NI 43-101 Technical Report
Preliminary Feasibility Study

of the

Sevier Lake Playa
Sulphate of Potash Project
Millard County, Utah

prepared for

EPM Mining Ventures Inc.

Prepared by:

Michael D. S. Blois Pr. Eng. – CH2M HILL
Michael Hardy P.E. – Agapito Associates, Inc.
Scott Effner P.G. – Whetstone Associates, Inc.
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David Waite P.E. – CH2M HILL

Report Date: November 18, 2013

Effective Date: October 25, 2013

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Important Notice Regarding Forward-looking Information

This Preliminary Feasibility Study (PFS) contains "forward-looking information" within the meaning of applicable Canadian securities legislation. Forward-looking information includes, but is not limited to, statements related to activities, events, or developments that the authors or the Company expect or anticipate will or may occur in the future, including, without limitation, statements related to the authors' or the Company's economic analysis of the Project, mineral resource estimate, the permitting process, environmental assessments, business strategy, objectives and goals, and exploration of the Sevier Playa Project. Forward-looking information is often identified by the use of words such as "plans," "planning," "planned," "expects" or "looking forward," "does not expect," "continues," "scheduled," "estimates," "forecasts," "intends," "potential," "anticipates," "does not anticipate," or "belief," or describes a "goal," or variation of such words and phrases or state that certain actions, events or results "may," "could," "would," "might" or "will" be taken, occur or be achieved. Forward-looking information is based on a number of factors and assumptions made by the authors or the Company and considered reasonable at the time such information is provided. Forward-looking information involves known and unknown risks, uncertainties and other factors that may cause the actual results, performance, or achievements to be materially different from those expressed or implied by the forward-looking information. The PFS is, by definition, preliminary in nature and should be considered speculative. It is based on a process flow sheet that may change, which would impact all costs and estimates. Operating Costs for the Project were based on assumptions including future energy costs, natural gas costs, water costs, labour, and other variables that are likely to change. Capital Costs were based on a list of equipment thought to be necessary for production. SOP price forecasts were based on third-party estimates and management assumptions that may change due to market dynamics. The mineral resource estimates were based on assumptions outlined in the "Resource Estimate" section. Some figures were calculated using a factor to convert short tons to metric tonnes. Changes in estimated costs to acquire, construct, install, or operate the equipment, or changes in projected pricing, may adversely impact project economics. Among other factors, the Company's inability to complete further mineral resource and mineral reserve estimates, the inability to complete the Feasibility Study, the inability to obtain sufficient recharge, the inability to anticipate changes in brine volume or grade due to recharge or other factors, changes to the economic analysis, the failure to obtain necessary permits to explore and develop the Sevier Playa Project, environmental issues or delays, inability to successfully complete additional drilling at the Sevier Playa Project, factors disclosed in the Company's current Management's Discussion and Analysis, as well as information contained in other public disclosure documents available on SEDAR at http://www.sedar.com may adversely impact the Project. Although the authors have attempted to identify important factors that could cause actual actions, events, or results to differ materially from those described in the forward-looking information, there may be other factors that cause actions, events, or results not to be as anticipated, estimated, or intended. There can be no assurance that forward-looking information will prove to be accurate. The forward-looking information contained herein is presented for the purposes of assisting investors in understanding the Company's plan, objectives, and goals and may not be appropriate for other purposes. Accordingly, readers should not place undue reliance on forward-looking information. The authors or the Company do not undertake to update any forward-looking information, except in accordance with applicable securities laws.

MICHAEL D. S. BLOIS Pr. Eng., QP
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CERTIFICATE of AUTHOR

I, Michael D. S. Blois, do hereby certify that:

1. I am currently employed as Vice President: Mining, Water & Environment by CH2M HILL Engineers Inc. at: 9191South Jamaica Street, Englewood, Colorado 80112.

2. I am graduate of the Royal School of Mines, Imperial College, University of London with a Bachelor of Science (Engineering) Honours in Mineral Technology (1975); and a Master of Business Leadership from the University of South Africa (1989); and have practiced my profession continuously since 1976.

3. I am a member in good standing of the Mining and Metallurgical Society of America, member #01348QP.

4. I have worked as a process engineer for a total of 37 years since my graduation from university; as an employee of a major mining company, and several major engineering companies. I have worked in South Africa, Australia, South America, Canada and the United States. I have been involved with a number potash projects from the feasibility study stage through to the program management of a multi-billion dollar project in South America. I am the project sponsor for a number of potash expansion projects in New Mexico.

5. I have read the definition of "qualified person" set out in the National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

6. I am responsible for the preparation of Sections 1, 2, 3(part), 13, 17, 18, 19, 21(part), 22, 24(part), 25(part), 26(part), 27 and Appendix B of the report titled "NI 43-101 Technical Report Preliminary Feasibility Study of the Sevier Lake Playa Sulphate of Potash Project, Millard County, Utah" with an effective date of October 25, 2013 (the "Technical Report").

7. I conducted a visit to the Sevier Lake project site on June 25th, 2013.

8. As of the date of this certificate, to the best of my knowledge, information, and belief, the parts of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

9. I do not hold, nor do I expect to receive, any securities or any other interest in any corporate entity, private or public, with interests in the properties that are the subject of this report or in the properties themselves, nor do I have any business relationship with any such entity apart from a professional consulting relationship with the issuer, nor to the best of my knowledge do I have any interest in any securities of any corporate entity with property within a two (2) kilometer distance of any of the subject properties.

10. I am independent of EPM Mining Ventures Inc. according to the criteria stated in Section 1.5 of NI 43-101.

11. I previously contributed to the preparation of the technical report on the Sevier Lake project titled "NI 43-101 Technical Report Preliminary Economic Assessment, EPM Mining Ventures Inc., Sevier Dry Lake, Utah, United States" dated November 16th, 2012.

12. I have read NI 43-101 and Form NI 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form.

13. I consent to the filing of the Technical Report with any stock exchanges or other regulatory authority and any publication by them, including electronic publication in the public company files on the websites accessible by the public, of the Technical Report.

Dated this 25th, day of October 2013

Signature of Qualified Person

10/25/2013

Michael DS Blois
01348QP
Mining & Metallurgical Society of America

MICHAEL D. S. BLOIS Pr. Eng., QP
Vice President: Mining, Water & Environment
CH2M HILL Engineers Inc.

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MICHAEL P. HARDY, P.E., P.Eng., QP
Principal
Agapito Associates, Inc.
715 Horizon Drive, Suite 340
Grand Junction, Colorado 81506

CERTIFICATE of AUTHOR

I, Michael P. Hardy, do hereby certify that:

1. I am currently employed as Principal, Agapito Associates, Inc. located at 715 Horizon Drive, Suite 340, Grand Junction, Colorado 81506.

2. I am a graduate with a degree in Civil Engineering from University of Adelaide, Australia, in 1969. I completed my Doctor of Philosophy in GeoEngineering at the University of Minnesota in 1973. I have practiced my profession since 1974.

3. I am and have been since 1976 a Registered Professional Engineer in the State of Colorado (Number 13857). I am a Registered Professional Engineer in the State of Texas (Number 98760). I have a temporary registration as a Professional Engineer with the Association of Professional Engineers and Geoscientists of Saskatchewan. I am a Registered Member of the Society for Mining, Metallurgy and Exploration (Member Number 1328850) and the American Society of Civil Engineers (Member Number 237352).

4. As a consulting engineer, I have been involved with potash exploration, solution mining pilot testing, solution mining engineering studies including feasibility studies, and resource and reserve estimation since 1999. Tasks include the investigation of the feasibility of commercial recovery of potash from bedded potash and/or halite deposits in North and South America, Kazakhstan and Africa; those studies specifically evaluated the technical feasibility of mining potash deposits using solution mining and/or conventional dry mining techniques. Specific activities have included development of pilot testing programs, mine layout, assessment of the geologic parameters impacting solution mining, evaluation of drill-hole data, 3D seismic data to support estimation of Measured, Indicated and Inferred Resources and, where appropriate, Mineral Reserves. As a consulting engineer, I have provided services over the past 18 years to several solution mining projects in industrial minerals such as salt (halite), trona, and nahcolite. These services have ranged from scoping to feasibility studies, geologic characterization, pilot test design and interpretation, resource and reserve estimation, cavern layouts, well completion design, and subsidence estimation and monitoring.

5. I have read the definition of "qualified person" set out in National Instruments 43-101 Standards of Disclosure for Mineral Projects ("NI 43-101") and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

6. I am responsible for the preparation of Sections 15 and 16 and parts of Sections 1, 3, 21, 24, 26 and 27 of the report titled "NI 43-101 Technical Report Preliminary Feasibility Study of the Sevier Lake Playa Sulphate of Potash Project, Millard County, Utah" with an effective date of October 25, 2013 (the "Technical Report").

7. I conducted a visit to the Sevier Lake project site on December 11th, 2012.

8. As of the date of this certificate, to the best of my knowledge, information, and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

9. I do not hold, nor do I expect to receive, any securities or any other interest in any corporate entity, private or public, with interests in the properties that are the subject of this report or in the properties themselves, nor do I have any business relationship with any such entity apart from a professional consulting relationship with the issuer, nor to the best of my knowledge do I have any interest in any securities of any corporate entity with property within a two (2) kilometer distance of any of the subject properties.

10. I am independent of EPM Mining Ventures Inc. according to the criteria stated in Section 1.5 of NI 43-101.

11. I have read NI 43-101 and Form NI 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form.

12. I consent to the filing of the Technical Report with any stock exchanges or other regulatory authority and any publication by them, including electronic publication in the public company files on the websites accessible by the public, of the Technical Report.

Dated this 25th, day of October 2013

Signature of Qualified Person

COLORADO REGISTERED
MICHAEL PETER HARDY
13857
PROFESSIONAL ENGINEER

MICHAEL P. HARDY, P.E., P.Eng., QP
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Vice President / Principal Hydrogeologist
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CERTIFICATE of AUTHOR

I, Scott Effner do hereby certify that:

1. I am currently employed as Vice President / Principal Hydrogeologist for Whetstone Associates, Inc. at 104 W. Ruby Avenue, Gunnison, Colorado 81230.

2. I am a graduate of Western State College, Gunnison, Colorado with a Bachelor of Arts degree (Geology), and University of Idaho, Moscow Idaho with a Master of Science degree (Geology) and have practiced my profession continuously since 1989.

3. I am a registered member in good standing of the Society for Mining Metallurgy and Exploration (member #4193144RM).

4. I am a Professional Geologist registered in the states of Idaho (registration # 1077) and Wyoming (registration # PG-3434) by the National Association of State Boards of Geology (ASBOG).

5. I have worked as a hydrogeologist / geochemist specializing in mining hydrology and groundwater modeling for a total of 20 years starting in 1993, and as an exploration geologist for 4 years prior starting in 1989. My professional experience includes hydrogeologic characterization and numerical modeling of groundwater flow and solute transport for mining projects in the western United States, Latin America, Africa, and Indonesia. These models and characterization studies have been prepared to support mining feasibility studies, dewatering designs for open pit and underground mines, permit applications, water supply analyses, and mine closure studies.

6. I have read the definition of "qualified person" set out in the National Instruments 43-101 Standards for Disclosure for Mineral Projects (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

7. I am responsible for the preparation of Sections 16.3.5, 26, 27 and Appendix A of the report titled "NI 43-101 Technical Report Preliminary Feasibility Study of the Sevier Lake Playa Sulphate of Potash Project, Millard County, Utah" with an effective date of October 25, 2013 (the "Technical Report").

8. That I did not conduct a visit to the Sevier Lake project site since it was deemed not necessary for the purposes of conducting numerical modeling of groundwater.

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9. As of the date of this certificate, to the best of my knowledge, information, and belief, the Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

10. I do not hold, nor do I expect to receive, any securities or any other interest in any corporate entity, private or public, with interests in the properties that are the subject of this report or in the properties themselves, nor do I have any business relationship with any such entity apart from a professional consulting relationship with the issuer, nor to the best of my knowledge do I have any interest in any securities of any corporate entity with property within a two (2) kilometer distance of any of the subject properties.

11. I am independent of EPM Mining Ventures Inc. according to the criteria stated in Section 1.5 of NI 43-101.

12. I did not previously contribute to the preparation of the technical report on the Sevier Lake project titled "NI 43-101 Technical Report Preliminary Economic Assessment, EPM Mining Ventures Inc., Sevier Dry Lake, Utah, United States" dated November 16th, 2012.

13. I have read NI 43-101 and Form NI 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form.

14. I consent to the filing of the Technical Report with any stock exchanges or other regulatory authority and any publication by them, including electronic publication in the public company files on the websites accessible by the public, of the Technical Report.

Dated this 25th, day of October 2013

Signature of Qualified Person

____

SCOTT EFFNER P.G.
Vice President / Principal Hydrogeologist
Whetstone Associates, Inc.

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LAWRENCE D. HENCHEL P.Geo., PG
Vice President Geologic Services
Norwest Corporation
136 East South Temple, 12th Floor
Salt Lake City, Utah 84111
Telephone: 801-539-0044 Facsimile: 801-539-0055 Email: lhenchel@norwestcorp.com

CERTIFICATE OF AUTHOR

I, Lawrence D. Henchel do hereby certify that:

1. I am currently employed as Vice President Geologic Services by Norwest Corporation at 136 East South Temple, 12th Floor, Salt Lake City, Utah 84111.

2. I graduated with a Bachelor of Science Degree in Geology from Saint Lawrence University, Canton, NY, USA in 1978.

3. I am a licensed Professional Geoscientist in the province of Alberta, Canada, #159013. I am a licensed Professional Geologist in the State of Utah, #6087593-2250 and I am a Registered Member of The Society for Mining, Metallurgy and Exploration, Inc., #4150015RM.

4. I have worked as a geologist for a total of thirty years since my graduation from university, both for mining and exploration companies and as a consultant specializing in coal and industrial minerals. I have worked with industrial minerals such as potash, trona, nahcolite, phosphate and gypsum over the past 20 years of my career in the United States, Mongolia, Africa and the Middle East. My experience with potash includes exploration, geological modeling and resource estimation for bedded deposits, SOP from alunite alteration and from mineral brines.

5. I have read the definition of "qualified person" set out in National Instrument 43-101 Standards of Disclosure for Mineral Projects ("NI 43-101") and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

6. I am responsible for the preparation of Sections 4 through 12, 14, 23 and 27 of the report titled "NI 43-101 Technical Report Prefeasibility Study for the Sevier Playa Project, Millard County, Utah", dated effective October 25, 2013 (the "Technical Report").

7. I conducted a visit to the Sevier Lake Playa project site on July 18th, 2013. Prior visits were conducted on March 25, 2010 and on August 1, 2011.

8. As of the date of this certificate, to the best of my knowledge, information and belief, the

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parts of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

9. I am independent of EPM Mining Ventures Inc., according to the criteria stated in Section 1.5 of NI 43-101.

10. I previously contributed to the preparation of three technical reports on the Sevier Lake Playa project which were titled: (1) “NI 43-101 Technical Report Preliminary Economic Assessment, EPM Mining Ventures Inc., Sevier Dry Lake, Utah, United States” dated November 16, 2012; (2) “Technical Report, Mineral Brine Resources of the Sevier Lake Playa, Millard County, Utah” dated May 31, 2012; and (3) “Technical Report, Sevier Lake Property, Millard County, Utah” dated May 20, 2011.

12. I have read NI 43-101 and Form NI 43-101F1, and the portions of the Technical Report for which I am responsible have been prepared in compliance with that instrument and form.

Dated this 25th, day of October 2013

Signature of Qualified Person

“ORIGINAL SIGNED AND SEALED BY AUTHOR”

LAWRENCE D. HENCHEL P.Geo., PG
Vice President Geologic Services
Norwest Corporation

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DAVID E. WAITE P.E., QP
CH2M HILL Engineers Inc.
215 South State Street, Suite 1000,
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Telephone: 801-350-5272 Facsimile: 801-355-2301 e-mail: david.waite@ch2m.com

CERTIFICATE of AUTHOR

I, David E. Waite, do hereby certify that:

1. I am currently employed as Senior Engineer by CH2M HILL Engineers Inc. at: 215 South State Street, Suite 1000, Salt Lake City, Utah 84111.

2. I am a graduate of Utah State University, Bachelor of Science in Civil Engineering (Cum Laude) and have practiced my profession continuously since 1993.

3. I have worked as a civil and environmental engineer for a total of 20 years since my graduation from university as an employee of several major engineering companies.

4. I have read the definition of “qualified person” set out in National Instrument 43-101 Standards of Disclosure for Mineral Projects (“NI 43-101”) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a “qualified person” for the purposes of NI 43-101.

5. I am responsible for the preparation of Section 20 and Section 27 of the report titled “NI 43-101 Technical Report Preliminary Feasibility Study of the Sevier Lake Playa Sulphate of Potash Project, Millard County, Utah” with an effective date of October 25, 2013 (the “Technical Report”).

6. I conducted a visit to the Sevier Lake project site on March 18th, 2013.

7. As of the date of this certificate, to the best of my knowledge, information, and belief, the parts of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

8. I do not hold, nor do I expect to receive, any securities or any other interest in any corporate entity, private or public, with interests in the properties that are the subject of this report or in the properties themselves, nor do I have any business relationship with any such entity apart from a professional consulting relationship with the issuer, nor to the best of my knowledge do I have any interest in any securities of any corporate entity with property within a two (2) kilometer distance of any of the subject properties.

9. I am independent of EPM Mining Ventures Inc. according to the criteria stated in Section 1.5 of NI 43-101.

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10. I previously contributed to the preparation of the technical report on the Sevier Lake project titled "NI 43-101 Technical Report Preliminary Economic Assessment, EPM Mining Ventures Inc., Sevier Dry Lake, Utah, United States" dated November 16th, 2012.

11. I have read NI 43-101 and Form NI 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form.

12. I consent to the filing of the Technical Report with any stock exchanges or other regulatory authority and any publication by them, including electronic publication in the public company files on the websites accessible by the public, of the Technical Report.

Dated this 25th, day of October 2013

Signature of Qualified Person

DAVID E. WAITE P.E., QP
Senior Engineer
CH2M HILL Engineers Inc.

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Contents

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Figures

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Abbreviations and Acronyms

2D	two-dimensional
3D	three-dimensional
3DBM	Geological model using Mine Sight® 3D block modeling software
°C	degree(s) Celsius
°F	degree(s) Fahrenheit
AAI	Agapito Associates, Inc.
AASHTO	American Association of State Highway and Transportation Officials
ac-ft/yr	acre-foot (feet) per year
AGRC	Automated Geographic Reference Center
ASTM	American Society of Testing and Materials
AWAL	American West Analytical Laboratory
bgs	below ground surface
BLM	U.S. Bureau of Land Management
CapEx	capital expenditure
CFR	Code of Federal Regulations
cfs	cubic foot (feet) per second
CH2M HILL	CH2M HILL Engineers, Inc.
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
cm	centimeter(s)
COC	chain-of-custody
Compass	Compass Minerals
CPMC	Crystal Peak Minerals Corporation
CRU	CRU International Ltd.
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DOGM	Utah Division of Oil, Gas, and Mining
DSB	DSB International
EA	Environmental Assessment
EIS	Environmental Impact Statement
Emerald Peak	Emerald Peak Minerals
EPM	EPM Mining Ventures Inc.
FEIS	Final Environmental Impact Statement
FOB	free on board
FONSI	Finding of No Significant Impact
ft	foot (feet)
ft^3	cubic foot (feet)

ft^3/d	cubic foot (feet) per day
ft^3/s	cubic foot (feet) per second
ft^3/yr	cubic foot (feet) per year
G&A	general and administrative
g/cm^3	gram(s) per cubic centimeter
g/L	gram(s) per liter
gal	gallon(s)
gpm	gallon(s) per minute
GPS	global positioning system
GSL	Great Salt Lake Minerals Corporation
ha	hectare(s)
Hazen	Hazen Research, Inc.
ICP	inductively coupled plasma
ICP-OES	inductively coupled plasma-optical emission spectroscopy
IDs	identifications
IGES	Intermountain GeoEnvironmental Services Inc.
IBLA	Interior Board of Land Appeals
in	inch (inches)
Intrepid	Intrepid Potash Inc.
IRR	internal rate of return
lb(s)	pound(s)
lb/ft^3	pound(s) per cubic foot
lb/in^2	pound(s) per square inch
K+S	K+S Kali
kg	kilogram(s)
kg/cm^2	kilogram(s) per square centimeter
km	kilometer(s)
km^2	square kilometer(s)
kV	kilovolt(s)
kW-hr	kilowatt-hour(s)
L	liter(s)
LoM	life of mine
L/min	liter(s) per minute
L/s	liter(s) per second
LRZ	Lower Resource Zone
LUMA	LUMA Resources LLC
m	meter(s)
m^3	cubic meter(s)

m^3/d	cubic meter(s) per day
m^3/s	cubic meter(s) per second
m^3/yr	cubic meter(s) per year
mg/L	milligram(s) per liter
mi	mile(s)
mi^2	square mile(s)
min	minute
mL	milliliter(s)
mL/min	milliliter(s) per minute
MBtu	million British thermal unit(s)
MS/MSD	matrix spike/matrix spike duplicate
MSL	mean sea level
Mt	million metric tonne(s)
Mton	million U.S. short ton(s)
MVR	mechanical vapor recompression
NELAC	National Environmental Laboratory Accreditation Council
NELAP	National Environmental LaboratoryAccreditation Program
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NI	National Instruments
NOI	Notice of Intent
Norwest	Norwest Corporation
NPDES	National Pollutant Discharge Elimination System
NPK	nitrogen, phosphorus, and potassium
NPV	net present value
oz	ounce(s)
P&IDs	piping and instrumentation diagrams
Parthenon	Parthenon Group
PEA	Preliminary Economic Assessment
Peak Minerals	Peak Minerals Inc.
PFS	Preliminary Feasibility Study
Project	Sevier Lake Playa Potash Project
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QC	quality control
QPs	qualified persons

RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
Salada	Salada Minerals LLC
SDIC	SDIC Luobupo
SDRI	steel double-ring infiltrometer
SEDAR	System for Electronic Document Analysis and Retrieval
SG	specific gravity
SITLA	Utah School and Institutional Trust Lands Administration
SQM	Sociedad Quimica y Minera
SR	State Route
SRC	Saskatchewan Research Council
Swenson	Swenson Technology, Inc.
SWPPP	Stormwater Pollution Prevention Plan
Technical Report	NI 43-101 Preliminary Feasibility Technical Report
ton	U.S. Customary Ton
tonne or t	metric tonne(s)
TDS	total dissolved solids
tpy	tonne(s) per year
UAC	Utah Administrative Code
UDAQ	Utah Division of Air Quality
UN FAO	United Nations Food and Agricultural Organization
UPDES	Utah Pollutant Discharge Elimination System
UPRR	Union Pacific Railroad
URZ	Upper Resource Zone
U.S.	United States
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
Whetstone	Whetstone Associates, Inc.
Wt%	weight percent
XRD	X-ray diffraction

Minerals, Formulas, Alternative Formulas, and Alternative Names

Mineral	Formula	Alternative Formula	Alternate Name
Anhydrite	$CaSO_4$		
Astrakanite	Na_2SO_4-$MgSO_4$-$4H_2O$	$Na_2Mg(SO_4)_2$-$4H_2O$	
Bischofite	$MgCl_2$-$6H_2O$		
Bitterns	$MgCl_2$ or $MgSO_4$		
Borates	BO_3 or BO_4		
Boron	B_2O_3		
Bromine	Br_2		
Calcite	$CaCO_3$		
Calcium	Ca		
Carnallite	$KMgCl_3$-$6H_2O$		
Chloride	Cl		
Epsomite	$MgSO_4$-$7H_2O$		
Glauberite	Na_2SO_4-$CaSO_4$	$Na_2Ca(SO_4)_2$	
Gypsum	$CaSO_4$-$2H_2O$		
Halite	NaCl		
Hexahydrite	$MgSO_4$-$6H_2O$		
Kainite	$MgSO_4$-KCl-$34H_2O$	$KMgSO_4Cl$-$3H_2O$	
Korshunovskite	$Mg_2(OH)_3Cl$-$4H_2O$		
Leonite	K_2SO_4-$MgSO_4$-$4H_2O$	$K_2Mg(SO_4)_2$-$4H_2O$	
Lithium	Li		
Magnesium	Mg		
Magnesium chloride	$MgCl_2$		
Magnesium oxide	MgO		
Magnesium sulphate	$MgSO_4$		
Pentahydrite	$MgSO_4$-$5H_2O$		
Picromerite (Schoenite)	K_2SO_4-$MgSO_4$-$6H_2O$	$K_2Mg(SO_4)_2$-$6H_2O$	
Potassium	K		
Potassium oxide	K_2O		
Potassium Sulphate	K_2SO_4		Sulphate of potash (SOP), potash
Potassium magnesium sulphate	K_2SO_4-$Mg_2(SO_4)_2$	$K_2Mg_2[SO_4]_3$	Sulphate of potassium magnesium (SOPM)
Potassium nitrate	KNO_3		Nitrate of potassium (NOP)
Schoenite (Picromerite)	K_2SO_4-$MgSO_4$-$6H_2O$	$K_2Mg(SO_4)_2$-$6H_2O$	
Sodium	Na		
Starkeyite (Cranswickite)	$MgSO_4 \cdot 4H_2O$		
Sulphates	SO_4		
Sylvite (Potassium chloride)	KCl		Potash or muriate of potash (MOP)
Thenardite	Na_2SO_4		Salt cake
Uranium	U_3O_8		
Water	H_2O		

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Summary

EPM Mining Ventures Inc. (EPM) commissioned CH2M HILL Engineers, Inc. (CH2M HILL), Agapito Associates, Inc. (AAI), Whetstone Associates, Inc. (Whetstone), and Norwest Corporation (Norwest) to prepare a Preliminary Feasibility Study (PFS) for its Sevier Lake Playa Potash Project (Project). This NI 43-101 Preliminary Feasibility Technical Report (Technical Report) summarizes the results of the PFS in accordance with National Instruments (NI) 43-101 Standards for Disclosure for Mineral Projects (NI 43-101).

EPM is a corporation domiciled in the Yukon Territory, Canada, with headquarters in Salt Lake City, Utah. Its common shares trade on the TSX Venture Exchange under the ticker symbol 'EPK' and also trade on the OTCQX International under the ticker symbol 'EPKMF.' The corporation operates the mineral development project through its indirect wholly owned subsidiary Peak Minerals Inc. (Peak Minerals) and through Emerald Peak Minerals LLC (Emerald Peak), of which Peak Minerals holds a 40 percent membership interest.

1.1 Introduction

The Project would be designed to produce approximately 300,000 tonnes per year (tpy) (330,693 tons/yr) of potash in the form of potassium sulphate (K_2SO_4) and other related minerals. Brine, extracted from lakebed sediments, would be concentrated in ponds by solar evaporation. The potassium-rich salts precipitated in the final ponds would be harvested and processed in a modern crystallization plant to produce saleable sulphate of potassium (SOP) and related products.

1.2 Property Description and Location

The Sevier Lake Playa property is located in southwestern Utah in the central portion of Millard County and is defined by the geographical boundaries of the Sevier Dry Lake centered approximately at latitude 38°57'59.88" N and longitude 113°07'4.33" W, or at 4313105N, 314505E using Universal Transverse Mercator (UTM) World Geodetic System 1984 (WGS84) coordinates.

The property is situated approximately 225 kilometers (km) (140 miles) southwest of Salt Lake City, Utah generally between the towns of Delta, Utah, 48 km (30 miles) to the northeast, and Milford, Utah, 40 km (25 miles) to the south-southeast. The lakebed covers an area of approximately 52,609 hectares (ha) (130,000 acres) and is approximately 42 km (26 miles) long by an average of 12.5 km (8 miles) wide.

A total of three entities control the potash leases that compose the Project. EPM controls, has financial investments in, or has entered into agreements with each of these entities. Table 1-1 summarizes the relationship of these entities to EPM, the dates of their lease acquisition, and the extent of their interests.

Leases held by Peak Minerals and LUMA Resources LLC (LUMA) were awarded by the United States (U.S.) Bureau of Land Management (BLM); those held by Emerald Peak were awarded by the Utah School and Institutional Trust Lands Administration (SITLA).

TABLE 1-1
Summary and General Description of Sevier Lake Leases

Leaseholder	Peak Minerals	Emerald Peak	LUMA
Relationship to EPM	Indirect wholly owned subsidiary	Peak Minerals holds a 40% membership interest	Contractual
Contractual agreements	100% owned via Peak Minerals Canada Ltd	40% membership interest owned by Peak Minerals with Commercial Services Agreement for leasehold operations	Cooperative Development Agreement for leasehold operations
Acres held	38,769 ha (95,801.76 acres)	2,593.83 ha (6,409.48 acres)	8,907.03 ha (22,009.97 acres)
Dates leases secured	April 5, 2011	September 1, 2008	April 5, 2011
Lease descriptions	See Table 4-2	See Table 4-3	See Table 4-4

1.3 Accessibility, Climate, Local Resources, Infrastructure, and Physiography

Access is primarily by vehicle from Delta, Utah, along U.S. Highway 6 to the northern edge of the Sevier Playa. The southern edge of the Project can be accessed by turning west from State Route (SR) 257 at the Black Rock railroad siding on secondary improved gravel roads. Numerous unimproved roads and trails suitable for 4x4 vehicles lead to the Project area from north-south routes along the edge of the playa.

The area is semi-arid with little precipitation. Low brush and sage exist on the margins while the playa surface itself is devoid of vegetation due to periodic flooding and the resulting salt crust has formed on the surface from the evaporation of mineral brine.

The nearby towns of Delta and Milford are small material supply centers and sources of local labour. Milford's population in the 2010 census was 1,420 and Delta's was 5,018. Both towns are on the Union Pacific Railroad (UPRR) line connecting Salt Lake City and Las Vegas. The proximity of the railroad and the Black Rock siding is attractive from a market access standpoint.

EPM controls sufficient property for all planned infrastructure, including evaporation ponds, brine recovery, and processing facilities. Corridors for power and natural gas lines would be on federal land and EPM is in the process of permitting rights-of-way for these. Expansion of the federal lease area around the edge of the playa may be required to improve perimeter access. This expansion would be undertaken once a final project decision is made. Access to power, natural gas, and water (H_2O) are all within a reasonable distance from the Project.

The property has undergone limited development with no known mining or commercial activity having taken place to date. Largely in an undisturbed natural state, the property had no permanent dwellings or structures until recent construction of a warehouse and storage area near the southern end of the playa by EPM. Two completed operational water supply wells, managed by BLM for stock use, are located just off of the playa with small storage tanks at the wellheads.

The property encompasses the Sevier Lake Playa located in western Utah's Sevier Desert. The playa is bounded on the east by the Cricket Mountains and on the west by the House Range. The San Francisco Mountains lie to the south of the playa and the Wah Wah Mountains to the southwest with the Wah Wah valley in between. The playa covers an area of approximately 52,609 ha (130,000 acres) at an altitude of about 1,376 meters (m) (4,514 feet [ft]) above mean sea level (MSL). The mountains east and west of the Sevier Lake Playa are at an altitude of about 2,438 m (8,000 ft) above MSL.

1.4 History

In the 1970s, Crystal Peak Minerals Corporation (CPMC) assembled a 53,823-ha (133,000-acre) lease-holding position encompassing the entire surface of Sevier Lake Playa, including the current Project area. It then embarked on a program to test the composition of the brine and sediments, thickness of salt crust, and to characterize the mineralogy and brine content of lakebed sediments. Weather stations were established to measure climatic conditions and Class A evaporation pans were erected to determine fresh water evaporation rates. Small-scale evaporation ponds were constructed on the floor of the playa to determine brine evaporation rates and to study the phase chemistry of evaporating brine and precipitated salts.

Interior dikes for a solar evaporation pond system were constructed, a north-trending brine collection canal was dredged, and roads and a campsite were constructed. A solar evaporation pond system was completed in 1987 and more than 1 million tons of salt were precipitated from the brine in the ponds to create permanent salt floors of sufficient thickness to support salt-harvesting equipment. Salt and high-magnesium chloride ($MgCl_2$) brine were produced in 1989 and 1990 and test ponds operated to produce low-grade potash salts.

Funding for the project was terminated with the death of Mr. W.D. Haden, the project's financier. In May 1993, representatives of CPMC filed the papers for "Relinquishments on Federal Potassium Leases." After CPMC performed the required reclamation work, their Sevier Lake Project was abandoned.

In 1997, Salada Minerals LLC (Salada) assembled a collection of federal sodium leases covering the south end of the playa. Salada also obtained five separate sections of potassium leases from SITLA. Salada's leaseholds went through the Environmental Assessment (EA) process culminating in a Finding of No Significant Impact (FONSI) decision by BLM issued in June 1997. Shortly thereafter, it is EPM's understanding that Salada's lease holdings were relinquished due to financial constraints prior to Salada performing any exploration or mining.

In September 2008, Emerald Peak acquired five SITLA leases. EPM obtained an interest in Emerald Peak and acquired 48 BLM potassium leases by competitive bid in April 2011. LUMA acquired 11 BLM potassium leases on that same date and entered into a Cooperative Development Agreement with Peak Minerals on April 5, 2011, bringing the total acreage under direct or indirect control by EPM to about 50,181 ha (124,000 acres).

1.4 Geological Setting and Mineralization

The property is located within the Basin and Range physiographic province. The ancestral Sevier Lake was formed within one of many north-trending grabens formed by the Basin and Range orogeny, which occurred in Miocene time. The north-trending mountains surrounding Sevier Lake Playa are remnant, up-thrown horst blocks adjacent to down-thrown grabens occupied by the present-day playa. During the Pleistocene period, the property was largely submerged by Lake Bonneville. The gradual receding of Lake Bonneville, followed by smaller Lake Gunnison and, ultimately, Sevier Lake, resulted in the accumulation of unconsolidated clay and marl in the down-thrown graben.

The Sevier Lake Playa is a terminal hydrologic system meaning that all surface water within the Sevier Lake Playa watersheds terminates at the playa and there is no exterior drainage from it. The accumulation of minerals eroded from the drainage area supplying the lake, coupled with persistent drought conditions, has altered the chemistry of the groundwater in the lakebed sediments to that of a mineral-rich brine. The brine formed within the lakebed as a result of these desert conditions that have persisted in the area over recent (Quaternary) geologic time.

The Great Salt Lake, adjacent Bonneville Salt Flats, and Pilot Valley, located 240 km (150 miles) north of Sevier Lake Playa, are modern-day corollaries to the Sevier Lake brine deposit. The Great Salt Lake is a terminal lake formed from the progressive drying of Lake Bonneville, followed by Lake Gunnison to present-day remnant waters in association with salt flats.

Although a 1979 geophysical survey indicated that the lakebed sediments might extend to over 1,219 m (4,000 [ft]) in depth, the target mineralization occurs in brine residing in relatively shallow playa sediments.

The mineral chemistry of the brine indicates that potash can be extracted following precipitation of salts from solar evaporation ponds and subsequent plant processing. Other products derived from the brine using the same process include halite (NaCl) and bitterns ($MgCl_2$ or $MgSO_4$). Lithium (Li) is present in the brine as well as minor concentrations of bromine (Br_2), borates (BO_3 or BO_4), and uranium (U_3O_8).

The top 30 m (100 ft) of the deposit can be characterized as follows:

- Salt crust up to 0.46 m (18 inches [in]) thick
- Lateral zonation in crust mineral chemistry
- Variations in brine saturations both laterally and with depth
- Variations in sediment grain size distribution
- Artesian brine flow in specific areas
- Elevated concentrations of sodium, potassium, magnesium, calcium, chloride (Cl), and sulphate (SO_4) in the brine

These features influence to varying degrees the target brine extent (volume) and potential for production of potash, halite, and bitterns from the brine. The focus of the mineral resource estimates presented in this Technical Report are two shallow brine horizons referred to as the Upper Resource Zone (URZ) and the Lower Resource Zone (LRZ).

The URZ is hosted in a fissured clay horizon, which generally extends from the surface to an average of approximately 6 m (20 ft) where fissuring is thought to decrease with depth to approximately 12 m (40 ft) below ground surface (bgs). The LRZ is hosted in a clay horizon with permeability developed in intercalated clayey silts, sands, and gravels occurring at various depths and thicknesses throughout the zone. The top of the LRZ is taken to be the uppermost occurrence of a coarse-grained permeable material, which varies with location. The LRZ bottom extends to a depth on average of approximately 21 m (70 ft). In places, the URZ and LRZ are distinct and separated by a transitional zone where little fissuring or coarser-grained intervals provide permeability. In other places, they are separated by a thin (15-centimeter [cm] [5.9-inch]) layer of relatively stiff clay limited, in some cases, the penetration of the direct-push holes.

The combined URZ and LRZ horizons vary from 12 to 30 m (40 to 100 ft) in depth from surface and are apparently limited at the base by another stiff clay horizon exhibiting relatively low moisture content. Drilling to date is insufficient to determine accurately a brine resource potential below the shallow horizons, although limited sampling has confirmed the presence of elevated brine concentrations below the bottom of the LRZ.

1.5 Exploration and Drilling

Early exploration of the Sevier Playa began as academic studies that included field mapping of surrounding formations and a gravimetric geophysical survey to explore the playa's structural characteristics at depth. Historical development efforts began with the drilling of over 700 auger holes across the lakebed by CPMC in the 1970s and 1980s with the goal of defining a brine resource within 6 m (20 ft) of the surface. The work done by CPMC provided a wealth of data on brine chemistry and sediment characterization as well as data on evaporation ponds and brine phase chemistry. A large solar evaporation impoundment was built and pilot-scale precipitation of halite and potash was conducted using fractional crystallization techniques.

A comprehensive exploration program was initiated once EPM gained control of the majority of the playa. EPM began its initial drilling program in spring 2011, with a first phase of exploration drilling on the state areas in August of that year to test methodology, procedures, and protocol. The BLM leases were later approved for exploration activities and drilling commenced on these in November 2011. In 2011 and 2012, a total of 404 exploration holes were drilled on both SITLA and BLM leases. An additional 10 wells were drilled as twin pairs on BLM leases for future hydrologic monitoring bringing the total holes drilled during the exploration phase to 414. During the months of February and March 2013, 17 additional mini-sonic exploration and infill holes were added on the SITLA, Peak Minerals BLM, and LUMA BLM leases bringing the total number of holes to 431 with a total of 5,579.8 m (18,306.4 ft) drilled.

Brine samples were collected and analyzed for key ionic constituents necessary for the production of potash and related compounds. Sediment cores were analyzed for moisture content and density to calculate interstitial brine volumes. Additionally, sediment samples from select mini-sonic holes were analyzed for clay and carbonate mineralogy and assayed for a suite of elements and oxides using inductively coupled plasma (ICP) mass spectrometry analysis.

1.6 Sample Preparation, Analysis, and Security

The sampling procedures and protocols were developed by CH2M HILL, in consultation with EPM and Norwest Corporation (Norwest), as part of their role as project consultants responsible for the sample well installations and further hydrologic characterization of the brine aquifers. Sampling during the EPM programs involved both unconsolidated sediment samples and samples of the brine. The sediment samples were taken primarily to quantify their level of saturation and the brine samples to characterize chemical composition and density.

1.6.1 Sample Preparation

Brine samples were collected at specified intervals in each hole after the well had stabilized a minimum of 48 hours. The wells were purged prior to sampling. Samples were collected using polyethylene tubing lowered to the sample interval and extracted using a low-flow peristaltic pump. Samples were collected in two 250-milliliter (mL) (8.45-ounce [oz]) bottles for a total sample volume of 500 mL (16.9 oz). The cation sample bottles contained nitric acid to preserve metal speciation and the anion bottles contained no preservative. The samples were labeled according to the well, depth interval, date, and time. All samples were kept in a cooler on ice to maintain a temperature between 0 degrees Celsius (°C) (32 degrees Fahrenheit [°F]) and 6°C (42°F).

Sediment sampling was conducted in two ways depending on drilling method. Direct push cores were field logged through the plastic sample sleeves and the ends sealed to retain as-received moisture content. These were transported to Intermountain GeoEnvironmental Services Inc. (IGES) labouratory in Salt Lake City by project personnel, where the core was opened, logged, and tested for moisture content. The sonic holes were logged in the field after a longitudinal sample of the core was collected and sealed and the core was transported to IGES for moisture content analysis.

1.6.2 Sample Analyses

Brine samples were analyzed for key chemical constituents associated with the ionic components of potash and related compounds. These analytes included the cations potassium, magnesium, and sodium using ICP mass spectrometry analysis; and the anions sulphate and chloride using ion chromatography. Samples were analyzed for density and total dissolved solids (TDS) as well. All analyses from the exploration program used in the resource model were conducted by American West Analytical Laboratory (AWAL) in Salt Lake City, Utah. AWAL is accredited by National Environmental Laboratory Accreditation Council (NELAC) and all analyses were performed in accordance to the NELAC Institute protocols. A total of 85 blind replicate samples were submitted to AWAL as part of the analytical quality control (QC) program.

Sediment samples were tested for moisture content at IGES using American Society for Testing and Materials (ASTM) International Method D2216, which is the determination of moisture content by reduction in mass due to loss of water by drying. Due to the quantity of gypsum ($CaSO_4$-$2H_2O$) identified in the sediments, the modified temperature of 60°C (140°F) was used in the drying process instead of the normal, higher-drying temperature of 110°C (230°F), in order to prevent the rendering of gypsum's hydrous component. IGES is an independent geotechnical engineering firm and rock mechanics labouratory and is certified with accreditation by the American Association of State Highway and Transportation Officials (AASHTO) Materials Reference Labouratory.

1.6.3 Sample Security

Sample preparation and security protocol for brine samples was designed by CH2M HILL, with the collaboration of EPM and Norwest. Brine samples were collected in bottles prepared by AWAL, labeled according to the well, depth interval, date, and time; and stored in coolers at proper temperature. Samples remained in the sole possession of the sampler until delivered to AWAL or securely stored to prevent tampering. Chain-of-custody (COC) forms were used to document the handling of the samples, and custody seals were placed on the cooler lids. Final transportation and delivery of the samples to AWAL was performed by CH2M HILL samplers who obtained direct COC sign-off at the labouratory.

Sediment samples were sealed with tape, and top and bottom depths were marked on the tube in permanent marker. Sample identifications (IDs) were composed of whole name and depth interval, and documented on the well site log and the COC form. Sealed core was boxed and checked against the COC form. The sealed core boxes were then transported directly to the IGES labouratory in Salt Lake City by project personnel (predominantly Norwest staff) with original COC forms that were signed by labouratory personnel on receipt.

1.7 Mineral Resource Estimates

A brine mineral resource was defined using EPM's current drilling and analytical data. The mineral resource is segmented into the URZ and LRZ, separated by a thin horizon of stiff clay that limited the penetration of the direct-push holes and is interpreted as a transitional zone between the two as described earlier in Section 1.5.

The brine resource estimate was developed using MineSight® three-dimensional (3D) block modeling software. The mineral resources were estimated based on analyses and descriptions of brine and hosting lakebed sediments sampled at regular depth intervals from vertically oriented drill holes collared on the playa surface.

Mineral resource plans illustrating the distribution of brine resources by levels of assurance for the URZ and LRZ are illustrated in Figure 14-14. Table 1-2 presents the brine resource in terms of the major dissolved cations and anions. Table 1-3 outlines tonnages of mineral-equivalent compounds that could be created using the available cations and anions in the brine resource. The equivalent compounds outlined in Table 1-3 assume a 100 percent recovery of the brine from the upper and lower brine aquifer. A total measured plus indicated in-place brine resource is estimated to be 5,691 million metric tonnes (Mt) (6,273 Mton) with a mineral equivalent estimate of potash at 31.49 Mt (34.71 Mton).

