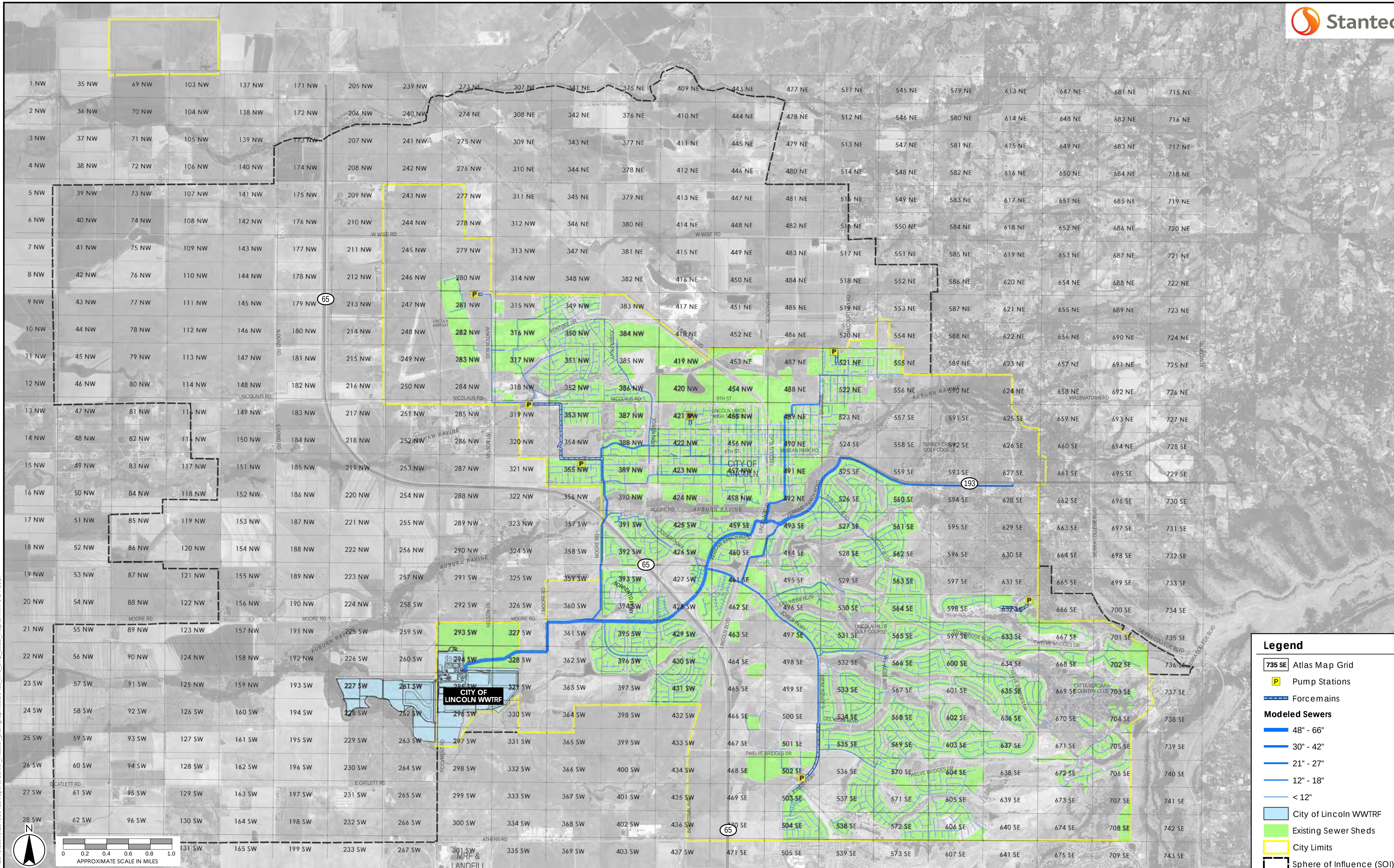
The collection system trunk model includes pipes greater than or equal to 12-inches diameter. After eliminating conduits and associated manholes less than 12-inches in diameter, 438 manholes remained. Invert and rim elevation data was missing upstream of the East Lincoln Parkway Pump Station, therefore the collection system upstream of Fieldstone Drive and Wilson Park was excluded from the model. The collection system upstream of the Flightline Drive Pump Station was also excluded from the model due to missing data. After exclusion of these areas, 357 manholes remained and the data was again evaluated for gaps. The refined manhole data gap assessment is presented in **Table 4-2**.

