



FINAL REPORT 2020 FACILITIES MASTER PLAN UPDATE



CITY OF LINCOLN, NE

BLACK & VEATCH PROJECT NO. 401472
FINAL REPORT • JULY 2020





Table of Contents

Executive Summary	ES-1
ES.1 Purpose and Study Area	ES-1
ES.2 Population	ES-3
ES.3 Water Capacity Requirements	ES-4
ES.3.1 Historical Water Usage	ES-5
ES.3.2 Water Demand Projections	ES-7
ES.4 Water Supply	ES-8
ES.5 Water Treatment	ES-10
ES.5.1 Water Quality Trends	ES-10
ES.6 Potential Future Regulations	ES-11
ES.6.1 Proposed Lead and Copper Rule Revisions	ES-11
ES.6.2 PFAS Action Plan and Regulatory Determination	ES-12
ES.6.3 Water Plant Expansion	ES-12
ES.7 Distribution System Facilities	ES-13
ES.7.1 Focus Areas	ES-13
ES.7.2 Distribution System Modeling	ES-13
ES.8 Distribution Water Quality	ES-14
ES.9 Recommended Improvements	ES-16
1.0 Introduction	1-1
1.1 Purpose	1-1
1.2 Scope	1-1
1.3 Climate Change Considerations	1-2
1.4 Acronyms and Abbreviations	1-2
2.0 Population	2-1
2.1 City of Lincoln Population	2-1
2.2 Population Distribution	2-3
2.2.1 Population by Service Level	2-3
3.0 Water Capacity Requirements	3-1
3.1 General	3-1
3.2 Historical Water Production and Usage	3-1
3.2.1 Ashland Pumpage	3-3
3.2.2 Plant Usage	3-5
3.2.3 Distribution System Usage	3-6
3.3 Historical Metered Sales	3-8
3.3.1 Historical System Metered Sales	3-8
3.3.2 Historic Metered Sales by Service Level	3-13
3.4 Water Demand Projections	3-16
3.4.1 Large Use/Industrial Demands	3-16

3.4.2	Climate Change Impact	3-16
3.4.3	Average Day Demand Projections.....	3-18
3.5	Water Usage Projections by Service Level.....	3-21
4.0	Supply	4-1
4.1	Water Rights	4-1
4.1.1	Nebraska’s Water Supply.....	4-1
4.1.2	Nebraska Water Law	4-3
4.1.3	Existing Surface Water Rights Held by the City of Lincoln for the Ashland Wellfield	4-3
4.2	Future Streamflow Evaluation	4-9
4.2.1	Modeling Scenarios	4-11
4.2.2	Modeling Results.....	4-11
4.2.3	Climate Change Impact	4-14
4.3	Supply Improvements.....	4-15
4.3.1	Aquifer Yield	4-15
4.3.2	MODFLOW Model Refinements	4-15
4.3.3	Sensitivity Analyses	4-15
4.3.4	Wellfield Expansion	4-16
5.0	Water Treatment.....	5-1
5.1	General	5-1
5.2	East Plant.....	5-1
5.2.1	Water Treatment.....	5-1
5.2.2	Water Supply	5-3
5.2.3	Source Water	5-3
5.2.4	Ozone Facilities.....	5-4
5.2.5	Filters	5-5
5.2.6	Clearwells & Reservoirs	5-7
5.2.7	Primary Disinfection.....	5-8
5.2.8	Secondary Disinfection	5-8
5.3	West Plant.....	5-8
5.3.1	Water Treatment.....	5-8
5.3.2	Water Supply	5-10
5.3.3	Aeration	5-10
5.3.4	Chlorine Contact Basins	5-10
5.3.5	Filters	5-11
5.3.6	Filter Clearwells.....	5-12
5.3.7	Transfer Pumps	5-12
5.3.8	North Reservoir	5-13
5.3.9	North High Service Pump Station.....	5-13
5.3.10	West Transmission Pump Station	5-13