The accuracy of resource estimates is, in part, a function of the quality and quantity of data available and of engineering and geological interpretation and judgment. Given the data available at the time this Technical Report was prepared, the estimates presented herein are considered reasonable. However, they should be accepted with the understanding that additional data and analysis available subsequent to the date of the estimates may necessitate revisions that could be material. There is no guarantee that all or any part of the estimated resources would be recoverable.

The authors are not aware of any environmental, permitting, legal, title, taxation, socioeconomic, marketing, political, or other factors that could materially affect the resource estimate, other than the continued validity of the Cooperative Development Agreement with LUMA. The current estimate is dependent on the continued renewal of the Cooperative Development Agreement with LUMA, which is in effect through July 15, 2014.

Mineral resources that are not mineral reserves do not have demonstrated economic viability.

TABLE 1-2
Brine Mineral Resource Summary and Major Dissolved Cations and Anions (Effective Date October 25, 2013)

	Brine Resource	Potassium (K)		Sulphate (SO_4)		Chlorine (Cl)		Sodium (Na)		Magnesium (Mg)	
Category	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**
Measured	1,937	0.261	5.063	2.161	41.854	8.072	156.332	6.627	128.353	0.326	6.321
Indicated	3,755	0.241	9.036	2.009	75.414	7.175	269.411	6.353	238.533	0.308	11.546
Measured plus indicated	5,691	0.248	14.099	2.060	117.268	7.480	425.743	6.446	366.886	0.314	17.866
Inferred	476	0.241	1.148	2.101	9.993	7.007	33.332	6.675	31.751	0.334	1.586

* Wt% = weight percent

TABLE 1-3
Mineral Equivalent Compounds from Brine Resource (Effective Date October 25, 2013)

		Mt				
		Potash	**Bitterns**	**Bitterns**	**Salt Cake**	**Halite**
Lease Area	**Classification**	**K_2SO_4**	**$MgCl_2$**	**$MgSO_4$**	**Na_2SO_4**	**NaCl**
SITLA	Measured	0.376	0.416	0.526	0.384	7.524
	Indicated	0.754	0.840	1.061	0.732	14.653
	Measured plus Indicated	1.130	1.256	1.586	1.115	22.177
	Inferred	0.004	0.004	0.005	0.008	0.087
BLM	Measured	10.471	11.391	14.391	32.981	225.649
	Indicated	16.272	17.998	22.738	53.577	346.196
	Measured plus Indicated	26.774	29.389	37.129	86.558	571.846
	Inferred	1.212	1.259	1.591	4.389	25.889

TABLE 1-3
Mineral Equivalent Compounds from Brine Resource (Effective Date October 25, 2013)

		Mt				
		Potash	Bitterns	Bitterns	Salt Cake	Halite
Lease Area	Classification	K_2SO_4	$MgCl_2$	$MgSO_4$	Na_2SO_4	NaCl
LUMA	Measured	0.497	0.657	0.830	1.067	10.492
	Indicated	3.116	3.803	4.804	7.027	55.327
	Measured plus Indicated	3.613	4.460	5.634	8.094	65.819
	Inferred	1.344	1.848	2.335	3.654	25.137
Total	Measured	11.344	12.464	15.746	34.432	243.666
	Indicated	20.142	22.641	28.604	61.335	416.176
	Measured plus Indicated	31.486	35.104	44.350	95.768	659.841
	Inferred	2.560	3.111	3.931	8.051	51.113

1.8 Mineral Reserve Estimates

At present, there are no declared mineral reserves. Reserves would be claimed after completion of work detailed in the recommendations section. Among other aspects, a full-scale, long-term demonstration trench test is proposed to validate the hydrogeologic model on which the PFS is based. This is needed because there is no documented commercial mining example based on trench production and trench recharge in similar geologic conditions.

The proposed work is intended to validate brine flows and concentrations over an extended period and would allow refinement of trench geometry and construction sequencing. The brine resource is contained in porous media of seemingly low permeability and effective porosity, yet they produce ample flow to support the proposed plant. A number of parameters used in the model are not well constrained so, until a better understanding is achieved, the author of this section believes it prudent to wait for additional field data before claiming reserves.

1.9 Groundwater Modeling

A comprehensive groundwater modeling effort was conducted to support the PFS. The modeling included several configurations designed to test different aspects of the conceptual model. Three-dimensional models of the entire playa system were developed to characterize stream-basin interaction and effects of areal recharge and evaporation rates. This was followed by 3D and two-dimensional (2D) models with the ability to simulate density-dependent flow and dual-domain transport. The models incorporated layer elevations derived from intercepts logged from over 400 boreholes and wells drilled during the exploration program. Field data incorporated in the models included estimates of hydraulic conductivity and storage coefficient based on HydroPhysical™ and aquifer stress test results employing both wells and trenches. Site-specific estimates of the vertical infiltration rate and evapotranspiration were also obtained. Data from labouratory testing incorporated into the modeling included unsaturated flow properties, saturated hydraulic conductivity, matrix porosity, and solute concentrations.

Initial modeling determined that the target production rate of 0.34 liters per minute (L/min) (0.09 gallons [gals] per minute [gpm]) per linear meter (foot) of extraction trench could be met with a total demand of make-up recharge water of 424liters per second (L/s) (+/- 90 L/s) (15 cubic feet per second [cfs] [+/- 3 cfs]). This modeling was followed by numerous 2D flow and transport simulations to characterize the dilution of the brine resource over time, to determine optimum trench spacing, and to support a cost-benefit analysis of extracting brine from the lower resource zone with deepened trenches versus wells. Multiple simulations incorporating trench spacing of 500, 750, and 1,000 m (1,640, 2,461, and 3,280 ft), varied trench flow rates, and well spacings of 100, 200, 250, and 400 m (328, 656, 820, and 1,312 ft) were carried out to prototype various designs. Results showed that acceptable brine mass rates could be extracted from two trench phases based on 1,000 m (3,280 ft) spacing followed by well extraction with individual wells spaced at 400 m (1,312 ft) each discharging at approximately 68 L/min (18 gpm).

1.10 Mining Operations

The mining methods proposed are comparable to other solar evaporation potash projects in the western U.S. and abroad. In general, the mineral-rich brine would be obtained from playa sediments using extraction trenches and extraction wells and pumped into large evaporation ponds. The potassium salts harvested from the final production ponds would be stockpiled and then mechanically conveyed to the process plant for final treatment. Recharge of the brine aquifer would occur by way of precipitation, groundwater, local runoff, and inflow from the Sevier River. Recharge would be managed and conveyed to specific areas of the playa through the use of recharge trenches and to maintain flow as brine is continually extracted.

1.11 Mineral Processing

The proposed process for the conversion of the Sevier Lake Playa brine into SOP would use standard operations common to the potash or soda ash industries. The process would consist of the following steps:

1. Solar evaporation and precipitation
2. Product stockpiling
3. Conditioning
4. Flotation
5. Conversion to leonite (K_2SO_4-$MgSO_4$-$4H_2O$) (multiple-effect crystallization)

6. Conversion to SOP (SOP crystallization)
7. Drying and storage

The lake brine would be collected in a trench or from extraction wells and pumped into a series of solar evaporation ponds. Water would be evaporated from the brine and salts would be selectively precipitated onto pond floors. The potash salts would be harvested and stockpiled. Flotation would separate the bulk of the potash salts from halite, epsomite ($MgSO_4$-$7H_2O$), and minor materials. Crystallization and evaporation steps would purify the potash salts ultimately producing SOP and related minerals.

Flotation concentrate solids would be sent to leonite multiple-effect crystallizers. The leonite crystals would be sent to SOP crystallizers where water would be added to dissolve out magnesium sulphate ($MgSO_4$) to produce SOP. Dried SOP crystals would be screened and sized to meet desired specifications. Oversize material would be combined with undersize product and load-out fines to be processed in a compaction circuit.

1.12 Exploration and Development

A series of wells and trenches have been completed for the purpose of hydrological characterization of the brine resource. Wells have been completed for brine sampling, pumping tests, and other hydrologic evaluations. Future exploration work is planned to expand the LRZ resource zone and improve our understanding of the lithologic features of the playa. To facilitate the conversion of mineral resources to mineral reserves, a long-term pilot scale trench test is planned to calibrate further the hydrology model along with additional hydrological testing in the existing and planned well network.

1.13 Capital Cost Estimate

A capital cost estimate was developed for a process plant with a capacity of 300,000 tpy (330,693 tons/yr). The estimate has an accuracy of +25/-20 percent. The capital expenditure (CapEx) estimate includes costs associated with the development of lake extraction systems, processing plant, administrative and maintenance infrastructure, rail load-out facility, and associated indirect costs. Table 1-4 summarizes the total estimated capital costs, including contingency.

TABLE 1-4
Summary of Costs (Q3 2013 U.S. Dollars)

	Total
Utility/Common Infrastructure	$44,910,519
Playa Infrastructure	$48,811,358
Stock Pile	$6,334,608
Process Building/Truck Load-out	$155,829,898

TABLE 1-4
Summary of Costs (Q3 2013 U.S. Dollars)

	Total
Truck Shop	$2,534,524
Administration Building	$2,214,671
Rail Load-out Site	$31,148,515
Total Direct Capital Costs	$291,784,093
Indirect Capital Cost	$50,295,926
Contingency	$36,319,281
Project Total	**$378,399,300**

1.14 Operating Cost Estimate

Operating costs were determined based on the production schedule, process equipment requirements, operating hours, hourly equipment operating costs, and Project labour force requirements. For the purpose of the economic analysis, the operating costs were separated into the following categories: labour; power; natural gas; reagents, consumables, and maintenance; salt harvest and haul to rail; and general and administrative (G&A). Table 1-5 provides a summary of the operating costs.

TABLE 1-5
Summary of Operating Costs (Q3 2013 U.S. Dollars)

	Operating Costs US$/t SOP	Percent
Labour	$34.76	19.2
Power	$13.97	7.7
Natural gas	$37.57	20.8
Reagents, consumables, and maintenance	$40.34	22.3
Salt harvest and haul to rail	$37.57	20.8
G&A	$16.70	9.2
Total	**$180.91**	**100**

1.15 Economic Analysis

An economic analysis was conducted to determine the net present value (NPV) and internal rate of return (IRR). The analysis was completed using a Discounted Cash Flow model that incorporated annual inflation for both revenues and costs. The SOP price was based on a forecast provided by CRU International Ltd. (CRU). Only measured and indicated resources were used for the determination of mine life, which was estimated at 30 years based on average annual production of 300,000 tpy (330,693 tons/yr. No inferred resources where considered. The economic indicators determined are presented in Table 1-6. The pretax and after-tax

NPV at an 8 percent discount rate was US$957 million and US$629 million, respectively; with a pretax and after-tax IRR of 24 percent and 20 percent, respectively. The payback period is estimated at 5.5 years from first production of saleable product.

TABLE 1-6
Summary of Economic Indicators

Economic Indicators	Pretax	After-Tax
$NPV_{8\%}$	US$957 million	US$629 million
IRR	24%	20%
Payback period		5.5 years

Of the variables analyzed, the investigation demonstrated that the IRR and NPV are most sensitive to variances in SOP price. The IRR was also quite sensitive to CapEx, while the NPV was also sensitive to the discount rate. Figures 1-1 and 1-2 show the relative sensitivity of each variable analyzed against the Project's after-tax NPV and after-tax IRR.

FIGURE 1-1
Sensitivity of After-tax NPV to Project Variables (U.S. Dollars)

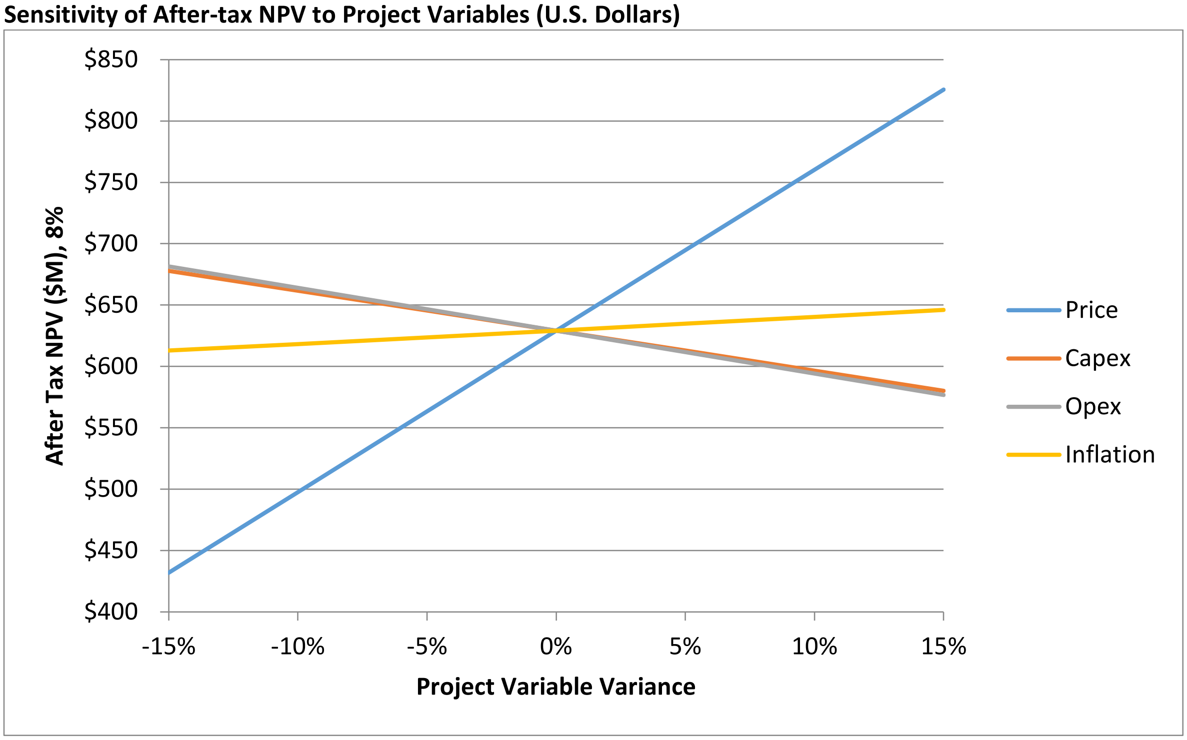
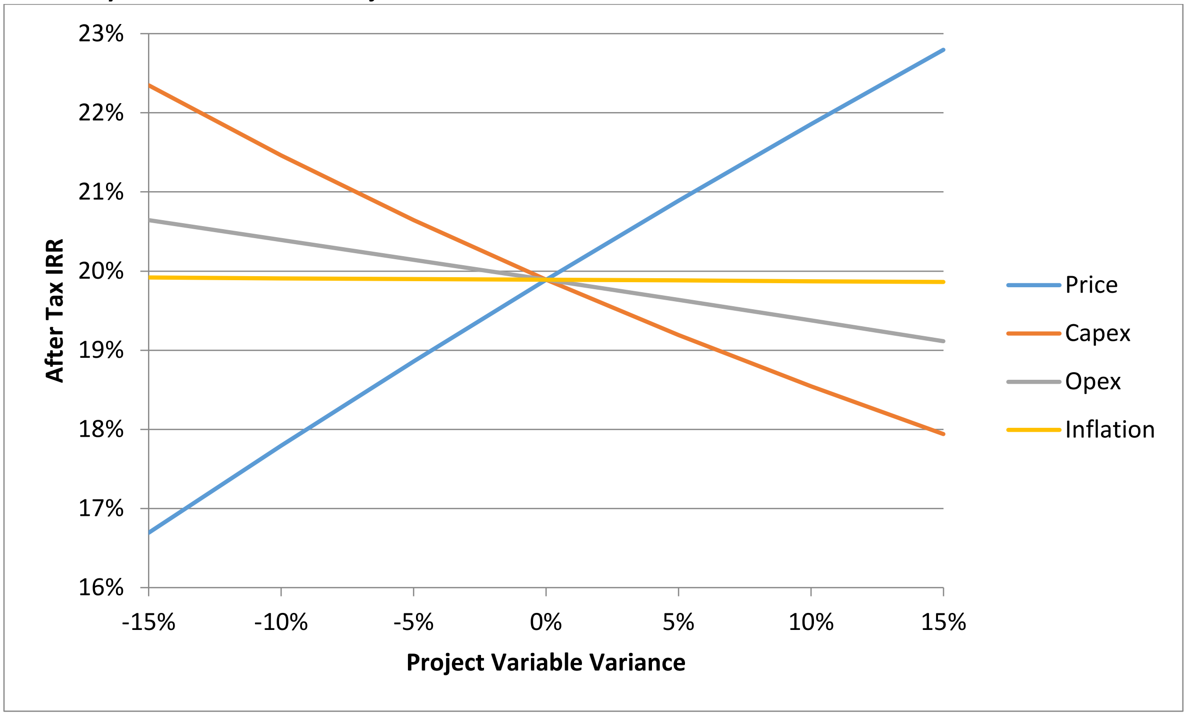


FIGURE 1-2
Sensitivity of After-tax IRR to Project Variables



1.16 Environmental and Permitting

EPM will be required to obtain regulatory approvals and permits to construct and operate the Project. Under the National Environmental Policy Act of 1969 (NEPA), the approval of an Environmental Impact Statement (EIS) is required for the assessment of possible impacts of the proposed mining project on federal lands. This would be achieved by obtaining an EIS Record of Decision (ROD). The permitting program will be governed primarily by three permits: a) the Utah Division of Air Quality (UDAQ) Minor Source Approval Order required for construction of the on-playa facilities (referred to as "On-Playa Approval Order"); b) a Prevention of Significant Deterioration (PSD) Approval Order that will be required for the construction of the processing plant (referred to as the "PSD Approval Order"); and c) the Utah Division of Oil, Gas, and Mining (DOGM) Large Mine Permit. An EIS ROD will also be necessary.

Work has commenced on the EIS, as well as on both the On-Playa Approval Order and the Large Mine Permit, including the collection of required background and preconstruction monitoring data. Time periods for the completion of applications, submittal, review, and approval of the EIS, the On-Playa Approval Order, and the Large Mine Permit is at least 12 months. The current completion schedule for the On-Playa Approval Order and the Large Mine Permit is second quarter 2014; the EIS completion is projected for fourth quarter 2014; and the PSD Approval Order is expected in fourth quarter 2015.

1.17 Conclusions

The Project has a large brine resource that is anticipated to be capable of supporting mining and processing operations for a minimum of 30 years. The brine would be obtained using a combination of extraction trenches and wells. The extracted brine would be processed to produce salable SOP product at an estimated rate of 300,000 tpy (330,693 tons/yr). The Project has an estimated capital cost of US$378 million. Operating costs are estimated at US$180.91 per tonne. The Project after-tax NPV at an 8 percent discount rate is US$629 million with an estimated IRR of 20 percent.

1.18 Recommendations

It is the opinion of the authors that the results of this study warrant continued efforts to advance the Project. The contents of this PFS provide sufficient justification for proceeding with the development of the Project.

The authors recommend that additional field and labouratory work be completed to finalize understanding of the playa hydrology in order to:

- Advance the stated mineral resources to mineral reserves:
  - Hydrology evaluation – US$1,494,175
- Advance the geotechnical work to a level sufficient to finalize civil design work on the playa:
  - Geotechnical – US$269,900
- Complete additional process work to validate and optimize the process flow sheet. Evaluate ancillary product alternatives, including lithium, to determine which of these can be incorporated into the flow sheet:
  - Process flow sheet improvement – US$505,000
- Complete feasibility study:
  - Feasibility Study – US$2,000,000
- Continue on-going environmental work necessary to obtain all permits and authorizations required for construction of the project as outlined in Section 20:
  - Environmental and permitting – US$1,500,000

Please review Section 26 for a complete description of the recommendations. The work program costs have been incorporated into the capital cost estimate for the Project.

Introduction and Terms of References

2.1 General

EPM is a Canadian-registered mining company domiciled in the Yukon, and publicly listed on the TSX Venture Exchange and OTCQX International. EPM is a development-stage, pre-revenue potash company primarily focused on an SOP project at the Sevier Playa in Millard County, Utah.

This report provides technical information for the Project. EPM, through its indirect wholly owned subsidiary Peak Minerals, controls directly or through agreement mineral leases on more than 50,000 ha (124,000 acres) on the Sevier Playa property in Millard County, Utah.

2.2 Purpose and Terms of Reference

EPM retained CH2M HILL of Denver, Colorado, and AAI, Whetstone, and Norwest of Salt Lake City, Utah, independent engineering consulting firms, to provide input to the PFS for the potential development and operation of an SOP processing plant at the Project.

2.3 Project Team, Responsibilities, and Personal Inspection

The following people served as the qualified persons (QPs) as defined in NI 43-101, Standards of Disclosure for Mineral Projects, and in compliance with Form 43-101F1:

- Mr. Michael D.S. Blois, Pr. Eng., QP, (CH2M HILL) is the QP responsible for the mineral processing and metallurgical testing, recovery methods, infrastructure, capital cost and operating cost estimates, and the overall preparation of the report.
- Mr. Michael Hardy, P.E., QP, (AAI) is the QP responsible for the mining methods, CapEx and operating cost for on playa activities and related recommendations and conclusions
- Mr. Scott Effner, P.G., QP, (Whetstone) is the QP responsible for groundwater modeling.
- Lawrence D. Henchel, P. Geo., QP, (Norwest) is the QP responsible for the resource estimate.
- Mr. David Waite, P.E., QP, (CH2M HILL) is the QP responsible for the environmental and permitting sections of the report.

The dates of the site visits conducted by the QPs are listed in Table 2-1. Scott Effner did not visit the site as it was deemed unrequired to fulfill his responsibility with the hydrological modeling.