Table 4-2 Refined Manhole Gap Assessment

Field Name	Description	Input Notes	Gap Assessment
STRUCT_ID	Structure ID, Unique Identifier	Letter/Numeric ID	36 Left Blank (10%), 9 duplicates found
THRU_INV	Manhole Invert Elevation	Numeric Entry	59 Blanks (17%)
RIM_INV	Manhole Rim Elevation	Numeric Entry	141 Blanks (39%)

As structure ID (STRUCT_ID) is the unique identifier for manholes, it is important for this field to be populated to import data into modeling software, track attribute updates, and transfer data to the City. The naming convention used for assigning structure IDs originates from the City's *Sewer Atlas Map Book*. The naming convention takes the following form, DDXXXSSYY, where DD refers to the quadrant of the Atlas map index (i.e. NW, NE, SW, or SE) and XXX refers to a specific area within that quadrant. The remaining portion of the structure ID, SS indicates that it is part of the sanitary sewer system, and YY provides the unique identifier. Manholes missing entries for STRUCT_ID or found to have a structure ID used elsewhere in the system, were assigned a structural ID in the following form DDXXXSS0YY. The addition of a zero indicates that the ID has been assigned and assures that there isn't a duplicate in the un-modeled system. The Atlas Map index is presented in **Figure 4-1**.

Invert and rim elevations are important for completing hydraulic modeling and assessing the impact of potential surcharges in the sanitary system. Blank entries for these fields will be generated based on the methodology for data correction and gap closure described in **Section 4.4.4**.



City of Lincoln
Wastewater Collection System Master Plan

Figure 4-1
Atlas Map Index

4.4.2 Pipes

The collection system pipeline shapefile contains a number of attribute fields used to define physical parameters and provide additional relevant information. For purposes of hydraulic modeling the most important attributes for pipelines are type, upstream manhole, downstream manhole, slope, upstream invert elevation, downstream invert elevation, diameter, material, and length. The pipe shapefile provides material, type, diameter, and length for each conduit. Upstream and downstream manholes and invert elevations were assumed based on manhole proximity, and corresponding manhole data. It was assumed that pipelines match crown to crown. Slopes then were determined from this information. It can be noted that based on the data provided, there are 4,164 pipes in the City's sanitary geodatabase. This includes active, proposed, private, and abandoned pipelines. The initial gap assessment is provided in **Table 4-3**.

Table 4-3 Pipe Data Gap Assessment

Field Name	Description	Input Notes	Gap Assessment
PIPE_ID	Structure ID, Unique Identifier	Letter/Numeric ID	1,339 Left Blank (~32%), 221 duplicates found
MATERIAL	Pipe Material	Text Entry	1 Blank (~0%)
TYPE	Pipe Type, Gravity Main (sspi) or Forcemain (ssfm)	Text Entry	0 Blanks (0%)
DIA	Diameter (in)	Numeric Entry	0 Blanks (0%)
Length	Pipe Length (ft)	Geodatabase	0 Blanks (0%)

Abandoned pipelines, those less than 12-inches in diameter, and those from areas upstream of the East Lincoln Parkway and Flightline Drive pump stations, were removed from the database. Pipes needed for connectivity that may be less than 12-inches in diameter, or those that had been recently constructed were added, giving 376 conduits. There were no blank entries for pipe diameter identified. Pipe length was assumed to be equal to that represented by GIS shape data. The refined data gap assessment is presented in **Table 4-4**.

Table 4-4 Refined Pipe Data Gap Assessment

Field Name	Description	Input Notes	Gap Assessment
PIPE_ID	Structure ID, Unique Identifier	Letter/Numeric ID	29 Left Blank (~8%), 36 duplicates found
MATERIAL	Pipe Material	Text Entry	0 Blank (0%)
TYPE	Pipe Type, Gravity Main (sspi) or Forcemain (ssfm)	Text Entry	0 Blanks (0%)
DIA	Diameter (in)	Numeric Entry	0 Blanks (0%)
Length	Pipe Length (ft)	Geodatabase	0 Blanks (0%)

As noted in the review of manhole data, it is important for the PIPE_ID field to be populated to import data into the modeling software, track attribute updates, and transfer information with the City. It is also important that these values are unique with no duplications. Review of the blank PIPE_ID fields indicates that 27 gravity pipelines and two forcemains were left blank. The 36 duplicate field entries were renamed, and IDs were generated for the 20 additional pipelines that were added to the geodatabase. IDs were generated for a total of 85 pipelines.