5.4	Chemical Systems	5-13
5.4.1	Chlorine	5-13
5.4.2	Ammonia	5-15
5.4.3	Polymer	5-17
5.4.4	Fluoride	5-19
5.5	Raw Water Quality	5-20
5.5.1	East Plant Raw Water Quality Data	5-21
5.5.2	West Plant Raw Water Quality Data	5-23
5.6	Finished Water Quality	5-25
5.6.1	East Plant Finished Water Quality Data	5-25
5.6.2	West Plant Finished Water Quality Data	5-28
5.7	Water Quality Trends	5-31
5.7.1	Temperature and pH	5-31
5.7.2	Nitrate and Nitrite	5-33
5.7.3	Manganese	5-35
5.7.4	Arsenic	5-37
5.7.5	Atrazine	5-38
5.7.6	Total Organic Carbon	5-40
5.7.7	Biological Stability	5-41
5.7.8	Disinfectant Residual	5-43
5.8	Regulatory Summary	5-45
5.9	Existing Regulations	5-45
5.9.1	Surface Water Treatment Rule	5-45
5.9.2	Total Coliform Rule	5-47
5.9.3	Revised Total Coliform Rule	5-47
5.9.4	Interim Enhanced Surface Water Treatment Rule	5-48
5.9.5	Filter Backwash Recycle Rule	5-48
5.9.6	Long-Term 2 Enhanced Surface Water Treatment Rule	5-49
5.9.7	Stage 1 Disinfectant/Disinfection Byproduct Rule	5-49
5.9.8	Stage 2 Disinfectant/Disinfection Byproduct Rule	5-50
5.9.9	Arsenic Rule	5-51
5.9.10	Radionuclides Rule	5-51
5.9.11	Lead and Copper Rule	5-51
5.9.12	Lead-Free Materials Regulations	5-52
5.10	Ongoing Regulatory Determination Process	5-53
5.10.1	Drinking Water Candidate Contaminant List	5-53
5.10.2	Unregulated Contaminant Monitoring Rules	5-54
5.11	Potential Future Drinking Water Regulations	5-55
5.11.1	Proposed Lead and Copper Rule Revisions	5-55
5.11.2	Radon	5-56
5.11.3	Contaminants on the Regulatory Horizon	5-57

5.12	Water Treatment Plant Improvements, Expansion and Rehabilitation.....	5-61
5.12.1	East Plant Improvements for Arsenic Removal.....	5-61
5.12.2	Water Plant Expansion	5-63
5.12.3	Water Plant Rehabilitation.....	5-64
6.0	Distribution System Facilities and Analyses	6-1
6.1	High Service Pumping and Transmission	6-1
6.2	Service Levels	6-3
6.3	Pumping Stations and System Storage.....	6-4
6.3.1	Low Service Level	6-4
6.3.2	High Service Level.....	6-8
6.3.3	Belmont Service Level.....	6-10
6.3.4	Southeast Service Level.....	6-11
6.3.5	Cheney Service Level.....	6-12
6.3.6	Northwest Service Level	6-14
6.3.7	Pumping Capacity Summary	6-15
6.3.8	Storage Capacity Summary	6-16
6.4	Distribution System Evaluations	6-17
6.4.1	Pumping Capacity Evaluation	6-17
6.4.2	Storage Capacity Evaluation.....	6-18
6.4.3	Distribution System Modeling Evaluations and Model Updates	6-23
6.5	Focus Area Evaluations	6-26
6.5.1	North 56 th Street and I-80	6-26
6.5.2	Folsom and Old Cheney	6-33
6.5.3	27 th and Rokeby	6-35
6.6	Year 2020 Distribution System Modeling.....	6-37
6.7	Year 2032 Distribution System Modeling.....	6-43
6.8	Other Modeling and Desktop Evaluations FOR THE 12-Year CIP	6-49
6.8.1	Valve Replacement and Automation at 51 st Street PS	6-49
6.8.2	NW 12 th Street Pumping Station.....	6-49
6.8.3	Vine Street Pumping Station East - Add Pump No. 8 w/ AFD.....	6-49
6.8.4	Innovation Campus - Phase 1 - 16-inch Main.....	6-49
6.8.5	I-80 & 56th Street Pumping Station - Supply Main and PS and Belmont Loop	6-49
6.8.6	16-inch Main on NW 56th Street, "O" St. to Partridge Lane	6-49
6.8.7	Decommission Merrill Street Pumping Station	6-50
6.8.8	Rehabilitate Eddy Current Drive - Northeast #6	6-50
6.8.9	31st and Randolph Valve Vault Relocation to "A" street.....	6-50
6.8.10	Add 20.9 mgd WTP South Pumping Station Pump No. 13	6-50
6.8.11	Add AFDs at Pioneers Pumping Station.....	6-50
6.8.12	Pressure Monitoring Stations	6-51
6.8.13	Decommission South 56th Street PS.....	6-51