TABLE 2-1
Qualified Persons

QPs	Designation	Company	Most Recent Site Visit	Initials
Michael D.S. Blois	Pr. Eng., QP	CH2M HILL	June 25, 2013	MDSB
Michael Hardy	P.E., QP	AAI	December 11, 2012	MH
Scott Effner	P.G., QP	Whetstone Associates, Inc.	None (see certification)	SE
Lawrence D. Henchel	P. Geo., QP	Norwest	July 18, 2013	LDH
David Waite	P.E., QP	CH2M HILL	March 18, 2013	DW

Each QP is responsible for sections of the report as outlined in Table 2-2. Certificates for each QP are included in this Technical Report.

TABLE 2-2
Report Sections of Responsibility

Section	Title of Section	QP
1.0	Summary	MDSB
2.0	Introduction and Terms of References	MDSB
3.0	Reliance on Other Experts	MDSB/MH
4.0	Property Description and Location	LDH
5.0	Accessibility, Climate, Local Resources, Infrastructure, and Physiography	LDH
6.0	History	LDH
7.0	Geological Setting and Mineralization	LDH
8.0	Deposit Types	LDH
9.0	Exploration	LDH
10.0	Drilling	LDH
11.0	Sample Preparation, Analyses, and Security	LDH
12.0	Data Verification	LDH
13.0	Mineral Processing and Metallurgical Testing	MDSB
14.0	Mineral Resource Estimates	LDH
15.0	Mineral Reserve Estimate	MH
16.0	Mining Method	MH/SE
17.0	Recovery Methods	MDSB
18.0	Project Infrastructure	MDSB
19.0	Market Studies and Contracts	MDSB
20.0	Environmental Studies, Permitting, and Social or Community Impact	DW
21.0	Capital and Operating Costs	MDSB/MH
22.0	Economic Analysis	MDSB
23.0	Adjacent Properties	LDH
24.0	Other Relevant Data and Information	MDSB/MH

TABLE 2-2
Report Sections of Responsibility

Section	Title of Section	QP
25.0	Interpretation and Conclusions	MDSB/MH
26.0	Recommendations	MDSB/MH/SE
27.0	References	All
Appendix A	Groundwater Flow and Transport Modeling Report, Sevier Lake Playa Brine Mining Project, Utah	SE
Appendix B	Financial Model	MDSB

2.4 Source of Information

The information presented in this Technical Report has been derived from a variety of studies and fieldwork completed by consultants on behalf of EPM for the development of the Project. A complete list of references is included in Section 27.

CH2M HILL has relied on EPM for guidance on applicable taxes and royalties, relevant to revenue or income from the Project.

2.5 Units of Measure

Unless stated otherwise, the primary units of measure reported here are the metric units (e.g. tonne); the corresponding US Customary units (e.g. tons) are given in brackets for convenience. To provide consistency, the comma has been used as the thousands separator for numbers in both the metric and the United States Customary units. To avoid confusion, the use of the thousands space separator has not been used.

Reliance on Other Experts

The Consultants, CH2M HILL, Norwest, and AAI, completed a variety of studies and fieldwork on behalf of EPM for the development of the Project. A complete list of references is included in Section 27. Selected information contained in this Technical Report was compiled from the Consultants listed below.

In their professional judgement, the authors have reviewed the data supplied by other experts and have taken appropriate steps to ensure that the work, information, and advice from the below noted consultants are sound for the purpose of this Technical Report.

Agapito Associates, Inc.

AAI has relied on independent experts retained by EPM in addition to experts employed and retained by AAI.

Data Verification

- Steven Carpenter, P.G., 2013, independent consultant retained by AAI to provide consultation and expertise on Sections 12, 14, 24, and 26.
- Vanessa Santos, P.G., Chief Geologist with AAI, provided review of Items 12 and 14, and contributed to Sections 24 and 26.

Mine Design

- David S. Butts, 2013, retained by EPM to provide consultation regarding evaporation pond design and use of Solar Pond Model, Rev. 3, and a rigorous design model created in Excel format to determine evaporation pond sizes and brine feed rates. This model and its use are discussed in Section 16.
- John H. Rahe, P.E., 2013, independent consultant retained by AAI to provide consultation and expertise with civil engineering design and construction cost estimating contributing to Sections 16 and 21.
- Jon Friedman, P.E., P.G., Senior Associate with AAI and project manager of Project for AAI. Provided geotechnical and civil engineering design and construction cost estimating contributing to Sections 16, 21, 24, and 26.

Hydrogeology

- Jon Kaminsky, P.G., L.H.G., Senior Hydrogeologist with Whetstone contributed to hydrogeologic modeling, interpretation, and reporting and coauthored the hydrogeologic summary report included as Appendix A. Provided contributions to Sections 16, 24, and 26.

CH2M HILL Engineers, Inc.

CH2M HILL has relied on independent experts retained by EPM in addition to experts employed and retained by CH2M HILL.

Process Plant

- Richard Rath, P.E., Processing Engineering Consultant. Provided oversight on Hazen Research, Inc. (Hazen) pond test work and contributed to process development.
- Swenson Technology, Inc. (Swenson) design and supply firm specializing in crystallizer technology. Process modeling and crystallization simulation. Specifically, the work provided was:
  - Thermodynamic modeling of solar ponds and potential SOP production processes
  - Pond simulation test work using vacuum crystallization to shorten evaporation time
  - Multi-stage leonite crystallization test work to verify leonite crystallization
- Hazen Research, Inc., testing labouratory. Metallurgical services and metallurgical test work. Specifically, the work provided was:
  - Pond simulation test work
  - Crystallization test work to verify leonite crystallization
  - Flotation test work to identify flotation conditions, recoveries, and grades
  - Analytical work on brine samples to verify brine constituents

Market Study

- The Parthenon Group (Parthenon), a market research firm retained by EPM, provided a market assessment and distribution strategy study.

Norwest Corporation

Norwest has relied on data compiled from historic reports regarding project history and prior development work, including historic resource estimates. These reports are listed in Section 27, most notably Gwynne (2006), Godbe (1984), and Rasmussen (1997). The findings and conclusions in this technical report are based on information developed by Norwest from data provided by EPM. It includes data provided by third parties, specifically analytical data developed by AWAL and Intermountain GeoEnvironmental Services Inc. (IGES).

SECTION 4

Property Description and Location

4.1 Location

The Project property is located in southwestern Utah situated in the central portion of Millard County and is defined by the geographical boundaries of the Sevier Lake Playa with approximate center at latitude 38°57'59.88" N and longitude 113°07'4.33" W, or at 4313105N, 314505E using UTM WGS84 coordinates. The general location of the property is illustrated in Figure 4-1.

The property is situated approximately 225 km (140 miles) southwest of Salt Lake City, Utah, generally between the towns of Delta, Utah (48 km [29.83 miles] to the northeast) and Milford, Utah (40 km [24.85 miles] to the south-southeast). The playa covers an area of approximately 52,609 ha (130,000 acres) and is approximately 42 km (26 miles) long by an average of 12.5 km (8 miles) wide.

The mineral deposits described in this Technical Report occur over the entire lakebed of the Sevier Lake Playa and immediate shoreline areas. The playa is dry for most of the year, but portions are occasionally covered with shallow meteoric water during certain months. The playa was originally fed with water from the drainage of the Sevier River watershed. Reservoir management and appropriation of Sevier River water for crop irrigation upstream normally consumes virtually all of the river water before it reaches the Sevier Lake Playa. Episodic climatic cycles of above-average precipitation and runoff result in periods of standing water, as occurred in 2011. The playa can be traversed by foot or by specialized wide-track vehicles when in a drier state during the summer and fall months.

4.2 Property Mineral Control

The leased lands for the Project are predominantly lands of the U.S., administered by BLM with isolated public land grid sections approximately 259 ha (640 acres) in size belonging to SITLA. The leases are controlled by the following three entities:

- Peak Minerals
- LUMA
- Emerald Peak

A small amount of land along the outer margins of the playa has not been leased. Figure 4-2 shows the location of the various mineral tenure areas.

Table 4-1 summarizes the relationship of entities controlling the potash leases involved with the Project. EPM controls, has financial investments, or has entered into agreements with, each of the entities.

FIGURE 4-1
General Location Map

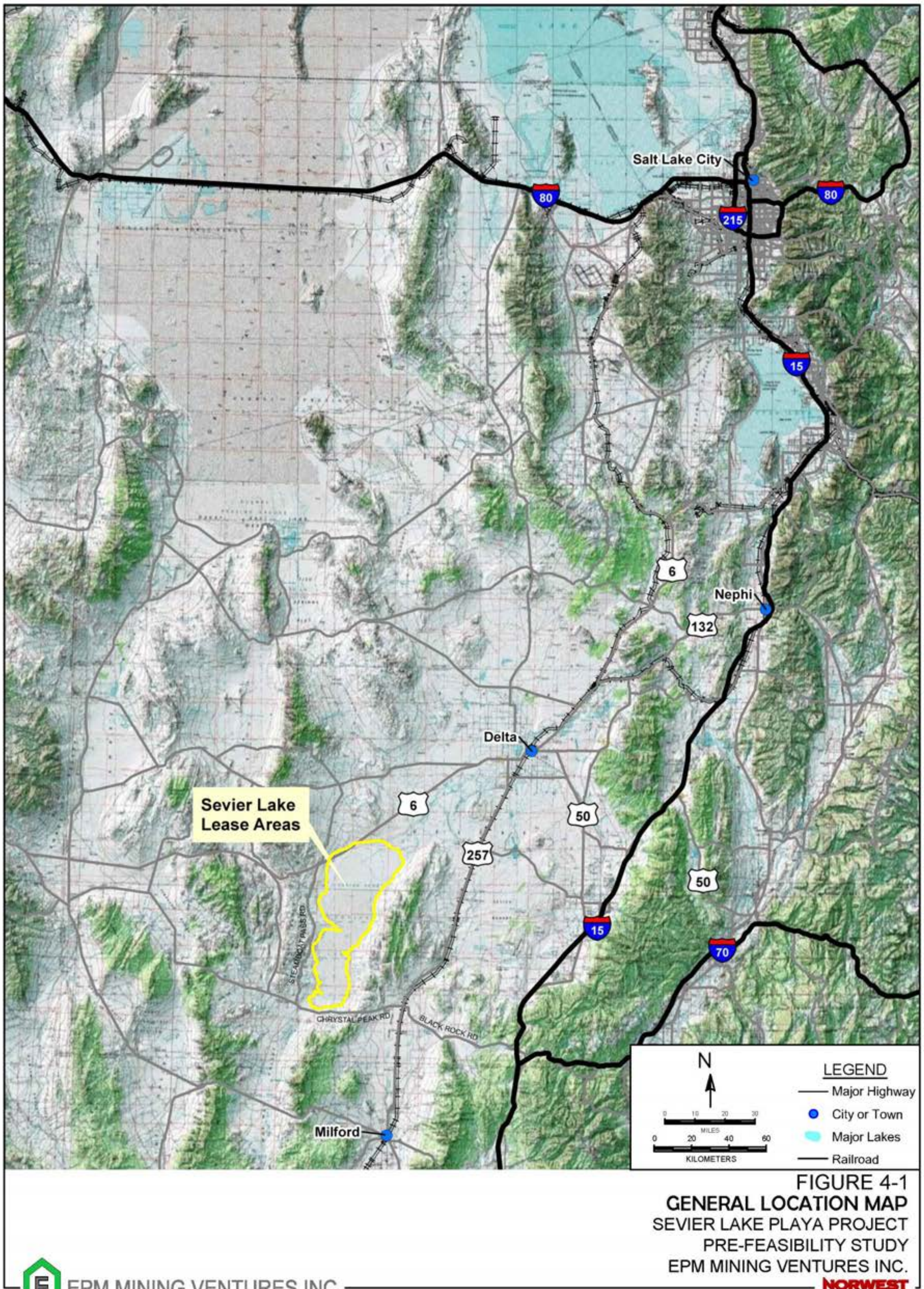


FIGURE 4-2
Mineral Lease Areas

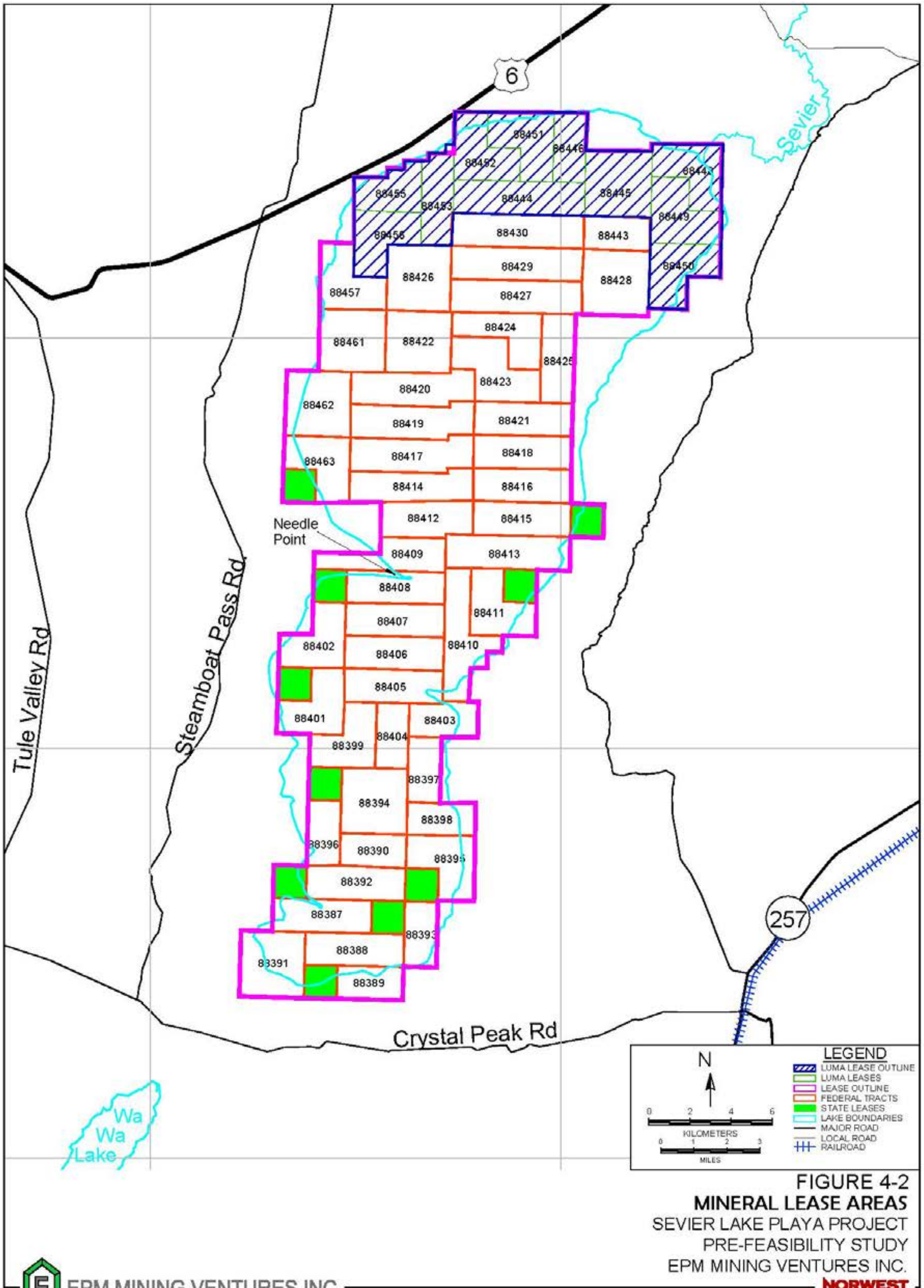


TABLE 4-1
Summary and General Description of Sevier Lake Playa Leases

Leaseholder	Peak Minerals	Emerald Peak	LUMA
Relationship to EPM	Indirect wholly owned subsidiary	Peak Minerals holds a 40% membership interest	Contractual
Contractual agreements	100% owned via Peak Minerals Canada Ltd	40% membership interest owned by Peak Minerals with Commercial Services Agreement for leasehold operations	Cooperative Development Agreement for leasehold operations
Area held	38,769 ha (95,801.76 acres)	2,593.83 ha (6,409.48 acres)	8,907.03 ha (22,009.97 acres)
Dates leases secured	April 5, 2011	September 1, 2008	April 5, 2011
Lease descriptions	See Table 4-2	See Table 4-3	See Table 4-4

These investments and agreements provide for operational control of the leases by EPM as described below and presented in Tables 4-2 through 4-4:

- **BLM Potassium Leases Issued to Peak Minerals –** On April 5, 2011, Peak Minerals leased federal potassium leases covering 38,769.66 ha (95,801.76 acres) of land on the Sevier Lake Playa by competitive bid from BLM. Peak Minerals is an indirect, wholly owned subsidiary and the U.S. operating company for EPM, which controls Peak Minerals via Peak Minerals Canada Ltd.
- **SITLA Potash Leases Issued to Emerald Peak –** On September 1, 2008, Emerald Peak leased SITLA potassium leases covering 2,593.83 ha (6,409.48 acres) of land on the Sevier Lake Playa by competitive bid from the State of Utah. Peak Minerals owns a 40 percent membership interest in Emerald Peak and has a Commercial Services Agreement granting Peak Minerals development and operational rights on these lands.
- **BLM Potassium Leases Issued to LUMA –** On April 5, 2011, LUMA leased federal potassium leases covering 8,907.03 ha (22,009.97 acres) of land on the Sevier Lake Playa by competitive bid from BLM. Peak Minerals has a Cooperative Development Agreement dated July 15, 2011, with LUMA that provides for Peak Minerals gaining development and operational control of LUMA's federal potassium leases. On June 27, 2012, but effective as of June 15, 2012, EPM executed a 12-month extension of the LUMA agreement. On June 5, 2013, but effective June 15, 2013, EPM executed a second 12-month extension of the LUMA agreement, thereby extending its term from July 15, 2013 to July 15, 2014.

Peak Minerals and LUMA entered into the Cooperative Development Agreement on July 15, 2011. The agreement is intended to develop the joint leases as a combined property, similar to the way an oil and gas field can be unitized between several different leaseholders. The agreement establishes the goal of working to create this unit with the regulating federal and state agencies. While there has been no decision by the agencies formally creating a Unit Agreement, it is likely to be successfully adopted given that BLM was the originator of the unitized approach to the liquid mineral commodity and it is supported by BLM, SITLA, EPM, and LUMA.

TABLE 4-2
Summary of Federal Potash Mineral Leases Controlled By Peak

UTU Number	Ha	Acres	UTU Number	Ha	Acres
88387	780.64	1,929.01	88412	727.76	1,798.33
88388	777.00	1,920.00	88413	979.78	2,421.09
88389	518.00	1,280.00	88414	971.56	2,400.77
88390	518.00	1,280.00	88415	802.35	1,982.65
88391	1,006.76	2,487.76	88416	782.34	1,933.20
88392	777.00	1,920.00	88417	969.86	2,396.57
88393	519.37	1,283.38	88418	777.00	1,920.00
88394	1,036.00	2,560.00	88419	969.49	2,395.65
88395	822.62	2,032.74	88420	969.11	2,394.72
88396	518.00	1,280.00	88421	777.00	1,920.00
88397	518.00	1,280.00	88422	973.89	2,406.53
88398	540.39	1,335.32	88423	968.75	2,393.82
88399	777.66	1,921.63	88424	756.62	1,869.64
88401	778.16	1,922.86	88425	699.64	1,728.85
88402	777.00	1,920.00	88426	1,036.00	2,560.00
88403	553.03	1,366.56	88427	1,035.68	2,559.21
88404	518.86	1,281.88	88428	1,036.00	2,560.00
88405	776.75	1,919.40	88429	1,035.04	2,557.64
88406	776.41	1,918.55	88430	1,034.41	2,556.07
88407	776.11	1,917.81	88443	518.00	1,280.00
88408	775.82	1,917.09	88457	763.40	1,886.40
88409	776.34	1,918.37	88461	968.60	2,393.45
88410	1,015.81	2,510.11	88462	1,031.48	2,548.83
88411	778.81	1,924.48	88463	773.51	1,911.39
		Totals	**UTU 48**	**HA 38,769.66**	**Acres 95,801.76**

TABLE 4-3

Summary of SITLA Potash Mineral Leases Controlled By Emerald Peak

	Lease Number	Ha	Acres
	ML 51479	259.00	640.00
	ML 51480	520.52	1,286.24
	ML 51481	518.00	1,280.00
	ML 51482	777.00	1,920.00
	ML 51483	519.31	1,283.24
Totals	**Lease 5**	**HA 2,593.83**	**Acres 6,409.48**

TABLE 4-4

Summary of Federal Potash Mineral Leases Controlled By LUMA

	UTU Number	Ha	Acres
	88444	1,033.77	2,554.50
	88445	1,034.86	2,557.18
	88446	549.74	1,358.44
	88448	814.39	2,012.41
	88449	856.10	2,115.47
	88450	861.67	2,129.20
	88451	856.10	2,048.40
	88452	790.51	1,953.40
	88453	728.28	1,799.62
	88455	631.86	1,561.35
	88456	777.00	1,920.00
Totals	**UTU 11**	**HA 8,907.13**	**Acres 22,009.97**

With the support of BLM, SITLA, Emerald Peak, and LUMA, Peak Minerals intends to unitize the leases and operate and develop them under a Unit Agreement designed to, among other things, obligate the lessors and the lessees to a development and production allocation arrangement that would grant Peak Minerals the sole rights to develop and operate the potassium resources on the Sevier Lake Playa. Work has begun on this document and EPM anticipates that an executed Unit Agreement will be in place in 2014.

Currently, Peak Minerals owns a 100 percent leasehold interest in federal potassium leases comprising 38,769.66 ha (95,801.76 acres). The leases grant full rights of access and rights to use the surface for leasehold mining activities. The term of the leases is 20 years from the date of issuance (April 5, 2011) and for so long thereafter as Peak Minerals complies with certain rental, minimum royalty, and minimum annual production requirements, as well as other terms and conditions of the leases. Minimum production and minimum royalty requirements do not commence until the sixth lease year. The leases are subject to readjustment at the end of each 20-year term.