The naming convention for pipelines takes a similar form to that used for manholes and other wastewater infrastructure, taking the form DDXXXSSPYY. Like the manhole naming convention, DD represents the quadrant of the City that the pipe is located in, XXX represents which specific portion of that quadrant, SSP indicates that it is a sanitary sewer pipe, and YY gives the pipe it's unique identifier. Generated PIPE_IDs take the form DDXXXSSP0YY. The zero is added to identify that the ID has been generated and guarantee that there is not a duplicate in the existing system. This also allows for easy replacement if the correct ID can be provided by the City in the future.

4.4.3 Pump Stations

The "sspump" shapefile contains attribute fields that provide relevant information related to the City's sanitary sewer pump stations. The majority of the physical parameters required for hydraulic modeling are not included, however, the shapefile provides the name, status, and location data.

Additional information regarding the pump stations has been provided to collect data beneficial for hydraulic modeling. The extent of the data required is dependent on the preferred approach for model development. The currently available information and data source for the network structures that have been collected and used in this Master Plan for pump stations are summarized in **Table 4-5**.

There are 13 pump stations in the City's geodatabase, 6 of which have been decommissioned. After eliminating pipes less than 12-inches in diameter, only two of the seven active pump stations were included in the hydraulic model. These two pump stations are the largest in the collection system; the East Lincoln Parkway Pump Station, and the Nicolaus Road Pump Station.

Table 4-5 Pump Station Data

Parameter	Data	Data Source
Nicolaus Road Pump Station		
Wet Well Dimensions	Large Manhole: 5-foot Inner Diameter Small Manhole: 4-foot Inner Diameter	2017 Improvement Drawings (CIP 395 Nicolaus Road Pump Station Improvements, Feb. 2017, Stantec)
Wet Well Floor Elevation	Large Manhole: 88.33 feet Small Manhole: 90.61 feet	2017 Improvement Drawings
Influent Sewer Invert Elevation	90.7 feet	2017 Improvement Drawings
Pump Station Capacity	3.4 MGD (reliable, 2017 improvements)	2017 Improvement Drawings
East Lincoln Parkway Pump Station		
Wet Well Dimensions	Large Manhole: 10-foot Inner Diameter Small Manhole: 6-foot Inner Diameter	2000 Record Drawings (Twelve Bridges Lincoln Parkway Sewer Lift Station, Sept. 2000, Sauers Engineering)
Wet Well Floor Elevation	Large Manhole: 115.0 feet Small Manhole: 121.0 feet	2000 Record Drawings
Influent Sewer Invert Elevation	129.0 feet	2000 Record Drawings
Pump Station Capacity	2.7 MGD (reliable)	2000 Record Drawings

4.4.4 Data Validation and Connectivity Review

Data validation is the process of confirming the hydraulic continuity and suitability of physical sewer data in terms of profile connectivity. Most modern modeling software packages include routines and queries to help perform validations. The following summarizes the data validation exercise for development of the City's collection system model.

After removing pipes less than 12-inches in diameter, an initial connectivity review was conducted. Pipelines were assigned upstream and downstream manholes based on invert elevation and position within the geodatabase. Where manhole rim and invert elevations were missing, available record drawings were reviewed to fill in data gaps. Where record drawings were unavailable, data was inferred. Invert elevations were interpolated based on the surrounding system slopes and invert elevations. Rim elevations were interpolated from high resolution LiDAR data provided by the City.

Since the construction of the WWTRF in 2004 and decommissioning of the old wastewater treatment plant, many capital improvement projects have taken place to redirect the collection system to the new WWTRF.

The following major collection system improvement projects were reviewed and incorporated into the geodatabase:

- Chambers Sewer/ Nicolaus RD PS FM Improvements
- E Street Infrastructure Project
- Midwestern Placer Regional Sewer Pipeline
- Improvement Plans for Three D South Moore Road & Offsite Utilities
- Chambers Drive 30-Inch Sewer & Manhole Modifications Project
- Moore Road 18" SSFM Relocation
- WWTP Improvements Project Auburn Ravine Effluent Pipeline
- Moore Road Off-Site Sewer
- Regional Sewer Pipeline

It was assumed that with the construction of the E street sewer all flow from east of E Street flows south, and all flow from west of E street continues to flow west through the "old part of town". This area is the oldest portion of the collection system, and spans the area between 1st street, Nicolaus Road and Joiner Parkway.