6.8.14	Northwest Reservoir (2 MG) and Pipeline	6-51
6.8.15	Belmont to Low PRV Station ("O" Street and NW 25th Street).....	6-52
6.8.16	Decommission NW 12th Street Pumping Station.....	6-52
6.8.17	Decommission Cheney Pumping Station.....	6-52
6.8.18	Yankee Hill Pumping Station - Add 6 mgd Pump.....	6-52
6.8.19	PRV Southeast SL to High SL - Vault near Southeast PS.....	6-52
6.8.20	Innovation Campus - Phase 2 - 12-inch Main.....	6-52
6.8.21	Adams Street Reservoir and Pipelines for HSL (5 MG)	6-52
6.8.22	54-inch Main from Northeast PS to 88th and Holdrege.....	6-52
7.0	Distribution System Water Quality	7-1
7.1	Disinfection Byproducts.....	7-1
7.1.1	Bromate.....	7-1
7.1.2	TTHMs and HAA5s	7-2
7.2	Lead and Copper.....	7-4
7.2.1	LCR Monitoring and Compliance.....	7-4
7.2.2	Lead Service Line Replacement Strategy	7-6
7.2.3	Identifying Lead Service Lines.....	7-6
7.2.4	LWS LSL Identification Program	7-7
7.2.5	Proposed Lead and Copper Rule Revisions.....	7-10
7.2.6	Funding for LSL Replacements.....	7-10
7.2.7	Examples of LSL Replacement Programs.....	7-11
7.2.8	LSL Replacement Plan Development.....	7-11
7.2.9	LSL Replacement Activities.....	7-12
7.3	Nitrification Water Quality Monitoring	7-13
7.3.1	TCR Monitoring Sites.....	7-13
7.3.2	Distribution Monitoring Sites	7-13
7.3.3	Distribution Water Quality Monitoring Map	7-14
7.4	Nitrification Overview	7-14
7.5	Nitrification Occurrence.....	7-15
7.5.1	Nitrification Management (2018 to present).....	7-25
7.6	Impacts of Distribution System Pipe Materials	7-28
7.7	Distribution System Water Age Modeling	7-30
7.7.1	Winter Operations	7-30
7.7.2	Water Age Modeling Scenario No. 1	7-32
7.7.3	Water Age Modeling Scenario No. 2	7-40
7.7.4	Modeled Water Age Relationship with Observed Water Quality	7-44
7.1.3	Yankee Hill "Influence Zone"	7-57
7.8	Distribution System Water Quality Improvement Alternatives	7-57
7.8.1	Water Quality Modeling Alternatives	7-57
7.8.2	Other Distribution Water Quality Improvement Alternatives	7-68

7.9	Distribution System Water Quality Summary & Recommendations.....	7-70
7.10	References.....	7-72
8.0	Recommended Improvements	8-1
8.1	General	8-1
8.2	Cost Estimates.....	8-1
8.2.1	Basis of Costs	8-2
8.2.2	Pipelines.....	8-2
8.2.3	Pumping.....	8-3
8.2.4	Storage.....	8-4
8.2.5	Pressure Reducing Valve Stations.....	8-4
8.2.6	Pressure Monitoring Stations	8-4
8.3	Recommended Phased Improvements	8-5
8.3.1	Phase I – Immediate Improvements (by Year 2026)	8-5
8.3.2	Phase II - Short-term Improvements (by Year 2032).....	8-10
8.3.3	Other Improvements – Long-Term.....	8-11
Appendix A.	Climate Change Assessment.....	A-1
Appendix B.	2020 Lincoln Wellfield Groundwater Modeling	B-1
Appendix C.	Transmission Main Condition Assessment.....	C-1
Appendix D.	Water Treatment Plant Condition Assessment.....	D-1