The same terms described previously apply to the federal potassium leases in which record title is held by LUMA. Peak Minerals will have development and operational control of these leases under the terms of its Cooperative Development Agreement dated July 15, 2011, but extended through July 15, 2014, and under a Unit Agreement or similar agreement and Operating Agreement that will be entered into by Peak Minerals, LUMA, and Emerald Peak.

The SITLA potash leases are owned 100 percent by Emerald Peak. They grant full rights of access and rights to use the surface and subsurface for uses "reasonably incident to the mining of leased substances." The term for all of the leases is for 10 years from the effective date of September 8, 2008, and for so long thereafter as leased substances are being produced in paying quantities. Peak Minerals owns 40 percent of the membership interest in Emerald Peak and also has the contractual commitment from Emerald Peak to enter into a Unit Agreement or similar agreement and an Operating Agreement. These agreements will name Peak Minerals as operator and give Peak Minerals the sole right to develop and operate the SITLA leases along with the BLM leases. The Emerald Peak agreement commits Peak Minerals to pay Emerald Peak the greater of US$40,000 per year or a 7.5 percent overriding royalty on all potash production allocated to the SITLA leases.

The LUMA potassium leases are subject to the same federal royalty rates as the Peak Minerals federal potassium leases. The LUMA agreement also commits Peak Minerals to pay LUMA a 1.25 percent overriding royalty on all production from, or allocated to, the LUMA leases. This agreement also grants LUMA the right, in addition to the overriding royalty, to elect either (1) a cash-only payment of US$2 million or (2) the number of shares in EPM equal in value to US$1 million, plus US$1 million cash at closing. The closing is conditioned on and subject to (1) all necessary approvals of Peak Minerals and/or EPM's shareholders and Board; (2) all necessary approvals of U.S. and Canadian governmental authorities, including but not limited to those of securities and exchange and environmental regulatory bodies, BLM, and SITLA; and (3) all applicable stock exchange rules, regulations, and approvals.

Norwest has reviewed the BLM and SITLA mineral lease documents and finds that they appear valid and reasonable for the operation of potash extraction within lease boundaries. No formal legal review or further due diligence has been performed.

4.3 Property with BLM Mineral Leases

Potash is defined by regulation under 43 Code of Federal Regulations (CFR) 3500 and The Mineral Leasing Act of 1920 as a solid "leasable" mineral. BLM issues leases in two different ways for solid leasable minerals, other than coal and oil shale—competitive issues in areas there is a mineral deposit and competitive leases through a bidding process.

Through Peak Minerals, EPM was awarded its leases under the competitive bidding process. Review of the lease documents determined that the following rents, royalties, and stipulations apply to the Peak Minerals leases:

- Production royalty on gross value of potassium compounds free on board (FOB) to market
  - Lease Years 1 through 5 = 2.0 percent
  - Lease Years 6 through 20 = 5.0 percent
- Minimum production/minimum royalty
  - Minimum royalty = US$3.00 per 0.405 ha (1 acre) beginning in Year 6
  - If minimum production royalties do not exceed requirements in Year 6, the minimum royalty is paid
- Rental and royalty
  - Lease Year 1 = US$0.25 per 0.405 ha (1 acre) (or fraction thereof)
  - Lease Years 2 through 5 = US$0.50 per 0.405 ha (1 acre) (or fraction thereof)
  - Lease Years 6 through 20 = US$1.00 per 0.405 ha (1 acre) (or fraction thereof)
- Lease term
  - Perpetuity provided lessee complies with terms and conditions of lease
  - Terms and conditions of lease renegotiated every 20 years
- Diligence requirements
  - Cancellation of lease pursued at end of 20-year lease term if potassium compounds are not being produced in paying quantities

The leases stipulate that the greater amount between rent and royalty is to be paid. Other stipulations carried by the leases were reviewed and found to be standard regulations pertaining to protection of the environment and human health, property reclamation, and reporting requirements. BLM requires that an exploration plan and environmental assessment (EA) be submitted prior to the commencement of any exploration activities, as well as an approved Notice of Intent (NOI) from DOGM. Mining operations on the lease will require an approved Plan of Operations from BLM and a mining permit approval from DOGM.

4.4 Property with Utah State Mineral Leases

The Utah State mineral leases managed by SITLA are effective for 10-year terms. The SITLA leases controlled by EPM are renewable annually for an initial term of 10 years. Annual maintenance fees are US$4.00 per 0.405 ha (1 acre). State royalties payable to SITLA are 5 percent gross value FOB the mine. The leases held by Emerald Peak stipulate that mineral production must commence by September 1, 2018.

4.5 Property Environmental Liabilities

An EA of the leaseholds was conducted in 1987 by BLM. The CPMC development and operational plans were reviewed and the leasehold area surveyed for such environmental concerns as wildlife habitat, threatened and endangered species, cultural/archaeological resources, and impact to recreational opportunities. A FONSI was issued in October 1987; the result being that the Project would not require an EIS to proceed.

Recently, the area has undergone two EAs conducted by BLM. The first was performed prior to the lease sale in 2011 to determine the potential impacts from leasing the minerals for development. No significant impacts were identified and the leases were offered for bid. As a follow-up to the leasing EA, BLM completed a second EA to assess the impacts of exploration drilling. Again, no significant impacts were identified and the exploration program was successfully initiated and completed. No known encumbrances or environmental liabilities are associated with the property at the time of this Technical Report.

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SECTION 5

Accessibility, Climate, Local Resources, Infrastructure, and Physiography

5.1 Property Access

Major airline access to the property is via the Salt Lake City International Airport. Daily commuter flights are available to Cedar City, Utah, approximately 80km (50 miles) to the south of the town of Milford. Access by vehicle from Salt Lake City is south via Interstate-15, approximately 137 km (85 miles) to the town of Nephi, then via SR 132 for 137 km (85 miles) to the town of Lynndyl, then following U.S. Highway 6 to the city of Delta. The northern margin of the playa is accessed by traveling southwest another 18 km (11 miles) along U.S. Highway 6.

The southern end of the Project can be accessed by travelling north from Cedar City on SR 130 and then SR 21 approximately 88 km (55 miles) to the town of Milford. North from Milford, SR 257 travels a distance of about 37 km (23 miles) to the Black Rock railroad siding of UPRR. The southern end of the property is accessed by traveling west from Black Rock on secondary improved gravel roads for an additional 21 km (13 miles) to the playa.

Two secondary north-south-trending improved gravel roads run along the west and east sides of the property. The road on the eastern side narrows and is less maintained than the Steamboat Pass Road on the west. Numerous unimproved roads and trails suitable for 4x4 vehicles lead from these north-south routes to the edge of the playa. The ability to travel on the playa varies seasonally depending on the amount of moisture on the saltpan. The margins of the playa can support a pickup truck in places but use of normal vehicles is risky due to their weight and the likelihood of becoming mired in the relatively soft playa sediments. Playa travel is best approached with all-terrain vehicles and has been creatively addressed by the use of snow cats with extra-wide treads. Recent exploration activities, being performed during a period of unusually wet playa conditions, used marsh buggies commonly employed in the bayous of the southern U.S as rig platforms, as well as air-propelled boats for personnel and equipment transport.

5.2 Climate

The Project area is semi-arid with 20.6 cm (8.11 in) average annual precipitation measured at the town of Delta (Rasmussen, 1997). Vegetation consists of low brush and sage on the margins of the Sevier Lake Playa, while the playa surface itself is devoid of vegetation due to periodic flooding and the resulting formation of a salt crust on the surface from the evaporation of the mineral brine.

Regional climate statistics from nearby towns and weather stations show an average maximum temperature of 19.1°C (66.4°F), ranging between a high in July of 33.9°C (93.0°F) and a low in January of 4.6°C (40.2°F). Minimum temperatures averaged 0.83°C (33.5°F), ranging between a high in July of 13.3°C (55.9°F) and a low in January of -10.1°C (13.8°F). Extremes range from a record low of -36.6°C (-34°F) to a record high of 40.6°C (105°F) (Gwynn, 2006).

The climate of the Project area is important in that proposed harvesting of the brine minerals is through the use of large-scale, shallow solar evaporation impoundments. The ideal conditions for this type of process occur in an area that is arid, relatively hot, and windy. The early developers of the Project established two weather stations that recorded climatic conditions at the playa for a period during the late 1970s. Data from the period of late June through early September 1979 (Gwynn, 2006) show daytime temperatures to average about 30°C (86°F) and night-time temperatures about 12.2°C (54°F). Wind speeds recorded during spring through fall averaged 24 to 32 km per hour (15 to 20 miles per hour).

Exploration activities can be conducted year round, as proven by the 2011/2012 program, which conducted drilling activities from November through April on the BLM leases. Potential mining operations would likely face climatic challenges related to decreased solar evaporation during winter months; however, it is envisioned that management of multiple pond systems at varying stages of development would provide sufficient feed stockpiles to maintain operations throughout the year.

5.3 Local Resources

The nearby towns of Delta and Milford are small material supply centers and sources of local labour. Milford’s population in the 2010 census was 1,420 and Delta’s was 5,018. Both towns are on the UPRR line connecting Salt Lake City and Las Vegas. Milford has UPRR facilities for its workers, since it is the halfway point between the two major cities. The proximity of the railroad and the Black Rock siding is attractive from a market access standpoint.

Labour would likely be recruited both locally and from throughout Utah and the Rocky Mountain west. The southwest Utah region has a history of mining for precious and base metals, alunite, and uranium, and likely would be a source for both skilled and unskilled labour. The operations producing both potash and halite from brine at the Great Salt Lake and Intrepid Potash Inc.’s (Intrepid’s) Wendover, Nevada facility suggest the availability of personnel skilled in the crystallization, harvesting, and processing aspects of brine mineral production.

5.4 Infrastructure

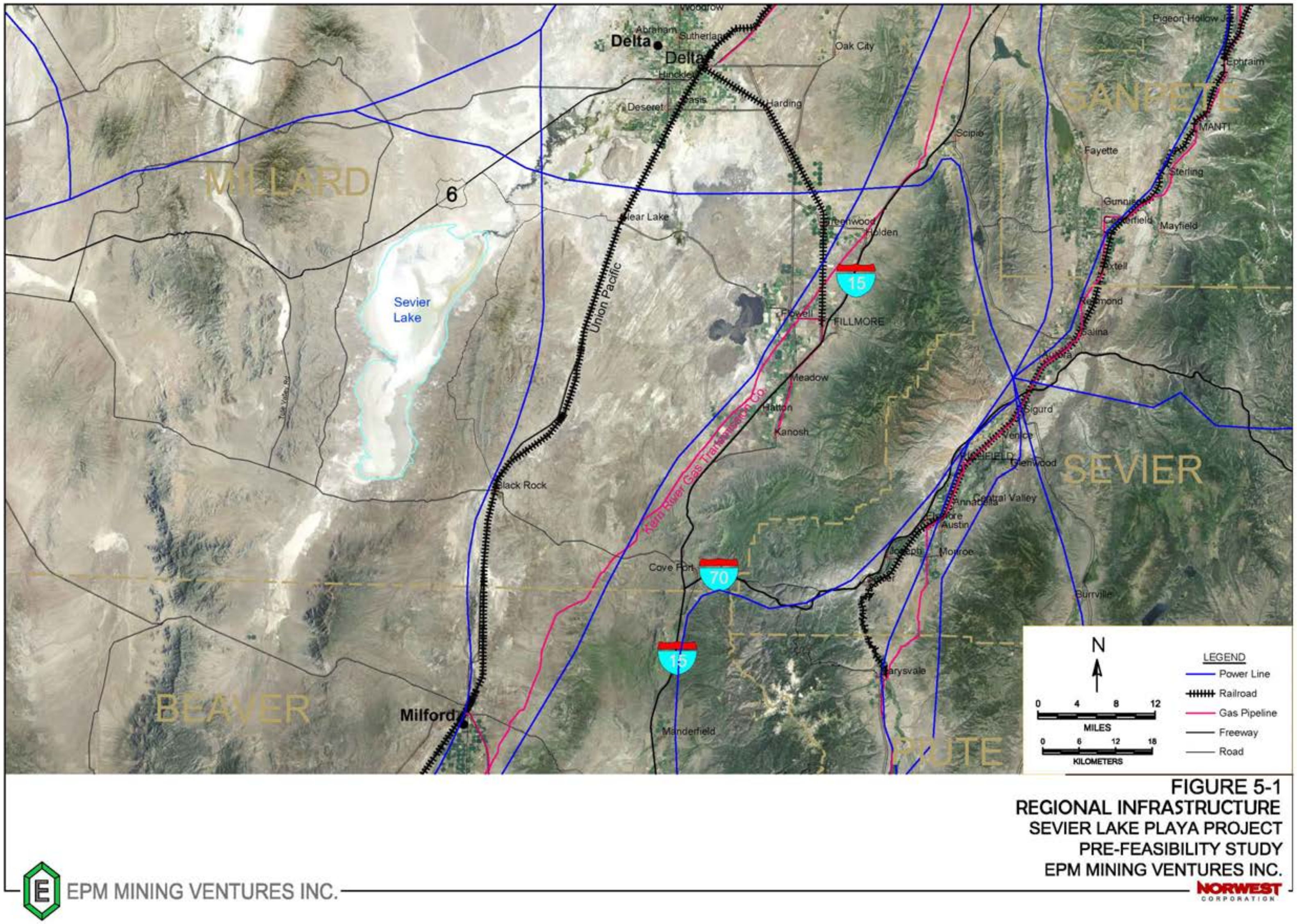
The property has undergone a limited amount of development with no known mining or commercial mineral harvesting having taken place to date. Largely in an undisturbed natural state, the property had no permanent dwellings or structures until recent construction of a warehouse and storage area near the southern end of the playa by EPM. Two completed operational water supply wells, managed by BLM for stock use, are located just off of the playa with small storage tanks at the wellheads. The road connecting the southern portion of the lake to the SR 257 has been upgraded with road base in anticipation of the future siting of a minerals processing plant in that area. Figure 5-1 shows the local infrastructure surrounding the Project with topography and satellite image, respectively.

Development work within the playa is limited to the excavation of a 7.7-km-long (4.8-mile-long) brine collection canal in the late 1980s, which was dug into the lakebed sediments approximately 6 m (20 ft) deep and bermed along the edges several meters (feet) above the playa surface, as well as several evaporation ponds that were to be fed by the canal via a series of feeder dikes. The canal, ponds, and feeder dikes remain in place in the south central margin of the playa, although the canal has been largely silted-in since brine collection and evaporation ceased in 1993.

Infrastructure components such as electric power, natural gas supply, and minerals processing plant siting are discussed in detail in Section 18. To summarize, access routes to power sources suitable for a commercial processing operation are being determined and negotiations for take-off have commenced with the local power company. Sources of natural gas would be through the Kern River Pipeline and discussions with the pipeline owner are underway as well. Plant siting has been located at the southern end of the playa due to its proximity to road and rail transportation. The relatively flat valley-bottom south of the lake provides sufficient area for facilities, waste, and product storage.

The Sevier Lake Playa area has no perennial streams and water that collects on the playa comes from precipitation and the Sevier River. Water to support the processing of minerals crystallized from the brine would have to be sourced from groundwater. EPM is in the process of obtaining sufficient groundwater rights and has submitted water right applications to the State Engineer’s office.

FIGURE 5-1
Regional Infrastructure



5.5 Physiography

The property encompasses the Sevier Lake Playa. The playa is located in western Utah's Sevier Desert in a broad valley 16 to 24 km (10 to 15 miles) wide. The playa is bounded on the east by the Cricket Mountains and on the west by the Black Hills portion of the House Range. The San Francisco Mountains lie just to the south of the playa and the Wah Wah Mountains to the southwest, with the Wah Wah valley between them. The dry Wah Wah Lake Playa is located within the Wah Wah valley and is 8 km (5 miles) south of Sevier Lake Playa with similar physiographic conditions. To the north of Sevier Lake Playa is the gently south-sloping surface of the Sevier Desert. The playa covers an area of approximately 52,609 ha (130,000 acres) at an altitude of about 1,376 m (4,514 ft) above MSL. The mountains east and west of the Sevier Lake Playa are at an altitude of generally above 2,438 m (8,000 ft) above MSL.

The Sevier River is the main source of water that flows into the terminal Sevier Lake Playa. Inflow from the Sevier River is unpredictable during most years because of reservoir storage and the heavy demand for irrigation water upstream. Satellite imagery acquired from August 1999 through August 2002 (Gwynn, 2006) indicates water to be on the surface of Sevier Lake Playa typically during November through April, though likely amounting to only several inches in depth and the result of local atmospheric conditions. During the remainder of the year (May through October), the majority of the playa's surface appears to be dry.

According to Gwynn (2006), water of abnormal depth was probably present on the lake from 1913 to 1915 and from 1922 to 1923. Additionally, during the period from 1983 through 1985, Sevier Lake Playa filled with water due to the above-average inflow from the Sevier River. At its peak, the depth of surface water was nearly 4 m (13 ft) above the playa, as reported by Larry Sower of CPMC (Gwynn, 2006). From 1986 through 1988, inflow to the playa was reduced significantly and the depth of the water declined.

Record snowfall and precipitation through the winter and spring of 2011 caused unusually high water levels in the numerous reservoirs along the course of the Sevier River. Consequently, water management authorities found it necessary to release retained water during the fall and early winter of 2011, rather than in the spring when it is used for irrigation and consumed before reaching the playa. The exploration activities conducted from November 2011 to April 2012 had to deal with surface water ranging from 0.3 to 0.6 m (1 to 2 ft) in depth.

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SECTION 6
History

As early as the late 1800s, various topographic surveys were conducted in the Sevier Lake Playa region. In 1869, the U.S. Army Corps of Engineers (USACE) led by First Lieutenant George M. Wheeler determined the true position of the playa (Gwynn, 2006). Between 1869 and 1977, most mapping work in the region focused on improving topographical and surface geology information with scientific studies undertaken in the 1960s for the purpose of assessing the lakebed mineralogy and brine chemistry. These studies served as the basis for more-detailed exploration and bulk sampling by CPMC starting in 1977.

6.1 CPMC Ownership

CPMC assembled a 53,823-ha (133,000-acre) lease position that encompassed the entire surface of Sevier Lake Playa, including the current Project area. In 1978, four holes were drilled by CPMC to depths ranging from 215 to 297 m (705 to 975 ft) to test the chemical composition of the deep sediments and brine. During the period 1979 to 1983, over 700, 6-m-deep (20-ft-deep) auger wells were completed by CPMC throughout the playa to test the composition of the brine and sediments, thickness of salt crust, and to characterize the mineralogy and brine content of the lakebed sediments. A deep brine test well was installed in 1988 to evaluate the brine composition near the 61-m (200-ft) depth level.

Weather stations were established to measure climatic conditions and Class A evaporation pans were erected to determine fresh water evaporation rates. Small-scale evaporation ponds were constructed on the floor of the playa to determine brine evaporation rates and to study the phase chemistry of evaporating brine and precipitated salts. The flooding of Sevier Lake Playa between 1983 and 1988 proved a major setback to the Project since up to 4 m (13 ft) of water covered the playa surface, destroying the weather stations and some of the experimental ponds, and delaying work on the Project.

After the period of flooding, CPMC resumed its work on the playa. A 5.6-km-long (3.5-mile-long) protective dike—separating the playa into a north half and a south half—was designed but never constructed. This dike would have been located at Needle Point. Interior dikes for a 1,214-ha (3,000-acre) solar evaporation pond system were constructed; a north trending, 7.7-km-long (4.8-mile-long) brine collection canal was dredged, and roads and a campsite were constructed. The solar evaporation pond system was completed in 1987 and it was reported that more than 1 million U.S. short tons[1] (Mtons) of salt was precipitated from the brine to create permanent salt floors in the ponds of sufficient thickness to support heavy salt-harvesting equipment.

[1] U.S. Customary Unit short tons (1 ton=907.2 kilograms [kg]/2,000 pounds [lbs])

Salt and high-magnesium chloride brine were produced in 1989 and 1990 and test ponds operated to produce low-grade potash salts. In addition, engineering designs for salt washing, drying, bagging, and load-out facilities were completed, and CPMC developed a flow sheet for the future production of SOP.

The demise of the Project, however, came with the death of Mr. W.D. Haden, the project's financier. On Mr. Haden's death, funding for the Project was terminated. In May 1993, representatives of CPMC filed the "Relinquishments on Federal Potassium Leases" papers. After CPMC performed the required reclamation work, their Sevier Lake Project was abandoned.

6.2 Salada Ownership

Salada assembled 6,216 ha (15,360 acres) of federal sodium leases in 1997 covering only the south end of the playa. Salada also held 518 ha (1,280 acres) in five separate sections of SITLA potassium leases. Salada's leaseholds also went through the EA process culminating in a FONSI by BLM issued in June 1997.

It is Norwest's understanding that Salada's lease holdings were relinquished and that Salada performed no exploration or mining. However, both CPMC and Salada did estimate potential tonnages of halite and potash, as well as other product mineral assemblages that could be produced from Sevier Lake Playa brine.

6.3 EPM Ownership

Emerald Peak acquired five SITLA leases in September 2008 and completed four wells in the southern portion of the playa to monitor and confirm brine chemistry. Peak Minerals acquired its 48 federal potassium leases by competitive bid in April 2011. LUMA acquired its 11 federal potassium leases on the same date and entered into the Cooperative Development Agreement with Peak Minerals on April 5, 2011.

Peak Minerals initiated an exploration and brine sampling program consisting of 21 holes on the SITLA leases during the month of August 2011. Following a lengthier federal permitting process, a full-scale program of exploration, brine and sediment sampling, and hydrologic well installation and testing was initiated in November 2011. The 2011/2012 field component of the program was completed in April 2012 and then moved into hydrological data collection and analysis. Additional drilling, during February and March 2013, provided data within the LUMA lease area and infill on the state and federal leaseholds.