4.5 HYDRAULIC MODEL CALIBRATION

The calibration process is required to verify the accuracy of the model at predicting the system performance under varying flow conditions. The flow monitoring data from the 2016 and 2017 flow monitoring studies were used to calibrate the model under observed dry weather and wet weather conditions. The calibrated model was then used to assess system performance under design storm conditions. The hydraulic model calibration was validated through comparison to the observed flow monitoring data collected from January 4, 2017 to March 7, 2017.

4.5.1 Dry Weather Calibration

Dry weather flow calibration was completed by running model simulations for two observed "dry weather" periods. Heavy rainfall was experienced throughout Northern California before and throughout the flow monitoring period and as a result, dry weather periods selected for model calibration have high levels of groundwater infiltration associated with them. The dry weather flow (DWF) observed during the flow monitoring period and distributed in the hydraulic model is 6.18 MGD. Typically, ADWF is calculated in the months of July – September, which is considered to be the dry season. The average wastewater flow observed at the WWTRF influent flow meter from July through September of 2017 (2017 ADWF) was 4.0 MGD.

Without flow monitoring data from July – September, in which flow recedes to baseline levels, accurate predictions of the distribution of groundwater infiltration within the collection system could not be made. The hydraulic model was calibrated based on a DWF flow value of 6.18 MGD. Although this value is higher than the ADWF observed during the dry season, this was considered to be a reasonable approach to building the hydraulic model based on the data available. DWF was distributed within each flow monitoring shed based on a contributing area weighted distribution, with consideration for weekday and weekend flow patterns. The model results at each monitoring site were compared to the "observed" monitored flow for the dry weather flow period. The model was further refined using data from the 2016 flow monitoring study. Dry weather flow distributions observed during the 2016 study were incorporated into the model for the Nicolaus Road Pump Station sewer-shed, (Flow Monitoring Shed 1) and a portion of the Regional Sewer sewer-shed (Flow Monitoring Shed 7), now Flow Monitoring Shed 7A. The parameters were varied in a systematic manner within a reasonable range until an acceptable fit to the observed flow was obtained. Comparisons were made between modeled vs. observed flow, depth, volume and velocity, with a target level of accuracy of +/- 15 percent.

Additional details regarding calibration can be found in **Appendix H**.

4.5.2 Wet Weather Calibration

The calibrated DWF model was expanded to include wet weather flow (WWF). Three rainfall events observed during the 2017 flow monitoring period were used for the calibration and validation process, these events are presented in **Table 4-6.** Event 1 produced the largest rainfall response based on flow monitoring observations and was therefore used for calibration. Events 2 and 3 were used to validate the results of the calibration.

Table 4-6 Wet Weather Events

Event	Start Date/ Time	End Date/ Time	Duration (days)	Total Rainfall (1) (in)
1	1/6/2017 21:40	1/14/2017 21:44	8.0	4.89
2	2/2/2017 0:30	2/14/2017 23:34	13.0	4.39
3	2/16/2017 2:00	2/24/2017 2:45	8.0	3.04

(1) Total rainfall is the average value from both V&A rain gauges.

Rainfall for each sewer-shed was interpolated between the two V&A rain gauges using the inverse distance weighting (IDW) method. The IDW method is an interpolation method that assumes the influence of each rain gauge location diminishes with distance. It should be noted that despite using the IDW method to account for some variability of rainfall, some error will still be introduced by assuming uniform rainfall within each sewer-shed. This should be considered when reviewing the calibration results.

In order to provide more accurate results for the Lincoln Crossing area (Flow Monitoring Shed 7A) flow monitoring and rainfall data from the 2016 flow monitoring study was used to individually calibrate the shed. Little rain fell during the 2016 monitoring period and only one event was considered suitable for use in this calibration.

The WWF model was calibrated using the "RTK Unit Hydrograph" method, with a set of three triangular unit hydrographs (UH) to represent the fast-response, medium-response, and slow-response to the rainfall dependent inflow and infiltration (RDII). Each UH is represented by three parameters (R, T, and K), which are used to calculate the intensity, duration, and rate of recession of the hydrograph.