LIST OF TABLES

Table ES-1	Recommended Improvements – Schedule and Cost Summary	ES-16
Table ES-2	Recommended Fire Flow and Main Extension Improvements.....	ES-19
Table 2-1	City of Lincoln Population (Historical and Projected).....	2-2
Table 2-2	Historical Population by Service Level	2-4
Table 2-3	Existing and Projected Population by Service Level	2-5
Table 3-1	Ashland Well Field Pumpage and Seasonal Peak Production	3-4
Table 3-2	Plant Usage	3-5
Table 3-3	Historic Water Usage and Peaking Factors (PF)	3-7
Table 3-4	Historical Metered Sales	3-9
Table 3-5	AWWA Performance Indicator Typical Values.....	3-11
Table 3-6	Historical Per-Capita Usage	3-12
Table 3-7	Comparison of Per-capita usage derived from Metered Sales Breakdown	3-14
Table 3-8	Potential Future Large Use Demands.....	3-16
Table 3-9	Average Day Demand Design Criteria	3-18
Table 3-10	Maximum Day, Maximum Hour, and Seasonal Peak 90-day Peaking Factors	3-18
Table 3-11	Future Demand Projections.....	3-19
Table 3-12	Average Day Projections by Service Level by Class	3-22
Table 3-13	Planning Peaking Factors by Class and Service Level.....	3-23
Table 3-14	Projected Water Requirements by Service Level	3-24

Table 4-1	Junior Surface Water Diversion Rights Upstream of the City’s Wellfield	4-7
Table 4-2	2040 Planning Horizon Difference in Modeled Streamflows (cfs)	4-12
Table 4-3	2060 Planning Horizon Difference in Modeled Streamflows (cfs)	4-12
Table 4-4	2040/2060 Planning Horizon Chance of the Listed Low Flows Occurring At Least Once	4-14
Table 5-1	East Plant Horizontal Collector Well Rated Capacities	5-3
Table 5-2	Log Removal/Inactivation for Filtration and Disinfection Required by SWTR	5-3
Table 5-3	East Plant Ozone Contact Basin Design Parameters	5-4
Table 5-4	East Plant Ozone Generation Design Parameters	5-4
Table 5-5	East Plant LOX Storage Design Parameters	5-5
Table 5-6	East Plant Filter Design Parameters	5-6
Table 5-7	East Plant Filter Backwash Operations	5-6
Table 5-8	East Plant Wash Water Supply Tank Design Parameters	5-7
Table 5-9	East Plant Clearwell Design Parameters	5-7
Table 5-10	South Reservoir Design Parameters	5-8
Table 5-11	West Plant Aerator Design Parameters	5-10
Table 5-12	West Plant Chlorine Contact Basin Design Parameters	5-10
Table 5-13	West Plant Filter Design Parameters	5-11
Table 5-14	West Plant Filter Backwash Operations	5-11
Table 5-15	West Plant Wash Water Supply Tank Design Parameters	5-12
Table 5-16	Filter Clearwell Design Parameters	5-12
Table 5-17	Chlorine Storage & Feed System Design Parameters	5-14
Table 5-18	Chlorine Feed Points	5-15
Table 5-19	Ammonia Storage & Feed System Design Parameters	5-16
Table 5-20	Ammonia Feed Points	5-16
Table 5-21	Polymer Storage and Feed System Design Parameters	5-17
Table 5-22	Polymer Feed Points	5-19
Table 5-23	Fluoride Storage & Feed System Design Parameters	5-19
Table 5-24	Fluoride Feed Points	5-20
Table 5-25	East Plant Raw Water Quality Summary	5-21
Table 5-26	West Plant Raw Water Quality Summary	5-23
Table 5-27	East Plant Finished Water Quality Summary	5-25
Table 5-28	West Plant Finished Water Quality Summary	5-28
Table 5-29	Categorization of Low, Moderate and High Concentrations of AOC and BDOC	5-43
Table 5-30	Log Removal/Inactivation Credits and Requirements Under the 1989 SWTR	5-46
Table 5-31	Maximum Contaminant Levels for Disinfection Byproducts in the Stage 1 DBPR	5-49