This Technical Report is a culmination of the brine resource exploration work conducted by EPM since August 2011 and documents activities, results, and conclusions from the exploration drilling and sampling. Current brine resource estimates are presented, as well as hydrological characterization, processing studies, and economic analysis.

No known commercial extraction operation has occurred on the property. As previously stated, CPMC performed some limited test production but not on a commercial scale.

6.4 Historical Product Tonnage Estimates

Godbe (1984) representing CPMC and Rasmussen (1997) representing Salada estimated the potential tonnages of halite, salt cake, potash, and bitterns that could be produced from salts resulting from solar evaporation of brine collected from the first 6 m (20 ft) of sediment below the Sevier Lake Playa surface. Both CPMC and Salada estimated the theoretical tonnages of precipitated potassium, magnesium, sodium, chloride, and sulphate from the average brine chemistries and then used the molecular mass of these ions to calculate tonnages. The following potential products were estimated from these ions:

- Halite ($NaCl$)
- Salt cake (Na_2SO_4)
- Potash (KCl or K_2SO_4)
- Bitterns ($MgCl_2$ or $MgSO_4$)

The average brine chemistries used for the tonnage estimates appear to be derived from analyses of brine samples collected from CPMC drill holes and the brine collection canal. The average brine chemistries could not be confirmed by Norwest. Given that the data available at the time of this Technical Report are from unverifiable historical documents, lack documentation of sampling or labouratory methods, and were reported prior to NI 43-101 guidelines being established, these historic estimates are not considered to be consistent with NI 43-101 standards. The historical tonnage estimates provided by Godbe (1984) and Rasmussen (1997) should be viewed as providing a theoretical basis for the potential to produce potash and/or other salt products from Sevier Lake Playa. Although the past work was significant, EPM intentionally did not pursue a validation of historical data, but moved forward with a plan to define a current resource using new drilling and sampling data.

6.5 CPMC Tonnage Estimates

Area of leases controlled by CPMC nearly covered the entire Sevier Lake Playa and Godbe's (1984) tonnage estimates for the first 6 m (20 ft) of the playa best illustrate the entire playa's potential to produce a range of salt products from the brine. Godbe's product tonnage estimates are based on the assumptions outlined in Table 6-1 and the tonnage estimates are listed in Table 6-2.

Based on the available data that have been reviewed, the assumptions used by CPMC appear to be conservative with the exception of the 56,656 ha (140,000 acres) areal estimate, which is slightly larger than the playa surface area of 52,609 ha (130,000 acres). The additional 4,047 ha (10,000 acres) are most likely the lateral area of the playa between the low and high water marks. The percent intra-formational brine (25 percent) used in Godbe's calculations is less than the water saturation levels determined from CPMC auger samples, which suggest an average saturation level of 30 percent. Additionally, the brine density of 1.03 grams per cubic centimeter (g/cm^3) (64 pounds per cubic foot [lb/ft^3]) is less than an average of approximately 1.10 g/cm^3 (68.7 lb/ft^3) calculated from brine sample data.

TABLE 6-1
CPMC Assumptions For Tonnage Estimates

Area (ha/acre)	56,656/140,000
Depth (m/ft)	6/20
Percent intra-formational brine	25%
Density brine (g/cm^3/lb/ft^3)*	1.03/64
Mtons brine to 6 m (20 ft) depth	975.74

* Density of water at 62 lb/ft^3 plus addition of 2 lbs salt

TABLE 6-2
CPMC Product Tonnage Estimates

Calculated Ionic Mass				Calculated Equivalent Compounds		
Ions	**Brine Wt%**	**Mtons Ions**	**Atomic Mass**	**Theoretical Product**	**Mtons Product**	**Product Type**
Na	7.200	70.25	23.0	KCl	6.69	Potash
Cl	11.250	109.77	35.5	$MgCl_2$	8.39	Bitterns
Mg	0.435	4.24	24.3	$MgSO_4$	10.60	Bitterns
K	0.360	3.51	39.1	Na_2SO_4	18.64	Salt Cake
SO_4	2.160	21.08	96.1	NaCl	163.29	Halite
Total	-	**208.86**	-	-	**207.61**	

Source: Godbe, 1984

Differences in total tonnages for the ions and products are most likely associated with rounding errors in the calculations and are viewed as materially insignificant. Theoretical tonnage estimates of muriate of potash (MOP) can be replaced by SOP on a 1:1 ratio (Godbe, 1984).

6.6 Salada Tonnage Estimates

Salada's lease areas included only southern portions of the Sevier Lake Playa (i.e., the area south of Needle Point). Rasmussen's (1997) product tonnage estimates are based on the assumptions outlined in Table 6-3 and the tonnage estimates are listed in Table 6-4.

The assumptions used by Salada for percent intra-formational brine and density appear to be closer to the values determined from the auger sampling than the CPMC estimates. The average brine chemistries are within expected ranges based on brine chemical analyses determined from the auger samples as presented in Section 12. Differences in total tonnages for the ions and products are most-likely associated with rounding errors in the calculations and are viewed as materially insignificant.

TABLE 6-3
Salada Product Tonnage Estimates

Area (ha/foot)	6,734/16,640
Depth (m/ft)	6/20
Percent intra-formational brine	28%
Density brine (g/cm^3/lb/ft^3)	1.14/71
Mtons brine to 6 m (20 ft) depth	144.44

TABLE 6-4
Salada Product Tonnage Estimates

	Calculated Ionic Mass			Calculated Equivalent Compounds		
Ions	**Brine Wt%**	**Mtons Ions**	**Atomic Mass**	**Theoretical Product**	**Mtons Product**	**Product Type**
Na	6.880	9.91	23.0	KCl	0.96	Potash
Cl	11.175	16.1	35.5	$MgCl_2$	1.17	Bitterns
Mg	0.411	0.592	24.3	$MgSO_4$	1.48	Bitterns
K	0.350	0.504	39.1	Na_2SO_4	2.74	Salt Cake
SO_4	1.290	1.87	96.1	NaCl	24.37	Halite
Total	-	**28.98**	-	-	**30.72**	

Source: Rasmussen, 1997

Both the CPMC and Salada tonnage estimates are not consistent with NI 43-101 standards for the reporting of mineral resources and are presented for historical perspective of product tonnage estimates of the first 6 m (20 ft) below the playa surface only. EPM is not treating these as current mineral resource estimates. A QP has not performed sufficient work to classify these estimates as current mineral resources or mineral reserves.

6.7 Prior EPM Estimates

A resource estimate in accordance with NI 43-101 standards has been performed for EPM and reported in two prior technical reports. The estimate was based on the results of the 2011/2012 drilling performed by EPM and had an effective date of May 1, 2012. The initial report was produced for EPM by Norwest and was dated May 31, 2012 (Norwest, 2012). Subsequently, the same resources were used as the basis of a Preliminary Economic Assessment (PEA) commissioned by EPM from March Consulting Associates, Inc. of Saskatoon, Saskatchewan, Canada, released on (and with an effective date of) November 16, 2012 (March, 2012). The effective date of the resource estimate delineated in the PEA remained May 1, 2012.

The May 1, 2012 resource estimate projected a total measured plus indicated resource consisting of the following dissolved cations and anions calculated from the brine resource by Wt% (Table 6-5).

TABLE 6-5
Brine Mineral Resource Summary and Major Dissolved Cations and Anions (Effective Date May 1, 2012)

	Brine Resource	Potassium (K)		Sulphate (SO_4)		Chloride (Cl-)		Sodium (Na)		Magnesium (Mg)	
Category	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**	**Wt%**	**Mt**
Measured	3,362	0.278	9.343	2.051	68.971	8.158	274.287	6.903	232.098	0.343	11.536
Indicated	1,576	0.247	3.885	2.078	32.738	6.959	109.653	6.586	103.776	0.322	5.081
Measured plus Indicated	4,938	0.268	13.228	2.060	101.709	7.775	383.940	6.802	335.874	0.337	16.617
Inferred	1,653	0.243	4.017	2.238	36.995	7.119	117.692	6.590	108.940	0.339	5.600

The tonnage of mineral equivalent compounds that could be created using the available cations and anions in the brine resource was reported as shown in Table 6-6 for the combined federal, state and LUMA leases.

TABLE 6-6
Mineral Equivalent Compounds from Brine Resource (Effective Date May 1, 2012)

Classification	Tonnes Mt				
	Potash K_2SO_4	**Bitterns $MgCl_2$**	**Bitterns $MgSO_4$**	**Salt Cake Na_2SO_4**	**Halite NaCl**
Measured	20.826	22.621	11.436	51.277	424.222
Indicated	8.659	9.964	12.589	26.492	168.463
Measured plus Indicated	29.485	32.585	41.167	77.769	592.686
Inferred	8.953	10.982	13.874	31.029	193.636

The two prior estimates also reported an inferred potassium resource of 4.02 Mt (4.43 Mton) with an equivalent inferred potash compound equivalent of 8.95 Mt (9.87 Mton).

The resource estimates reported in the two prior technical reports did not include drill results from the 2013 exploration program and have been superseded by the estimates presented in this Technical Report. There is no guarantee that all or any part of the past or current estimated resources would be recoverable. Mineral resources that are not mineral reserves do not have demonstrated economic viability.

SECTION 7

Geological Setting and Mineralization

Sevier Lake Playa is located within the Basin and Range physiographic province. The Basin and Range physiographic province covers over 10 percent of the continental U.S., including all of Nevada and parts of Idaho, eastern Oregon, Utah, Arizona, and southeastern California. Formation of the Basin and Range province began during the Miocene, approximately 24 to 25 million years ago, during regional uplift of a sizeable portion of the western U.S. In this formative period, the east-west extension of the continental crust resulted in uplifted north-south trending mountains (horsts) and intervening, down-dropped valley platforms (grabens), bounded by normal faults. Subsequent erosion of the mountains led to sediment-filled valleys of the grabens. It is in one of these north-south-trending sediment-filled valleys where the Sevier Lake terminal playa was formed.

7.1 Sedimentation and Associated Mineralization

The subsequent Pleistocene period was characterized by the deposition of lacustrine shore deposits from Lake Bonneville along the high-lying areas surrounding what is now the Sevier Lake Playa. As Lake Bonneville receded from its maximum extent from southern Idaho to southwestern Utah, a fresh water lake (Lake Gunnison) remained in the Sevier Desert Basin. Lake Gunnison emptied into the Great Salt Lake to the north through the Old River Bed (Rasmussen, 1997) north of the Sevier River. Further decline in the Lake Gunnison water levels ended with the present day isolation of the Great Salt Lake in the north and Sevier Lake in the south, as can be seen in Figure 4-1. Continued desert-forming conditions and drought through the Quaternary period to present contributed to the current brine accumulation in unconsolidated lacustrine and alluvial sediments below the playa surface.

Figure 7-1 shows that the north-south-trending mountains surrounding Sevier Lake Playa exposed Paleozoic basement rocks as a result of uplift during the Basin and Range orogeny. The Cricket Mountains in the east expose Cambrian-age quartzites and limestones, while the Black Hills/House Range Mountains in the west are composed of Ordovician-age dolomites. Below the playa and on the lower-lying margins of the surrounding mountains, a layered series of sedimentary deposits and erosional features of Pleistocene and Quaternary age have been surface mapped and observed from drill cuttings. These largely unconsolidated sediments are composed of a mix of sand, marl, and clay. The courser-grained sandy and marly layers contain saturated and semi-saturated levels of brine and water that have accumulated in the subsurface over the dry Quaternary period.

As suggested by Case and Cook (1979), the depth to bedrock may be as deep as 1,372 m (4,500 ft). Four wells drilled by CPMC on the margins of the playa show the basin sediment to be a minimum of 297 m (975 ft) deep, since no Paleozoic bedrock was encountered in these holes. EPM drilled a hole in lake sediments to 152 m (497 ft) in depth as well. Lithologic logs of these holes illustrate mainly fine-grained, gray-green to brown clays with minor amounts of gypsum, sand, silt, salt, and carbonaceous and vegetal material from surface to total depth.

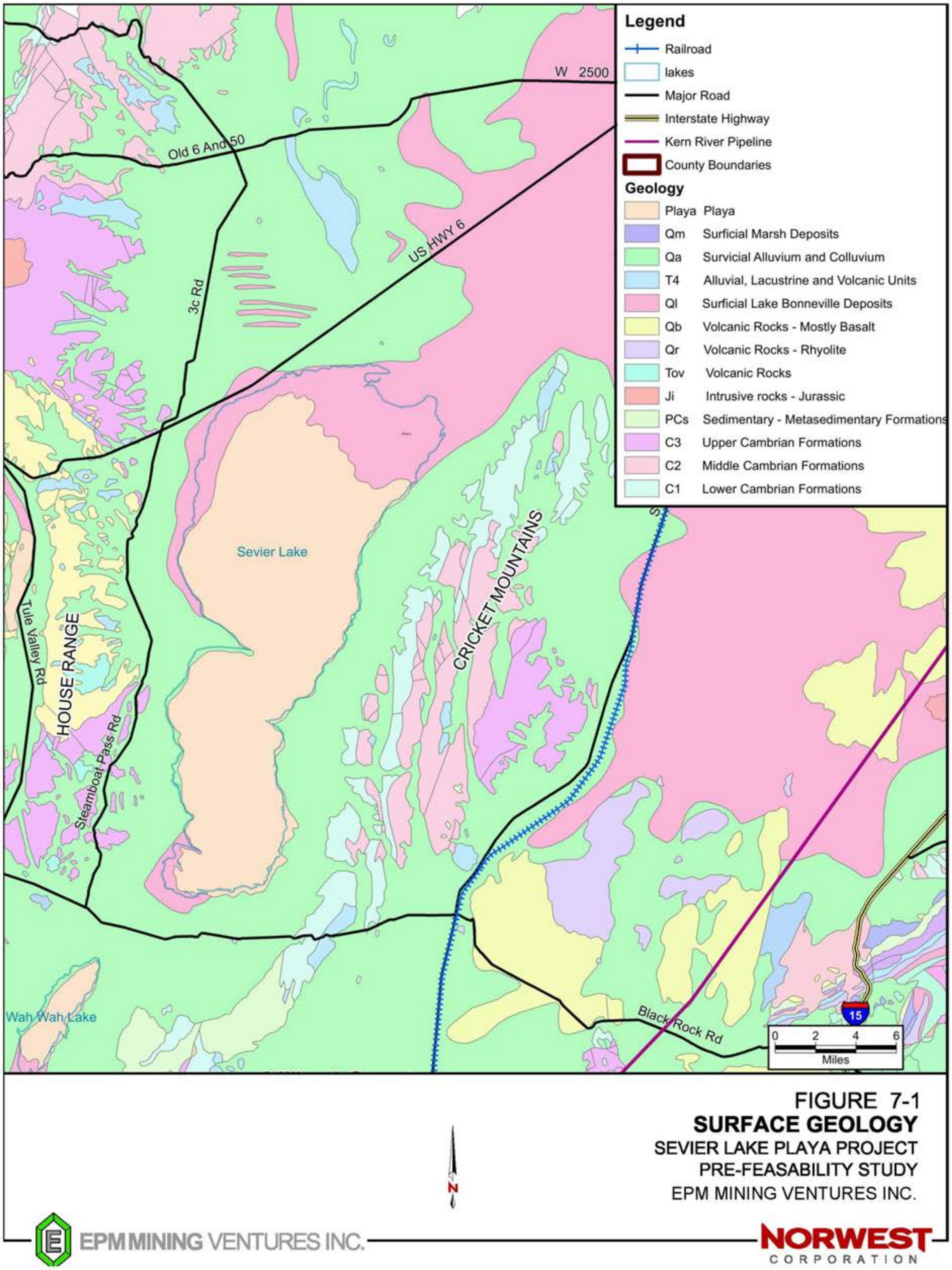
7.2 Geologic Structure

A detailed structural study of the region was undertaken by Case and Cook (1979) after completing a gravity survey in the area. Their interpretation of the Sevier Lake Playa structure is illustrated in Figures 7-2 and 7-3. Figure 7-4 shows an additional interpretation incorporating some of the lithologic intercepts from surrounding water wells and deep lake exploration holes. Between the playa and the Cricket Mountains to the east, a major north-south-trending normal fault zone exists, designated as the East Sevier Lake Fault Zone. There is an estimated vertical displacement of over 1,219 m (4,000 ft) with down-throw on the west. This fault zone forms the east margin of the east-tilted Sevier Lake graben and the west margin of the east-tilted Cricket Mountains horst. The Sevier Lake graben is bordered on the west by the West Sevier Lake Fault Zone. The graben that underlies Sevier Lake Playa reportedly consists of two separate fault blocks, designated as the northern and southern blocks. These two blocks have been displaced differentially with respect to each other and with respect to the adjacent mountain blocks.

7.3 Mineralization

Composition of the crust covering the playa consists of evaporite minerals and is up to 0.45 m (18 in) thick as determined from drilling and augering data. Evaporite minerals forming the crust tend to be zoned on the playa surface with halite being the dominant mineral in the center of the lakebed, followed by glauberite and then gypsum near the playa shore (Gwynn, 2006; Rasmussen, 1997).

FIGURE 7-1
Surface Geology



Soluble salts in the sediment-hosted brine are the target mineralization of current development work. The source of soluble salts is the erosion and leaching of Paleozoic-era bedrock in the Sevier and Bear River drainages. Observation and sampling of playa sediments and brine have identified the following features that characterize the top 30m (100 ft) of the deposit:

- Salt crust up to 0.45 m (18 in) thick
- Lateral zonation in crust mineral chemistry
- Variation in brine saturation both laterally and with depth
- Variation in sediment grain size distribution
- Artesian brine flow in some areas
- Elevated concentrations of sodium, potassium, magnesium, calcium, chloride, and sulphate in the brine

These features influence to varying degrees the target brine extent (volume) and potential for production of potash, halite, and bitterns from the brine. The focus of the resource estimates presented in this Technical Report are two shallow (depths less than 30m [100 ft]) brine horizons termed the URZ and LRZ. The combined URZ and LRZ horizons vary from 12 to 30 m (40 to 100 ft) in depth from the surface and are bound at the base by a stiff clay horizon. Drilling to date is insufficient to accurately determine a brine resource potential below these two shallow aquifers.

Past and present development efforts have focused on using large-scale solar evaporation ponds to extract salt compounds from the brine through concentration and fractional crystallization. The extent to which the mineralization can support an ongoing operation of extraction is currently being studied.

FIGURE 7-2

Gravity Survey Interpretation – Case and Cook (1979)

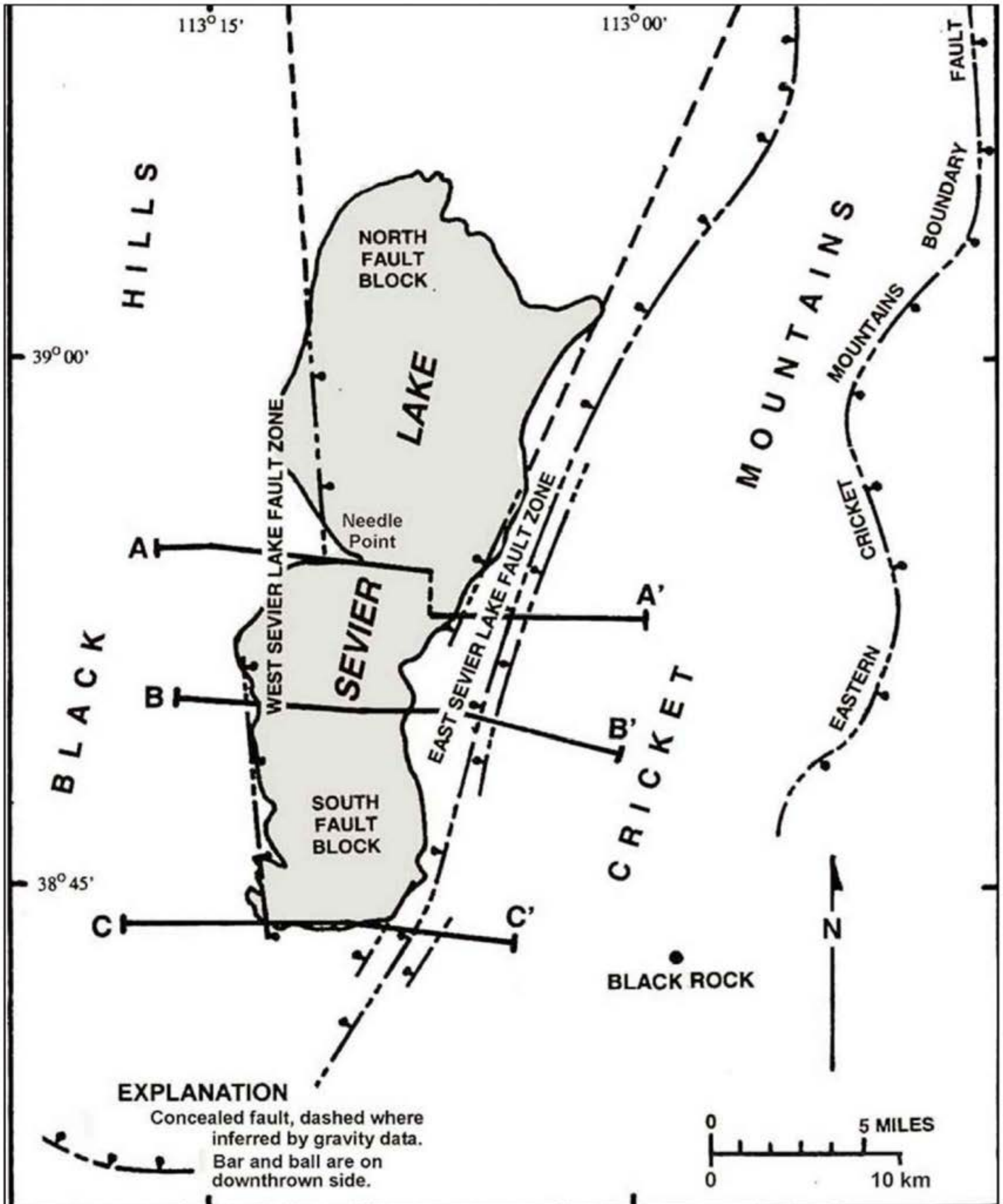


FIGURE 7-2
GRAVITY SURVEY INTERPRETATION CASE AND COOK (1979)
SEVIER LAKE PLAYA PROJECT
PRE-FEASIBILITY STUDY
EPM MINING VENTURES INC.
EPM MINING VENTURES INC.
NORWEST CORPORATION