Once initial unit hydrographs for each flow monitoring shed were developed, calibration was performed. Parameters were input to the hydraulic model on a trial basis and routed flow hydrographs produced by the model at each monitoring site were compared to the observed flow. Comparisons were made between modeled versus monitored flow with a target level of accuracy of +/- 15 percent. Final WWF calibration results are presented in **Table 4-7**. WWF calibration results for Site 7A are presented in **Table 4-8**.

Table 4-7 WWF Calibration Results

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Event 1, PWWF (MGD)										
Modeled	2.91	0.67	3.34	12.06	8.70	9.94	34.99	3.48	2.17	1.88
Measured	2.75	0.62	3.16	11.47	8.17	8.78	39.76	5.21	2.18	2.08
Error	5.9%	7.8%	5.5%	5.1%	6.5%	13.2%	-12.0%	**-33.2%**	-0.2%	-9.7%
Event 1, Total Volume (MG)										
Modeled	10.29	1.81	9.32	35.51	22.94	26.63	106.80	13.43	9.61	6.96
Measured	10.08	1.70	8.69	36.12	23.26	25.71	104.30	13.12	9.20	6.81
Error	2.1%	6.4%	7.2%	-1.7%	-1.4%	3.6%	2.4%	2.4%	4.4%	2.2%
Event 2, PWWF (MGD)										
Modeled	2.17	0.42	2.54	9.83	5.26	6.11	27.13	3.53	1.85	1.96
Measured	2.14	0.48	2.52	10.29	5.79	6.63	24.45	3.46	1.68	1.79
Error	1.5%	-13.4%	0.5%	-4.5%	-9.2%	-7.8%	11.0%	2.1%	10.6%	9.7%
Event 2, Total Volume (MG)										
Modeled	13.48	2.28	11.17	42.98	28.21	32.92	134.50	19.25	13.57	9.90
Measured	14.08	2.11	10.40	44.17	28.42	33.96	136.80	19.06	12.65	9.89
Error	-4.3%	8.2%	7.4%	-2.7%	-0.7%	-3.1%	-1.7%	1.0%	7.3%	0.1%
Event 3, PWWF (MGD)										
Modeled	2.50	0.44	2.37	9.03	5.97	6.84	26.32	3.19	1.90	1.74
Measured	2.08	0.41	2.76	9.54	6.39	7.13	31.11	3.31	1.86	1.66
Error	**20.3%**	7.2%	-14.2%	-5.4%	-6.5%	-4.0%	**-15.4%**	-3.8%	2.2%	4.6%
Event 3, Total Volume (MG)										
Modeled	8.70	1.42	7.25	28.02	18.09	21.08	86.68	12.27	8.59	6.32
Measured	9.42	1.36	7.04	27.34	18.19	23.13	86.58	12.09	8.51	6.31
Error	-7.6%	4.2%	3.0%	2.5%	-0.5%	-8.9%	0.1%	1.5%	0.9%	0.2%

Table 4-8 Site 7A WWF Calibration Results

Site 7A, Event 1A	PWWF (MGD)	Total Volume (MG)
Modeled	0.55	3.73
Measured	0.55	3.56
Error	0.7%	4.7%

The calibrated WWF model peak WWF results are generally within +/- 15 percent of the measured flows with the exception of the following:

Site 1: The model over predicts the PWWF from this sewer-shed, most notably during Event 3. Due to the proximity of the flow monitor to the Nicolaus Road forcemain discharge location, it is possible that the model over predicts the effects of inertia on the flow and is not introducing enough attenuation to the peaks. At this time, the model should be considered a conservative representation of this sewer-shed.

Site 7: The model slightly over predicts PWWF during Event 2. This site is the farthest downstream and the process of model calibration required that this sewer-shed be balanced with all the other sites.

Site 8: Although the total RDII volume for the first rainfall event was calibrated within 2.5 percent, the model is not predicting the response of the storm with that level of accuracy. It should be noted that for the second and third rainfall events the model is both qualitatively and quantitatively accurate. For the first rainfall event, it is possible that due to the spatial variability of actual storms, this sewer-shed may have been inundated with higher intensity rainfall than simulated in the calibration model.