Table 5-32	Maximum Residual Disinfectant Levels in the Stage 1 DBPR.....	5-50
Table 5-33	Percent TOC Removal Required by Enhanced Coagulation and Enhanced Softening in the Stage 1 DBPR.....	5-50
Table 5-34	Radionuclide Rule MCLs.....	5-51
Table 6-1	WTP High Service Pumps	6-1
Table 6-2	Service Levels	6-4
Table 6-3	Northeast Pumping Station.....	6-5
Table 6-4	51st Street Pumping Station.....	6-6
Table 6-5	“A” Street Reservoirs.....	6-6
Table 6-6	“A” Street Pumping Station	6-7
Table 6-7	Vine Street Pumping Stations	6-9
Table 6-8	South 56th Street Pumping Station	6-9
Table 6-9	Belmont Pumping Station.....	6-10
Table 6-10	Merrill Pumping Station.....	6-11
Table 6-11	Pioneers Pumping Station.....	6-11
Table 6-12	Southeast Pumping Station.....	6-12
Table 6-13	Yankee Hill Pumping Station.....	6-13
Table 6-14	Cheney Booster Pumping Station.....	6-13
Table 6-15	NW 12 th Street Booster Pumping Station.....	6-14
Table 6-16	Distribution System Pumping Capacity Summary	6-15
Table 6-17	Distribution System Floating Storage Capacity Summary	6-16
Table 6-18	Transmission Ground Storage Facilities	6-16
Table 6-19	Year 2020 Pumping Capacity Evaluation.....	6-17
Table 6-20	Year 2032 Pumping Capacity Evaluation.....	6-18
Table 6-21	Storage Evaluation 2020.....	6-19
Table 6-22	Storage Evaluation 2032.....	6-22
Table 6-23	Large Use/Industrial Demand Projections.....	6-27
Table 7-1	Maximum Contaminant Levels for Disinfection Byproducts.....	7-1
Table 7-2	Summer/Winter Operations, Ground Storage Alarm Levels.....	7-31
Table 8-1	Main Cost Utilized for Capital Improvement Program	8-3
Table 8-2	Recommended Improvements – Phase I and Phase II.....	8-13
Table 8-3	Immediate Fire Flow Improvements	8-17
Table 8-4	Distribution Main Extensions – Immediate	8-18
Table 8-5	Distribution Main Extensions - Phase I.....	8-20
Table 8-6	Distribution Main Extensions - Phase II	8-24

LIST OF FIGURES

Figure ES-1	Study Area and Priority Growth Areas	ES-2
Figure ES-2	City of Lincoln Historical and Projected Population	ES-3
Figure ES-3	Existing and Projected Population by Service Level	ES-4

Figure ES-4	Historical Water Use and Per Capita Usage	ES-6
Figure ES-5	Future Demand Projections and Well Field Pumpage Requirements.....	ES-7
Figure ES-6	90-Day Low-Flow Conditions for the Historical Data and Each Scenario for the 2040 Model Results for Recurrence Intervals Between 5 Years and 500 Years.....	ES-8
Figure ES-7	Future Supply Expansion.....	ES-9
Figure ES-8	Raw Water Arsenic Concentration from January 2017 through August 2019.....	ES-11
Figure 1-1	2040 Priority Growth Area	1-5
Figure 2-1	City of Lincoln Historical and Projected Population	2-3
Figure 2-2	Historical Population by Service Level	2-4
Figure 2-3	Existing and Projected Population by Service Level	2-5
Figure 2-4	Population Characteristics.....	2-6
Figure 3-1	Ashland Well Field Pumpage, Monthly Average 2010 - 2019	3-3
Figure 3-2	Historical Water Use and Per-Capita Usage	3-13
Figure 3-3	2018 Metered Usage Characteristics by Service Level.....	3-15
Figure 3-4	SP:AD Peaking Factors vs. PMDSI	3-17
Figure 3-5	Future Demand Projections and Well Field Pumpage Requirements.....	3-20
Figure 3-6	Average Day Demand by Service Level.....	3-21
Figure 4-1	The Lower Platte Basin Overview Screen in INSIGHT Gives A Summary Of The Basin's Characteristics and Projected Water Demands	4-2
Figure 4-2	The Lower Platte Basin Annual Water Supply for June-August in INSIGHT	4-2
Figure 4-3	Annual Total Demand Estimates for the Lower Platte Basin for the June- August Season in INSIGHT	4-3
Figure 4-4	Storage Permits Upstream of the City's Wellfield that are Junior to the City's Water Right	4-5
Figure 4-5	Permits to Divert Surface Water Upstream of the City's Wellfield that are Junior to the City's Water Right	4-6
Figure 4-6	Areal Extents of Regional Groundwater Models.....	4-10
Figure 4-7	90-Day Low-Flow Conditions for the Historical Data and Each Scenario for the 2040 Model Results for Recurrence Intervals Between 5 Years and 500 Years.....	4-13
Figure 4-8	90-Day Low-Flow Conditions for the Historical Data and Each Scenario for the 2060 Model Results for Recurrence Intervals Between 5 Years and 500 Years.....	4-14
Figure 4-9	Future Supply Expansion.....	4-16
Figure 5-1	East Plant Process Flow Diagram.....	5-2
Figure 5-2	West Plant Process Flow Diagram	5-9
Figure 5-3	Raw Water Temperature for Samples Collected from the East and West Plant from January 2014 to December 2018.....	5-31
Figure 5-4	Raw Water pH for Samples Collected from the East and West Plant from January 2014 to December 2018.....	5-32
Figure 5-5	Raw water nitrate concentration for samples collected from the East and West Plant from January 2014 through July 2019.....	5-33