FIGURE 7-3
Gravity Survey Sections – Case and Cook (1979)

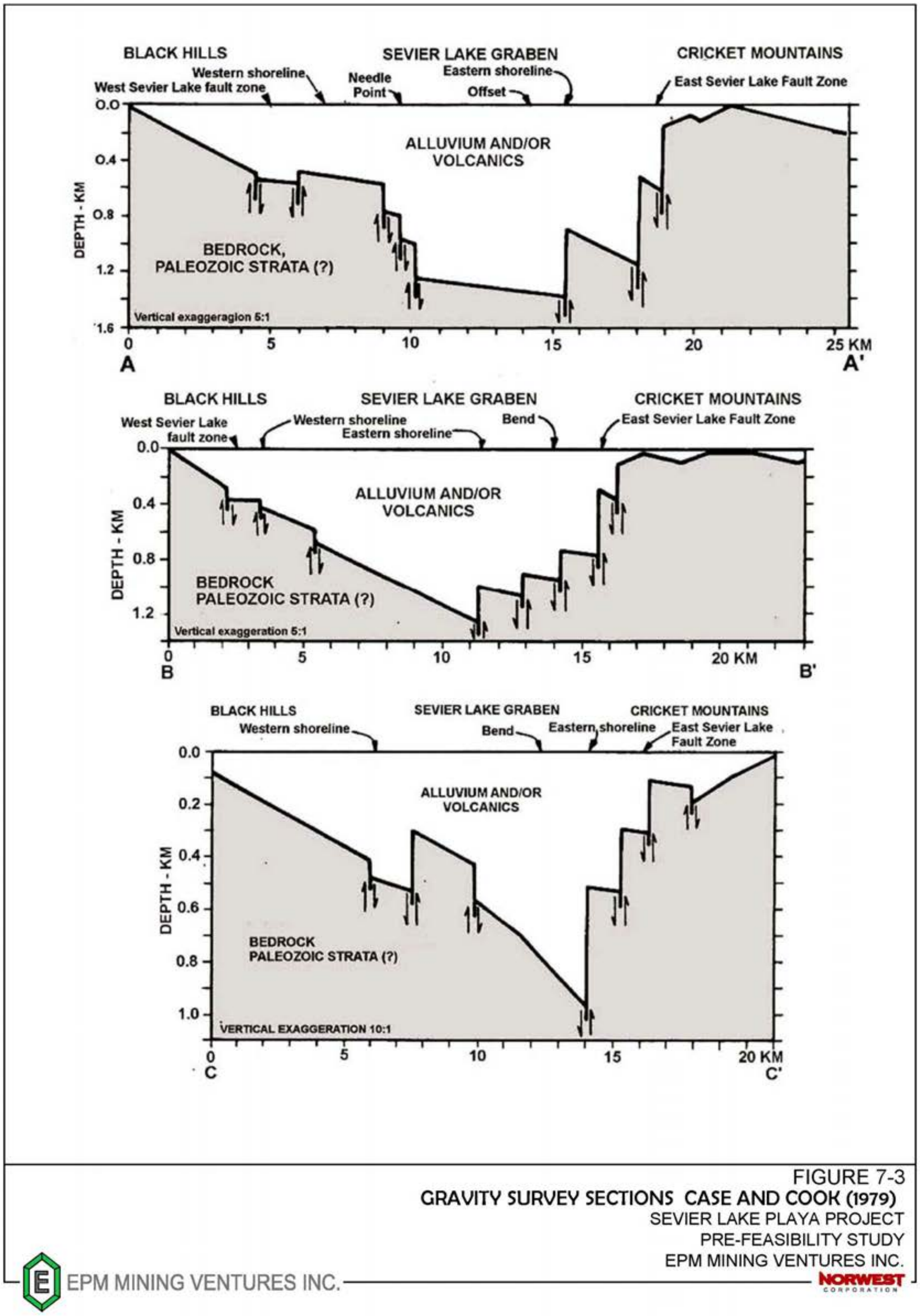
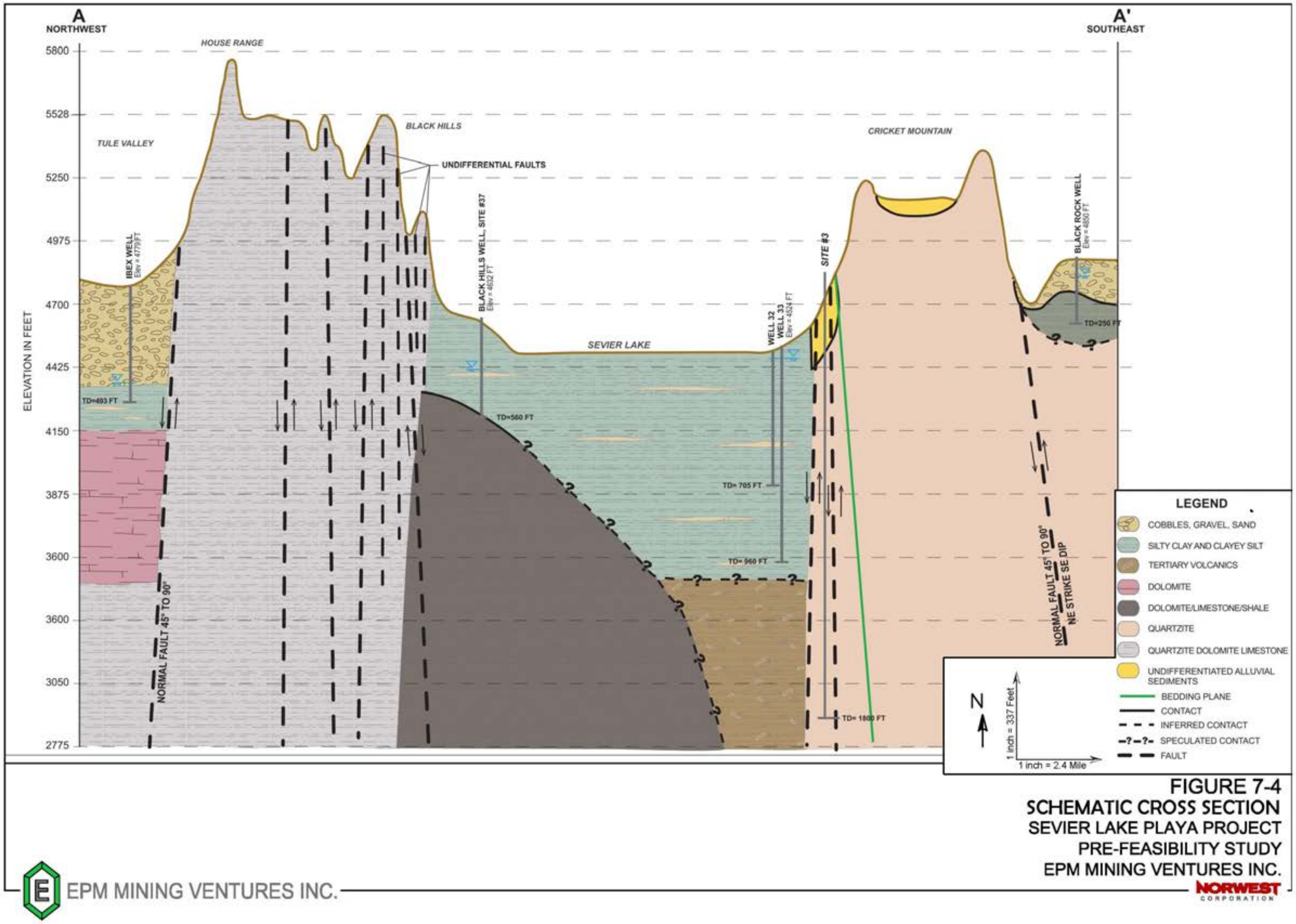


FIGURE 7-4

Schematic Cross-section – after Case and Cook (1979)



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Deposit Types

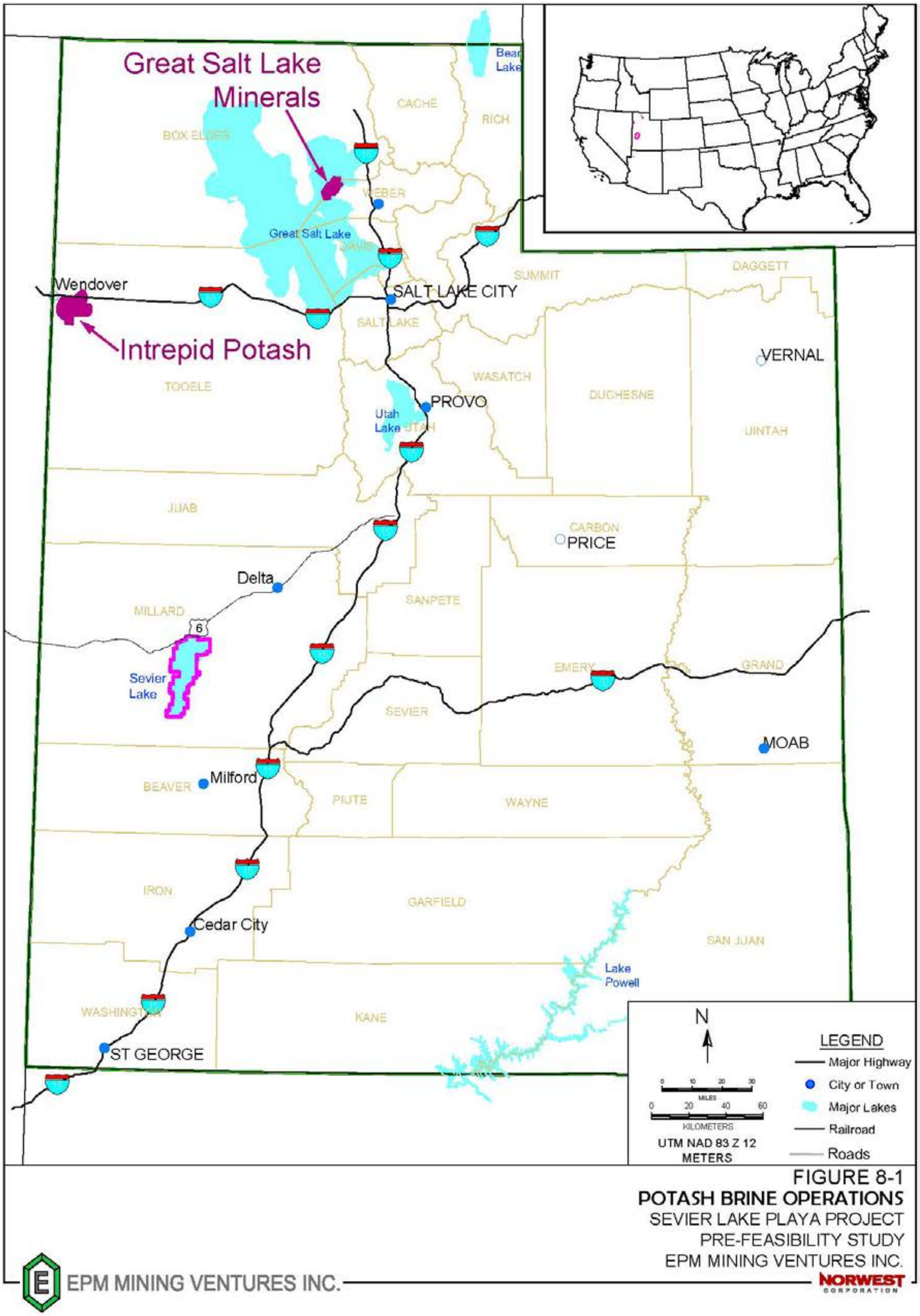
The deposit type is a terminal lakebed brine deposit. The brine deposit is sedimentary in origin and composed of the natural concentration of mineral salts in groundwater found in the terminal lakebed. The brine is contained within the unconsolidated lakebed sediments composed primarily of clay and marl. While the sediments may play a role in the mineral occurrence, development efforts to date have focused primarily on the mineral content found in the brine. The interaction between the brine mineralization and their potential for recharge by water flowing through the lakebed sediments bears further investigation.

Most of the world's potash occurrences are found in subsurface bedded salt deposits that can yield high-grade ore amenable to underground mining or in-situ recovery methods. The playa lakes of Utah and of "salars," a similar physiographic environment found along the eastern Andes region of Chile and Argentina, are areas where vast resources of brines have been identified. These mineral brines are sought for not only their potash but for other valuable minerals such as lithium and boron (B_2O_3).

The market generally refers to two primary types of potash—MOP and SOP. Eighty-eight percent of the potash used in fertilizer is in the form of MOP; the remainder is primarily from SOP, which typically commands a premium price. SOP rarely occurs naturally; most is produced synthetically or through beneficiation and processing. Brine deposits rich in sulphates are more likely to produce SOP than chloride-rich brine.

Figure 8-1 shows the location of Sevier Lake Playa in relation to the other two mineral brine occurrences in Utah—the Great Salt Lake and the Great Salt Lake Desert—where Great Salt Lake Minerals Corporation and Intrepid, respectively, are producing potash products. While the two operations produce potash, GSL produces SOP by solar evaporation of the brackish surface waters of the Great Salt Lake while Intrepid produces MOP through solar evaporation of brine collected as groundwater through an extensive canal system leading to its solar evaporation ponds near Wendover, Nevada. The Intrepid operation is the closest corollary to Sevier Lake Playa in that the brine occurs as groundwater hosted in fine-grained sediments and evaporites. However, the brine chemistry at Intrepid's Wendover operation is more suitable for MOP production due to its lack of sulphates.

FIGURE 8-1
Existing Potash Brine Operations



8.1 Mineral Deposit Type

The mineral salts typically found in solution may be precipitated from the brine by concentration due to solar evaporation, as has occurred since the ancestral lake became landlocked. The most common evaporite mineral is halite. Other less common precipitated minerals include glauberite, limited amounts of gypsum, schoenite, leonite, epsomite, thenardite (Na_2SO_4), carnallite ($KMgCl_3$-$6H_2O$), sylvite, hexahydrite ($MgSO_4$-$6H_2O$), bischofite ($MgCl_2$-$6H_2O$), and starkeyite (cranswickite) ($MgSO_4 \cdot 4H_2O$).

Major ionic concentrations in the brine include sodium, magnesium, potassium, chloride, and sulphate. Additional elements and chemical compounds present in low concentrations include lithium, uranium, boron, and bromine. The natural concentration of these elements in the brine provides an opportunity to produce halite, potash (either MOP or SOP), and bitterns by means of precipitation, harvesting, and processing of mineral salts from solar evaporation ponds located on the playa surface. SOP is the targeted mineral compound of the development efforts of the Sevier Lake Playa Project.

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SECTION 9

Exploration

Numerous exploration programs and scientific studies have focused on the Sevier Lake Playa deposit, climate, sediment and brine characterization, and potential for production of potash and related minerals. These works are historic and have only marginal context to the objective of defining a current mineral resource for the property.

The Norwest 2011 Technical Report describes past exploration and development work in some detail, and Gwynn (2006) in rather more depth. Key items to note include the 1979 gravity survey by Case and Cook relative to delineation of potential depth of basin sediments; and the CPMC exploration campaigns consisting of over 700 shallow auger holes, several deep reverse circulation holes, and excavation of a brine collection canal at the south end of the playa.

A topographic survey was conducted to locate the collars of the boreholes drilled during the 2011/2012 exploration program and to define accurately the lakebed margin and delineate the potential resource area. The playa surface was surveyed with transects and the playa margin was delineated with a dense array of survey points. The playa margin data were validated using a 1,381-m (4,530-ft) contour to remove all points falling outside of this contour to prevent spillways in the hydrologic model. These data were incorporated into the geologic model used in the current resource estimate, and were later updated with locations of the collars of boreholes drilled during the 2013 exploration program.

A series of wells and trenches have been completed for the purpose of hydrological characterization of the brine resource. Wells have been completed for pumping tests and other hydrologic tests. The Project has moved into a stage of detailed hydrologic characterization as described in subsequent sections of this Technical Report.

No down-hole, wire-line geophysical surveys were conducted in support of resource delineation; however down-hole geophysics is being used for further hydrological characterization. Besides the Case and Cook gravity survey, the author is not aware of any other ground or areal geophysical surveys that may have been performed.

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Drilling

10.1 Historic Drilling

The great majority of historic drilling was conducted by CPMC. Over 700, 11.4-cm-diameter (4.5-in-diameter) auger holes were completed between 1979 and 1983. The holes extracted lakebed sediments down to a depth of 6 m (20 ft) from the surface and were cased with 5-cm diameter (2-in-diameter slotted polyvinyl chloride (PVC) pipe to the end of hole. Attempts were made by CPMC to auger every quarter section; however, the program was unable to cover the entire playa before the project was discontinued. Composite samples containing brine and sediment were extracted from those holes taken at 1.5-m (5-ft) intervals. These sediment and brine samples were used for the following purposes:

- Mapping of surface crust
- Mapping of surface mineral chemistries
- Determining sediment mineralogy
- Testing of brine water chemistry
- Measuring sediment sample water saturation levels
- Determining depth and extent of brine within 6 m (20 ft) from the surface
- Performing particle size analysis of sediment samples

CPMC conducted additional deeper exploration holes and several additional wells were completed by other parties between 2003 and 2008. The past exploration is significant in providing a historical baseline for brine chemistry and also for identifying potential for developing the property into a shallow aquifer SOP operation. EPM considered a validation program that might use the CPMC drill results but determined that a current data collection program would provide the accuracy and characterization required for mineral resource and reserve reporting.

10.2 EPM Drilling Programs

EPM began planning and implementing its initial drilling program in spring 2011 after the federal leaseholds were awarded. Exploration permits for the SITLA leases were approved in 2011 and it was determined to start with a first phase of exploration drilling on those leases in August of that year to test methodology, procedures, and protocol. The BLM leases were later approved for exploration activities and drilling commenced on those leases in November 2011. In 2011 and 2012, a total of 404 exploration holes were drilled on SITLA and BLM leases, with drilled footage totaling 4,757.6 m (15,866.3 ft). An additional 10 wells were drilled as vertically nested sites on BLM leases bringing the total holes drilled during the exploration phase to 414. During the months of February and March 2013, 17 additional mini-sonic exploration and infill holes were added on the SITLA, Peak Minerals BLM, and LUMA BLM leases, bringing the total number of holes to 431 with a total of 5,579.8 m (18,306.4 ft) drilled.

Exploration holes drilled by EPM used a combination of direct-push and mini-sonic coring techniques. Direct-push drilling is a method where the coring tools are “pushed” or driven into the ground; no core barrel rotation is involved so all the samples are retrieved uncontaminated from the hole. The main application for this method is for drilling various soils, clays, and sands, both consolidated and unconsolidated. Direct-push holes generally penetrated 15 m (50 ft) or less.

Sonic drilling employs the use of high-frequency, resonant energy to advance a core barrel without rotation and, again, is used primarily for sampling unconsolidated sediments. EPM’s mini-sonic drilling was generally shallow, reaching between 15 m (50 ft) and 30 m (100 ft). Two mini-sonic holes were drilled to greater depths (up to 151.5 m [497 ft]) to determine the possibility of deeper aquifers.

Statistics for all drilling from 2011 through 2013 are presented in Tables 10-1 and 10-2, with detailed data for each hole included in Appendix B as Table B-1. Locations of the various well types are illustrated in Figure 10-1. All holes drilled during the EPM program were of vertical orientation.