The calibrated WWF model total flow volume results are typically within +/- 10 percent of actual measured flow at monitoring sites. Additional details regarding WWF calibration can be found in **Appendix H**.

4.5.3 On-going Calibration

On-going calibration is recommended to ensure the model is up-to-date for potential future uses. Updates are continuously being made to the physical infrastructure geodatabases and should be reviewed and incorporated into the model as appropriate over time. In addition, dry weather flow and wet weather flows should be reviewed and the loading data adjusted as necessary based on future flow monitoring data. As part of the City's flow monitoring efforts, locations should be strategically selected to focus on areas of interest to ensure the model is accurate for more localized areas. In this way, the model will be a "living" City tool, expanding to include new infrastructure and improvements as they occur and reflecting new flow data as it is collected over time.

4.6 DESIGN CRITERIA

After building the hydraulic model of the existing system and performing calibration, unit flow factors described in **Chapter 3.0** were applied to generate flow estimates within the model for various simulation scenarios. The design criteria described in this section establishes minimum infrastructure requirements for future development scenarios. Buildout of the SOI area will require construction of new sewer infrastructure, including new large trunk sewers. Design criteria used to simulate future infrastructure is presented in **Table 4-9**.

Table 4-9 Future Infrastructure Design Criteria

Design Criteria	Value
Manhole Spacing	~ 500 feet
Manhole Drops	Sewers < 36-inches in diameter: • 0.1 feet Sewers >= 36-inches in diameter: • 0.1 feet at bends > 15-degrees • 0.0 feet (through manholes) on straightaways
Manhole Depth	10 – 30 feet
Manning's "n"	Manning's formula shall be used to determine the relation of slope, design flow, velocity, and diameter. The "n" value shall not be less than 0.013 for all new pipes. (1)
Velocity	2 – 7 fps
Pipe Size	Hydraulic Loading Ratio (HLR) < 100%
Rim Elevation/ Grade	Lidar Data

(1) Some pipe materials can be modeled with lower n values (i.e. plastic pipe), but over time they become nicked and covered in biofilm that can make them hydraulically rougher. An n value of 0.013 is considered an acceptable standard to cover various materials and their possible conditions over time.

An overview of the criteria for the flow input data for dry and wet weather conditions for the current and future model scenarios simulated as part of this planning effort are summarized in **Table 4-10**.

Table 4-10 Model Input Design Parameters

<table>
<tr><th>Design Parameters</th><th>Dry Weather Flow Model</th><th>Wet Weather Flow Analysis</th></tr>
<tr><td rowspan="2">Dry Weather Flows</td><td colspan="2">Current Conditions (1):
Sewage generation is based on DWF determined for each flow monitoring shed, flow was distributed within the sewer-shed based on the area of each contributing parcel.</td></tr>
<tr><td colspan="2">Future Growth:
Future sewage generation was determined by the land uses and wastewater generation rates described in Chapter 3.0. Future flow was evenly distributed in SOI areas.</td></tr>
<tr><td rowspan="2">Peaking Factors</td><td colspan="2">Current Conditions:
Diurnal patterns were derived from the flow monitoring data for weekdays and weekends to capture differences in sewage generation trends.</td></tr>
<tr><td colspan="2">Infill Growth:
Diurnal patterns from the model calibration based on the sewer-shed receiving flows from the proposed development.
SOI Growth:
A peaking factor of 2.3 was used based on the City's Design Criteria.</td></tr>
<tr><td rowspan="2">Regional Flows</td><td colspan="2">Current Conditions:
Flow from the SMD1 collection system was modeled as a point load based on flow monitoring data (flow monitoring location 4).</td></tr>
<tr><td colspan="2">Future Growth:
PWWF from SMD1 was modeled as 14.7 MGD which is the maximum capacity of the Mid-Western Placer Regional Pump Station.
Flow from the City of Auburn and Bickford range were modeled as point loads using information provided by the City.</td></tr>
<tr><td>Design Storm</td><td>NA</td><td>All Scenarios:
10-yr, 24-hour Huff distribution design storm was used to model and evaluate the system under PWWFs in the existing system.</td></tr>
<tr><td rowspan="2">Wet Weather Infiltration</td><td>NA</td><td>Current Conditions:
Developed based on widely accepted RTK unit hydrograph method using flow monitoring data.</td></tr>
<tr><td>NA</td><td>Infill Growth:
Sewer-shed specific RTK parameters based on model calibration and the sewers receiving flow.
SOI Growth:
PWWFs within the SOI are simulated using a peaking factor of 2.3.</td></tr>
</table>

(1) Flow Monitoring Shed 1's dry weather flow was distributed in the model based on the distribution of flow observed in the *2016 Nicolaus Road Pump Station Flow Monitoring Study by V&A in 2016*.