Figure 5-6	Raw water nitrite concentration from samples collected from the East and West Plant from January 2014 through August 2019	5-34
Figure 5-7	Raw Water Manganese Concentration from the East and West Plant from January 2017 through August 2019.....	5-35
Figure 5-8	Finished Water Manganese Concentration from the East and West Plant from January to August 2019.....	5-36
Figure 5-9	Raw Water Arsenic Concentration from the East and West Plant from January 2017 through December 2018	5-37
Figure 5-10	Raw Water Atrazine Concentration from the East and West Plant from February 2013 through August 2018.....	5-39
Figure 5-11	East and West Plant Finished Water Atrazine Concentration from January 2014 to July 2019.....	5-40
Figure 5-12	East and West Plant Finished Water TOC Concentration from January 2014 to April 2019	5-41
Figure 5-13	East and West Plant Finished Water AOC Concentration from July 2004 to July 2009.....	5-42
Figure 5-14	East and West Plant Finished Water Total Chlorine Residual from January 2014 to January 2019.....	5-43
Figure 5-15	East Plant Finished Water Chloramine Speciation from January 2014 to August 2018	5-44
Figure 5-16	West Plant Finished Water Chloramine Speciation from January 2014 to January 2019.....	5-45
Figure 5-17	Future Treatment Expansion.....	5-62
Figure 6-1	Existing Transmission and Distribution System Schematic.....	6-2
Figure 6-2	Maximum Day Hourly Peaking Factors	6-23
Figure 6-3	Average Day Hourly Peaking Factors	6-24
Figure 6-4	Modeled Maximum Day Hourly Usage, 2020	6-24
Figure 6-5	Modeled Average Day Hourly Usage, 2020	6-25
Figure 6-6	Modeled Maximum Day Hourly Usage, 2032	6-25
Figure 6-7	2014 Master Plan Recommendations	6-26
Figure 6-8	I-80 and N 56 th Street Area Map	6-28
Figure 6-9	Booster Pump Station Alternative Location 1.....	6-29
Figure 6-10	Booster Pump Station Alternative Location 2.....	6-30
Figure 6-11	Airport Runway 16-Inch Main Crossing.....	6-32
Figure 6-12	Airport Runway Pipe Abandoned/Retired - Pressure Evaluation	6-32
Figure 6-13	Folsom and Old Cheney Development Area.....	6-34
Figure 6-14	27 th and Rokeby Existing and Future Pipes w/ Service Level Boundaries	6-35
Figure 6-15	27 th and Rokeby Potential Pressures.....	6-36
Figure 6-16	Belmont and Low Storage Levels (2020 MD EPS).....	6-38
Figure 6-17	“A” Street and High Storage Levels (2020 MD EPS)	6-38
Figure 6-18	Southeast and Cheney Storage Levels (2020 MD EPS)	6-39
Figure 6-19	51 st Street and Northeast Storage Levels (2020 MD EPS)	6-39
Figure 6-20	Year 2020 Maximum Day EPS Scenario Schematic	6-40

Figure 6-21	Year 2020 EPS Modeling Pressure Results	6-41
Figure 6-22	Belmont and Low Storage Levels (2032 MD EPS).....	6-43
Figure 6-23	“A” Street and High Storage Levels (2032 MD EPS)	6-44
Figure 6-24	Southeast and Cheney Storage Levels (2032 MD EPS)	6-44
Figure 6-25	51 st Street, Northeast, and the Northwest Storage Levels (2032 MD EPS).....	6-45
Figure 6-26	Year 2032 Maximum Day EPS Scenario Schematic	6-47
Figure 6-27	Year 2032 EPS Modeling Pressure Results	6-48
Figure 6-28	54-inch Main from Northeast PS to 88th and Holdrege Modeling Evaluation (Control Set Held Constant).....	6-53
Figure 6-29	2020 MD EPS Model Results – Northwest Service Level.....	6-54
Figure 6-30	2020 MD EPS Model Results – Belmont Service Level	6-55
Figure 6-31	2020 MD EPS Model Results – Low Service Level.....	6-56
Figure 6-32	2020 MD EPS Model Results – High Service Level	6-57
Figure 6-33	2020 MD EPS Model Results – Southeast Service Level	6-58
Figure 6-34	2020 MD EPS Model Results - Cheney Service Level	6-59
Figure 6-35	2020 MD EPS Model Pressures – Northwest Service Level.....	6-60
Figure 6-36	2020 MD EPS Model Pressures – Belmont Service Level	6-61
Figure 6-37	2020 MD EPS Model Pressures – Low Service Level.....	6-62
Figure 6-38	2020 MD EPS Model Pressures – High Service Level.....	6-63
Figure 6-39	2020 MD EPS Model Pressures – Southeast Service Level	6-64
Figure 6-40	2020 MD EPS Model Pressures – Cheney Service Level	6-65
Figure 6-41	2032 MD EPS Model Results – Northwest Service Level.....	6-66
Figure 6-42	2032 MD EPS Model Results – Belmont Service Level	6-67
Figure 6-43	2032 MD EPS Model Results – Low Service Level.....	6-68
Figure 6-44	2032 MD EPS Model Results – High Service Level	6-69
Figure 6-45	2032 MD EPS Model Results – Southeast Service Level	6-70
Figure 6-46	2032 MD EPS Model Results – Cheney Service Level.....	6-71
Figure 6-47	2032 MD EPS Model Pressures – Northwest Service Level.....	6-72
Figure 6-48	2032 MD EPS Model Pressures – Belmont Service Level	6-73
Figure 6-49	2032 MD EPS Model Pressures – Low Service Level.....	6-74
Figure 6-50	2032 MD EPS Model Pressures – High Service Level.....	6-75
Figure 6-51	2032 MD EPS Model Pressures – Southeast Service Level	6-76
Figure 6-52	2032 MD EPS Model Pressures – Cheney Service Level	6-77
Figure 7-1	Bromate Concentration and RAA at the East Plant Point of Entry from November 2014 to August 2018	7-2
Figure 7-2	TTHM Locational Running Annual Average from 2015 to 2018.....	7-3
Figure 7-3	HAA5 Locational Running Annual Average from 2015 to 2018.....	7-3
Figure 7-4	Historical LCR Compliance Monitoring for Lead	7-4
Figure 7-5	Lead LCR Compliance Data for 2013, 2016 and 2019	7-5
Figure 7-6	Copper LCR Compliance Data for 2013, 2016, and 2019	7-6
Figure 7-7	Diagram of LWS Service Line Connection to a Residence.....	7-8