5.0 CAPACITY ASSESSMENT

5.1 PURPOSE

The purpose of this chapter is to present capacity evaluation criteria used to assess collection system model simulation results and to provide a description of each of the simulated scenarios.

This chapter is divided into the following sections:

- Level of Service Criteria
- Modeled Scenarios

5.2 LEVEL OF SERVICE (LOS) CRITERIA

The 10-year, 24-hour design storm was applied to the model to simulate PWWFs and evaluate the system's the level of service (LOS) performance in meeting the following criteria:

- Sewer Capacity
- Hydraulic Grade Line (HGL)
- Velocity
- Pump Station Capacity

5.2.1 Sewer Capacity

The collection system is assessed based upon the following wastewater flow metrics.

Hydraulic Loading Ratio (HLR)

Collection system performance is assessed based upon the hydraulic loading ratio (HLR) within each sewer under dry weather and peak wet weather conditions. The HLR is a commonly used as a metric to evaluate the capacity and performance of a collection system. The HLR is mathematically defined as the peak modeled flow divided by the full pipe capacity derived from Manning's equation.

The Existing Level of Development Scenario was evaluated under dry weather conditions and wet weather conditions. Under dry weather flow conditions, sewers with HLRs of 50 percent or less are considered to meet LOS criteria. Sewers having HLRs greater than 50 percent indicates that there may not be capacity for flow under peak conditions.

Improvements proposed for future buildout scenarios are evaluated under design storm conditions. Improvements will be proposed based on HLRs nearing 100 percent in new sewers for these scenarios, or PWWF conditions as stipulated by the City's Design Standards. LOS criteria used to evaluate HLR is presented in **Table 5-1**.

Table 5-1 Allowable Hydraulic Loading Ratio (HLR)

Scenario	Flow Conditions	Acceptable HLR (Max Flow/Full Flow)
Existing Level of Development Scenario	Dry Weather	Less than 50%
Existing Level of Development Scenario	Wet Weather	See Allowable Surcharge Criteria Described Below
Future Buildout Scenarios	Wet Weather	Less than or equal to 100%

Residual Capacity

The residual capacity is the remaining capacity within a sewer when subjected to PWWF conditions. The residual capacity is mathematically defined as Manning's full pipe flow capacity minus the peak modeled flow. This performance indicator is useful for illustrating the relative remaining capacity throughout the collection system for use in evaluating future servicing strategies.

Depth to Diameter (d/D) Ratio

The peak sewer depth under PWWF conditions is an important factor in understanding capacity limitations of a collection system. The d/D ratio is the peak modeled depth of flow (d) divided by the pipe diameter (D). Typical LOS criteria allow a maximum d/D ratio of 0.70-0.85.

5.2.2 Allowable Surcharge Criteria

Freeboard in a manhole is defined as the distance between the rim elevation and the hydraulic grade line (HGL). Surcharging occurs when the HGL exceeds the pipe crown elevation. The maximum allowable surcharge in the gravity portion of the existing collection system is 1-foot. Manholes in the existing system must also maintain at least 8 feet of freeboard during a design storm event. No surcharging will be allowed in existing "saddle" type manholes or for new manholes proposed under future development scenarios. LOS criteria for allowable surcharge and freeboard is presented in **Table 5-2**.

Table 5-2 Allowable Surcharge Criteria

Scenario	LOS Criteria
Existing Manholes	• When the rim elevation is less than or equal to 8-feet above the pipe crown: No Surcharging Allowed • When the rim elevation is more than 8-feet above the pipe crown: A pipeline is hydraulic deficient if there is less than 8-feet of freeboard or the surcharging is greater than or equal to 1-foot above the pipe crown. Exception: When the manhole is a saddle type, no surcharging is allowed.
Future Manholes	No Surcharging Allowed

5.2.3 Velocity

Velocities within the collection system will be rendered in plan view. Typical LOS criteria defines an acceptable velocity range of 2 – 7 fps.