Figure 7-8	Estimated LSLs or Galvanized Iron Service Lines in Lincoln's Distribution System (10/27/2016).....	7-9
Figure 7-9	Map of Distribution System Water Quality Monitoring Sites	7-14
Figure 7-10	Locations of D2, D5 and Belmont Water Quality Monitoring Sites	7-16
Figure 7-11	Total Chlorine Residual at Distribution System Monitoring Sites in the Belmont Service Level from January 2014 to January 2019.....	7-16
Figure 7-12	Nitrite Concentration at Distribution System Monitoring Sites in the Belmont Service Level from January 2014 to January 2019.....	7-17
Figure 7-13	Total Chlorine Residual Heat Map from April to November 2016	7-19
Figure 7-14	Total Chlorine Residual Heat Map from April to November 2017	7-20
Figure 7-15	Total Chlorine Residual Heat Map During Peak Nitrification Season from September to December 2016.....	7-21
Figure 7-16	Total Chlorine Residual Heat Map During Peak Nitrification Season from September to December 2017	7-22
Figure 7-17	Heat Map Illustrating the Change in Nitrite Concentration Throughout the Distribution System During Peak Nitrification Season from September to December 2017	7-23
Figure 7-18	Heat Map Illustrating the Change in Heterotrophic Plate Counts Throughout the Distribution System During Peak Nitrification Season from September to December 2017	7-24
Figure 7-19	Total Chlorine Residual Heat Map During Peak Nitrification Season from September to December 2018, demonstrating effectiveness of nitrification control measures.....	7-26
Figure 7-20	Heat Map Illustrating the Change in Nitrite Concentration Throughout the Distribution System from August to December 2018.....	7-27
Figure 7-21	Map Identifying Distribution System Infrastructure by Year of Installation and Pipe Material	7-29
Figure 7-22	Category Legend for Figure 7-23 through Figure 7-28.....	7-33
Figure 7-23	Northwest SL Water Age Scenario 1 (Average-Left, Maximum-Right).....	7-34
Figure 7-24	Belmont SL Water Age Scenario 1 (Average-Left, Maximum-Right).....	7-35
Figure 7-25	Low SL Water Age Scenario 1 (Average-Left, Maximum-Right).....	7-36
Figure 7-26	High SL Water Age Scenario 1 (Average-Left, Maximum-Right).....	7-37
Figure 7-27	Southeast SL Water Age Scenario 1 (Average-Left, Maximum-Right)	7-38
Figure 7-28	Cheney SL Water Age Scenario 1 (Average-Left, Maximum-Right)	7-39
Figure 7-29	Belmont/Northwest Average Water Age (Airpark o.o.s Left, NW 12 th o.os Right)	7-41
Figure 7-30	Belmont/Northwest Maximum Water Age (Airpark o.o.s Left, NW 12 th o.os Right)	7-42
Figure 7-31	Pioneers PS Influenced Area (Airpark o.o.s Left, NW 12 th o.o.s Right)	7-43
Figure 7-32	Overall System Modeled Water Age vs. Observed Chlorine Residual	7-46
Figure 7-33	Northwest/Belmont SL Modeled Water Age vs. Observed Chlorine Residual	7-47
Figure 7-34	Low SL Modeled Water Age vs. Observed Chlorine Residual	7-48
Figure 7-35	High SL Modeled Water Age vs. Observed Chlorine Residual	7-49

Figure 7-36	Southeast/Cheney SL Modeled Water Age vs. Observed Chlorine Residual	7-50
Figure 7-37	Overall System Modeled Water Age vs. Observed Nitrate Concentration.....	7-51
Figure 7-38	Overall System Modeled Water Age vs. Nitrite Concentration	7-52
Figure 7-39	Service Level Pipe Material by Volume.....	7-53
Figure 7-40	Service Level Pipe Material by Length	7-54
Figure 7-41	Service Level Pipe Age (Decade) by Volume	7-55
Figure 7-42	Service Level Pipe Age (Decade) by Length	7-56
Figure 7-43	Yankee Hill Source Influence vs. Southeast/Cheney Water Age	7-57
Figure 7-44	Average Water Age Comparison with Flushing – Belmont Service Level	7-60
Figure 7-45	Maximum Water Age Comparison with Flushing – Belmont Service Level.....	7-61
Figure 7-46	Average Water Age Comparison with Flushing – Northwest Service Level.....	7-62
Figure 7-47	Maximum Water Age Comparison with Flushing – Northwest Service Level	7-63
Figure 7-48	Average Water Age Comparison with Flushing – Southeast Service Level.....	7-64
Figure 7-49	Maximum Water Age Comparison with Flushing – Southeast Service Level.....	7-65
Figure 7-50	Average Water Age Comparison with Flushing – Cheney Service Level.....	7-66
Figure 7-51	Maximum Water Age Comparison with Flushing – Cheney Service Level.....	7-67
Figure 7-52	Process Schematic of UGSI Monochlor® Chloramine Booster System	7-68
Figure 8-1	Recommended Phased Improvements for the Distribution System	8-29