5.2.4 Pump Station Capacity

This result compares peak inflow to the reliable pumping capacity of the pump station to identify potential capacity constraints.

5.3 MODELED SCENARIOS

This Master Plan assessed system performance for the existing level of development scenario and the following projected growth scenarios for the City of Lincoln's wastewater collection system. Simulated scenarios are summarized in below:

5.3.1 Existing Level of Development:

Scenario 1 – Existing Dry Weather Flow Model: This modeled scenario simulates the existing collection system under dry weather flow conditions, calibrated to flow data from flow monitoring. DWF distributed in the model includes a large groundwater infiltration component and does not represent ADWF observed at the WWTRF during the dry season. The results of this simulation present a conservative evaluation of the existing collection system under typical dry weather conditions.

Scenario 2 – Existing Wet Weather Flow Model: This modeled scenario simulates flow in the existing collection system during a 10-year, 24-hour design storm event. This model was constructed using the calibrated wet weather flow model and applying a 10-year, 24-hour rainfall event with a Huff Distribution. The results of this simulation evaluate the existing collection system under PWWF conditions.

5.3.2 Future Development Scenarios

Scenario 3 – Buildout of the Existing Sewer-sheds: This modeled scenario is the existing wet weather flow model evaluated in Scenario 2 with the addition of flow from vacant parcels within the existing sewer-sheds. Vacant or entitled parcels were identified by the City of Lincoln. Sanitary flow from these parcels was approximated using methods described in **Chapter 3.0**. Sewer-shed unit hydrographs corresponding to the location of the infill have been applied to estimate PWWFs under design storm conditions. The results of this simulation represent PWWF in the collection system if all vacant parcels within the existing service area were to be developed.

Scenario 4 – Buildout of City Limits: This modeled scenario represents buildout of the existing service area, with the addition of flow from recently annexed Village 1 and Village 7. Sanitary flows from Villages 1 and 7 were approximated using the methods outlined in **Chapter 3.0**. PWWF from these Villages was approximated using a peaking factor of 2.3. The results of this simulation represent the maximum buildout flow through the existing collection system and the trunk extensions required to accommodate flow from Villages 1 and 7.

Scenario 5 – Buildout of the SOI: This modeled scenario represents full buildout of the City's SOI. It includes flow from all Villages, Special Use Districts (SUDs) and the additional spaces identified in **Chapter 3.0**. Sanitary flow and PWWF from Villages and SUDs were calculated as described for Villages 1 and 7 above. The results of this simulation represent an estimate of PWWF in the collection system at buildout of the City's General Plan area and the new trunk sewers needed to serve future development.

Scenario 6 – Buildout of the SOI, plus Regional Flow: This modeled scenario simulates flow from buildout of the City's General plan and flow from the regional flow entities. Regional wastewater flow estimates are presented in **Chapter 3.0.** The results of this simulation represent the approximate PWWF from all planning areas and the new trunk sewers needed to accommodate this flow. A summary of the modeled scenarios is provided in **Table 5-3**.

Table 5-3 Summary of Modeled Scenarios

Scenario	Description	Cumulative Planning Regions/ Regional Entities	Simulated DWF (MGD)	Simulated PWWF (MGD)
Scenario 1	Existing Dry Weather Flow	• Existing Developments, Including current SMD1 (DWF)	6.2 (1)	10.2
Scenario 2	Existing Wet Weather Flow	• Existing Developments, including SMD1 (WWF) (2)	6.2	47.2
Scenario 3	Buildout of Existing Sewer-sheds	• Infill Developments	9.9 (3)	55.0
Scenario 4	Buildout of City Limits	• Recently Annexed (Villages 1 & 7) • "Additional Spaces"	13.3	60.3
Scenario 5	Buildout of the SOI	• SUD-B/Village 5 • Village 2 • Village 3 • Village 4 • Village 6 • SUD-A • SUD-C	26.6	93.3
Scenario 6	Buildout of the SOI, plus Regional Contributors	• Bickford Ranch • City of Auburn	29.5	100.3

(1) ADWF observed at the WWTRF in 2017 = 4.0 MGD.

(2) Wet weather flow from SMD1 was equated to the peak capacity of the Mid-Western Placer Regional Pump Station, 14.7 MGD.

(3) DWF estimate includes additional ADWF contribution from SMD1.