TABLE 10-1
EPM 2011/2012 and 2013 Programs – Hole Types

EPM Lease	Direct Push	Shallow Sonic	Deep Sonic	Auger	Monitor Twins	Total
Federal	357	33	1	0	10	401
State	17	7	1	1	0	26
LUMA	0	4	0	0	0	4
Total	**374**	**44**	**2**	**1**	**10**	**431**

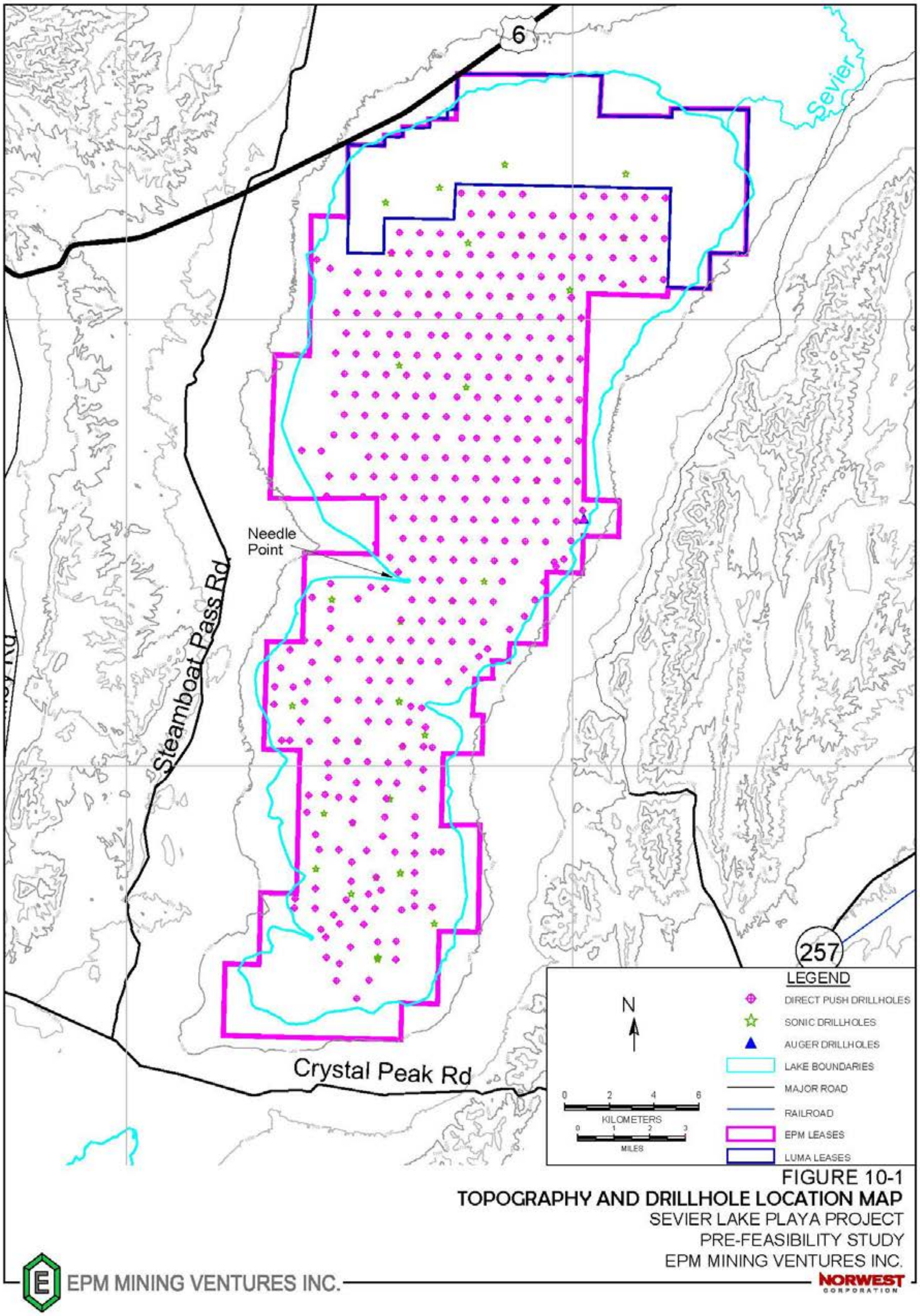
TABLE 10-2
EPM 2011/2012 and 2013 Programs – Exploration Hole Depth Summary

EPM Lease	Number Holes*	Minimum Depth		Maximum Depth		Average Depth		Total	
		m	ft	m	ft	m	ft	m	f
Federal	391	4.6	15.0	151.5	497.0	12.9	42.3	5,043.2	16,545.9
State	26	6.1	20.0	80.8	265.0	17.7	58.1	461.0	1,512.5
LUMA	4	11.3	37.1	24.1	79.1	18.9	62.0	75.6	248.0
All leases	421	4.6	15.0	151.5	497.0	13.3	43.5	5,579.8	18,306.4

* Excludes vertically nested monitoring wells

FIGURE 10-1

Topography and Drill Hole Location Map



10.2.1 SITLA Leases

Initial field activities on the SITLA leases commenced on August 1, 2011, and lasted for approximately 1 month. During that period, 22 holes were completed using a Geoprobe® direct-push rig or a mini-sonic rig. An auger rig was tested on one hole but proved unsuitable both from a rate of penetration perspective but also due to its unsuitable sample quality.

Two to four holes, typically located 760 to 1,070 m (2,500 to 3,500 ft) apart were drilled on seven of the 10 SITLA license blocks. The plan was laid out with the locations occurring in the center of each square meter (mile) section and at the center of each quarter section.

The direct-push rig drilled an 8.3-cm-diameter (3.26-in-diameter) hole and produced a 5.1-cm-diameter (2-in-diameter) soil core in a plastic sample tube, which was opened and logged at the well site by a Norwest geologist. The completed hole was then cased with a 5.1-cm-diameter (2-in-diameter) PVC casing from bottom to 0.75 m (2.5 ft) above the playa surface. The casing was factory slotted from near total depth to typically within 1.5 to 3 m (5 to 10 ft) of surface and then cement placed around a solid piece of casing. A filter sock was secured to the open-bottom end of the casing to prevent sediment incursion. Figures 10-2 and 10-3 are photographs showing the installation of casing and an example of a completed well during the SITLA lease field program.

A mini-sonic rig was also in operation on the SITLA leases during the 2011/2012 program and completed four shallow (less than 30 m [100 ft]) holes and one deep hole to 73 m (240 ft). The rig ran a 6-by-4 configuration, drilling a 15.2-cm (6-in) hole and producing a nominal 8.9-cm (3.5-in) core. The holes were completed in a similar fashion as the 2011/2012 holes with slotted casing from total depth to near surface. The deep sonic hole was screened at two different intervals to evaluate deep versus shallow brine horizons.

The state program showed that much of the sediment consisted of fine-grained clays with thin interbedded horizons of silt or sand. The clays were, however, commonly saturated with brine to a depth of 6 to 10 m (20 to 30 ft), beyond which the clay stiffened. This clay commonly brought the direct-push rig to refusal, or a condition of extremely slow penetration, and the holes were usually terminated at this point.

FIGURE 10-2
Photo of Direct-Push Hole Casing Installation

FIGURE 10-3
Photo of Direct-Push Hole Casing Completion

10.2.2 BLM Leases

The initial BLM lease program lasted from early November through mid-April of 2012. The objective of the program was to complete brine sampling locations at sufficient density throughout all of the EPM leasehold areas to enable a resource estimate of predominantly measured plus indicated assurance categories. A statistical analysis using brine chemistry data and a preliminary model of select ion concentrations indicated that a 900 m (3,000 ft) and 1,500 m (5,000 ft) radius from brine sample locations could be used for delineating measured and indicated assurance areas. A plan was developed using hole spacing of approximately 900 m (3,000 ft) for the federal lease areas. Drilling generally progressed from the south end of the playa northward.

The drilling effort was conducted using one or two direct-push rigs working in conjunction with a mini-sonic rig. The direct-push rig(s) used a system creating a 5.7-cm (2.24-in) hole and yielding a 2.54-cm (1-in) soil core.

Direct-push sample tubes from the federal program were not removed from the plastic sleeves, but were logged at the well site through the sleeve. Pocket penetrometer measurements taken at core sleeve ends were labeled with depths and sealed at the tubing ends. Areas of core loss were noted in the field. This procedure was implemented to accommodate labouratory moisture content analysis without losing moisture from the core due to atmospheric conditions at the well site. The core was later opened, photographed, and logged in the labouratory prior to moisture content analysis. Direct-push holes were completed with 2.54-cm (1-in) PVC casing slotted from total depth to within 1.5 to 3 m (5 to 10 ft) of surface. A surface seal was obtained by pushing a solid piece of 10-cm (4-in) Schedule 40 PVC through the halite surface crust surrounding the 2.54-cm (1-in) casing to a depth of 0.9 to 1.2 m (3 to 4 ft) below the playa surface.

The mini-sonic rig used for the federal program was equipped with an 8-by-6 configuration creating a 20.3-cm (8-in) hole and producing a 15.2-cm (6-in) core. Core samples were laid out for logging by a Norwest geologist; photographed, logged, tested at intervals with a pocket penetrometer; and moisture content samples removed and sealed. The mini-sonic holes were then completed with 10-cm (4-in) slotted PVC, approximately half of the wells from total depth to 1.5 to 3 m (5 to 10 ft) from the surface, the others completed at targeted horizons for further hydrologic testing. Planned test wells were gravel packed through target intervals and otherwise grouted to the surface.

The 2011/2012 federal program faced some unique challenges in drilling operations and transportation of personnel and equipment due to a build-up of surface water at the north end of the playa. This situation was caused by the unusual influx of surface water from the Sevier River. Standing water reaching 0.3 to

0.6 m (1 to 2 ft) in depth was present in the north throughout most of the federal program and required the rigs to be mounted on amphibious marsh and cargo buggies with haulage to and from the drill locations performed by air boat. Figures 10-4 and 10-5 portray some of the conveyance methods used during this period.

FIGURE 10-4
Photo of Pontoon Cargo Buggy

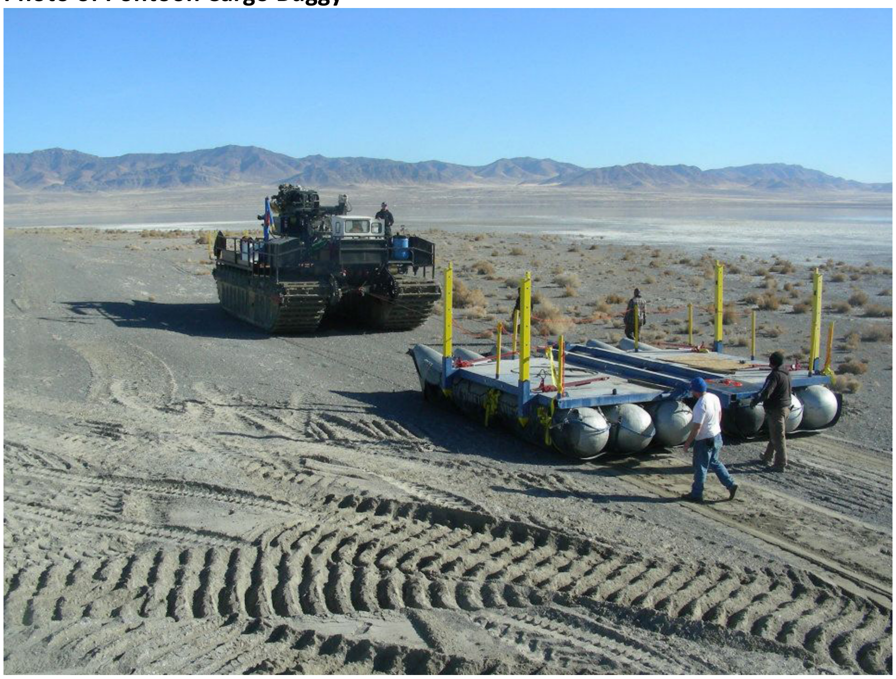


FIGURE 10-5
Photo of Airboat for Personnel and Equipment Transport

10.2.3 Drilling Program

A total of 17 exploration/infill holes were drilled during February and March of 2013. The objective was to obtain data points and establish additional resource within the LUMA lease area as well as to obtain additional deeper penetrations through the brine horizons on the federal and SITLA leaseholds. Additionally, several holes were drilled in proximity to 2011/2012 wells to be used for further hydrologic investigations.

Drilling techniques and data collection methodologies were similar to the previous EPM sonic programs. The new sonic holes were logged in the field by Norwest geologists. The lithologic core descriptions from these field logs, together with moisture content sample results, were used to further delineate brine horizon characteristics and the basal surface of the brine resource. Brine samples were collected from all holes and core samples of sediments from 10 of the 2013 holes were selected for ICP assay.

10.2.4 Comment on Section 10

The main objective of the EPM drilling programs was to obtain sufficient samples of the lakebed brine to characterize it as a resource and, with further study, potentially define a portion of the brine resource as a reserve. Even though the drilling programs were conducted in a fashion common for other mineral commodities (i.e., sediment core was extracted and logged for key physical properties and sent to a labouratory for further analysis), the true target of the drilling programs was always to identify a resource of mineral brine. The characterization of the sediments was done primarily to identify the volume and density of the brine-saturated sediments and to quantify its saturation through moisture content analyses.

The drilling program is judged to be successful in these objectives after completion of modeling and statistical analysis of the acquired data. It is the author’s opinion that the exploration completed to date is sufficient to estimate brine resources appropriate for this level of study and to the degree of assurance reported in Section 14.

The EPM programs established a network of hydrologic testing installations that are being used to further characterize the yields and sustainability of the brine aquifer. This work is being conducted by AAI, Whetstone, and CH2M HILL and is described in subsequent sections of this Technical Report. Additional work should include studies to refine estimates of hydraulic transmissivity throughout the defined brine resource and include additional isolated well completions to characterize distinct horizons if the resource is found to be vertically zonated.

Sample Preparation, Analyses, and Security

Sampling during the EPM 2011/2012 and 2013 programs involved both unconsolidated sediment samples and samples of the liquid brine. The sediment samples were taken primarily to quantify their level of saturation and the brine samples to characterize chemical composition and density. The objective of this sampling program was to identify the in-situ resource of ions necessary to produce potash and related mineral compounds through fractional crystallization.

11.1 Sampling Method and Approach

11.1.1 Sediment Sampling

Sampling of the lakebed sediments was conducted during the 2011/2012 federal program and the 2013 program. The sediment sampling methodology was developed after the completion of the state program and the recognition of the need to acquire accurate moisture content and sediment density data. Sediment sampling protocols and procedures were developed and performed by Norwest geologists. Sampling was performed in two ways, depending on whether the sample was taken from a direct-push or from a sonic hole.

Direct-push core was captured and remained in the plastic sample sleeves. A precursory lithologic description was made from the open tube ends and from features visible through the plastic. Initially, the tubes were cut into two 0.8 m (2.5 m) lengths. Later, the procedure was modified to work with the full, uncut 1.6-m (5-ft) core section. Core loss was noted and logged where it occurred. Field measurements of sediment compaction were taken at the tube ends using a pocket penetrometer and recorded on the log.

Immediately after logging, the core tubes were sealed with plastic core caps from the tubing manufacturer. Red- and black-coloured caps were used to confirm top and bottom of the core run. The caps were then sealed with tape and top and bottom depths marked on the tube in permanent marker. Sample IDs, also marked on the core tube, were composed of hole name and depth interval and documented on the well site log and the COC form.

Sealed core was boxed and checked against the COC form. The sealed core boxes were then transported directly to the IGES labouratory in Salt Lake City by Project personnel (predominantly Norwest staff) with original COC forms that were signed by labouratory personnel on receipt. IGES is an independent geotechnical engineering firm and rock mechanics labouratory and is certified with accreditation by the AASHTO Materials Reference Labouratory.

Sampling of sediment on a sonic rig site was initially targeted at providing moisture content data below the typical 15 m (50 ft) range of the direct-push rigs to characterize the saturation of the lower shallow horizon. During this stage of the sonic program, a 1.5 m (5 ft) longitudinal slice of core was sampled at successive intervals below 15 m (50 ft) bgs and sealed in 3.8-L (1-gal) plastic bags that were labeled with unique field sample IDs. Approximately 10 bags were then stored in a Lexan sonic core tube, sealed, and labeled for transport to the labouratory. Later in the federal program, the procedure was modified to acquire 3 m (10 ft) samples from surface to total depth using methodology described previously. These procedures continued throughout the 2013 sonic program as well. In all instances, final transportation of the samples to the IGES labouratory was performed by project personnel, predominantly Norwest staff members, with direct COC sign-off at the labouratory.

11.1.2 Brine Sampling

Sampling of the mineral brine was conducted during both the state and federal programs. The sampling procedures and protocols were developed by CH2M HILL, in consultation with EPM and Norwest, as part of their role as project consultants responsible for the sample well installations and further hydrologic characterization of the brine aquifer. CH2M HILL personnel performed brine sampling after the well installation was completed and after a minimum 48-hour stabilization period had elapsed. Prior to sampling, the water level and total well depth were documented using an electronic sounding tape. Low-flow peristaltic pumps were used for sampling the wells. The wells were purged prior to sampling. Polyethylene tubing, attached to a weight, was lowered down the well to specified depths. Because the intention was to collect samples representative of conditions after re-equilibration and to minimize disturbance of the water column, the wells were sampled with the minimal amount of purging deemed necessary.

The procedure for purging and sampling included the following instructions:

- Slowly lower a peristaltic pump tube to the uppermost sampling interval
- Purge the well at a flow rate of between approximately 100 mL/min (0.026gpm) and 500 mL/min (0.132 gpm)
- Purge until the turbidity has visually improved, not to exceed 15 minutes (note that the upper interval is often fairly clean and the necessary purge time is often less than 15 minutes)
- Collect samples at the same flow rate of between 100 and 500 mL/min (0.026 and 0.132 gpm)
- Lower the pump tubing to the next sampling interval and repeat the above steps (note that for most direct-push wells, there were generally two sampling intervals)

For wells where it was suspected that a volume greater than approximately 3.8 L (1 gal) of surface water may have entered the top of the well boring or casing during drilling and well construction, additional well purging was performed before sampling with the peristaltic pump. At least two borehole volumes were purged from these wells using a submersible pump. To minimize clogging of the filter pack material and collapse of formation around the filter sock and well screen, pump rates no greater than about 3.8 L/min (1 gpm) were used. After this purging, the well was allowed to re-equilibrate for at least 24 hours before sampling according to the peristaltic pump procedures above, or after the well had returned to 90 percent of its initial volume (not exceeding 48 hours from purging).

Samples were collected at approximate 7.6-m (25-ft) intervals with at least three intervals sampled in each well during the state program. The federal program sampled fewer intervals since review of the assay results showed low variability of the brine column. The nominal 15-m (50-ft) direct-push wells were then sampled at two horizons, typically at 3-m (10-ft) and 10.7-m (35-ft) depths. The sonic holes drilled on the LUMA leases during 2013 were only sampled once and the sample was taken from within the respective well's screened interval. Duplicate samples were collected as part of the quality assurance/quality control (QA/QC) program.

11.2 Sample Preparation, Security, and Analyses

11.2.1 Sample Preparation and Security

Sample preparation and security for sediment samples is discussed previously in Section 11.1.1. Sample preparation and security protocol for brine samples was designed by CH2M HILL, with the collaboration of EPM and Norwest.

Samples were collected in two 250-mL (8.45-oz) bottles for a total sample volume of 500 mL (0.132 gal). The cation sample bottles contained nitric acid to preserve metal speciation and the anion bottles contained no preservative. The samples were labeled according to the well, depth interval, date, and time.

For QA, blind field duplicates were submitted at the rate of one per 10 samples. AWAL, an independent labouratory located in Salt Lake City, ran method blanks, labouratory control samples, and matrix spike/matrix spike duplicates (MS/MSDs) at the rate of one per 20 samples to conform to their National Environmental Labouratory Accreditation Program (NELAP) certification.

All samples were kept in a cooler on ice to maintain a temperature between 0°C and 6°C. Samples remained in the sole possession of the sampler until delivered to AWAL or securely stored to prevent tampering. COC forms were used to document the handling of the samples, and custody seals were placed on the cooler lids.

Final transportation and delivery of the samples to AWAL was performed by CH2M HILL samplers who obtained direct COC signoff at the labouratory.

11.3 Analytical Program

All brine sample analyses from the Sevier Lake Playa wells were performed by AWAL at its Salt Lake City facility. It also analyzed duplicate brine samples prepared by CH2M HILL, which were inserted as blind control samples in the analysis chain. A total of 839 unique brine analyses had been completed as part of the playa exploration and used in the resource model. An additional 85 blind duplicate samples had been completed, but were not used in defining the resource.

AWAL is accredited by the NELAP and all analyses were performed in accordance to the NELAP protocols. It was engaged by EPM on a contractual basis and is independent of the issuer.

Samples were analyzed for the cations magnesium, sodium, and potassium; the anions chloride and sulphate; and specific gravity (SG) (i.e., density). On any section where four or more holes were drilled, and at a rate of one sample per section, analyses were made for lithium, bromine, and barium; TDS; and other trace minerals. Table 11-1 lists the analytes included in the EPM analytical program and their test methods.

TABLE 11-1
Brine Analyses and Methods

Analysis	Test Performed	Minimum Reporting Limit	Description
TDS	SM2540C	500 mg/L	TDS Dried at 180°C ±4°C
Density (SG)	SM2710F	0 g/cm^3	Gravimetric Test of Known Volume
Chlorides	EPA 300.0	500 mg/L	Ion Chromatography
Sulphates	EPA 300.0	3,750 mg/L	Ion Chromatography
Sodium	EPA 6010C	10,000 mg/L	ICP Atomic Emission Spectroscopy
Potassium	EPA 6010C	1,000 mg/L	ICP Atomic Emission Spectroscopy
Magnesium	EPA 6010C	1,000 mg/L	ICP Atomic Emission Spectroscopy

mg/L = milligram(s) per liter

Eighty-five duplicate brine samples were introduced for QA/QC purposes. Alternative labouratories or analytical methods were not compared as part of the exploration program's procedures. A check sample comparison was later performed as part of the processing and crystallization work done by Hazen Research Inc. (Hazen). Hazen analyzed select brine samples using an alternative method (barium precipitation) and found the results provided a more accurate ion balance than the AWAL results and therefore a more accurate quantification of ion species. A comparison between a 20 sample set obtained in 2013 showed a difference in key analyte values averaging approximately 10 percent, with the greatest difference occurring in sulphate and chloride. The values for potassium and magnesium compared very closely with the Hazen results.

Sediment samples were analyzed by IGES for moisture content using ASTM International Method D2216, which is the determination of moisture content by reduction in mass by drying. Due to the quantity of gypsum identified in the sediments, the modified temperature of 60°C (140°F) was used in the drying process instead of the normal, higher-drying temperature of 110°C (230°F). This is done in instances where hydrous minerals, such as gypsum, render their hydrous component at the higher temperature as water thus skewing the reported moisture content. Analysis of moisture content data at both temperatures was compared for splits of the first sediment samples to be processed and showed the higher drying temperature yielded an average moisture content 3 percent higher than the lower temperature. The lower temperature results were used in the resource model dataset.

Sediment samples from 10 holes drilled during the 2013 program were also analyzed for a comprehensive suite of metals and mineral compounds at the Saskatchewan Research Council (SRC). SRC's Geoanalytical Labouratory is a respected labouratory in potash and related minerals due to its working relationship with Canada's large potash deposits. The results indicated that the sediments contain no current economically recoverable minerals; however, exhibit levels of potassium and sulphate that may support mineral recharge of circulating groundwater. Additional study will be required to support this possibility.

After review of the original analytical data and blind brine sample comparisons, the author is of the opinion that the sample preparation and analytical methods used by AWAL and IGES are appropriate for determination of the brine geochemistry and in-place volume for the purposes of this study. Security measures are found to be of a high standard and do not compromise the results used in this Technical Report.

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Data Verification

12.1 Drilling and Sampling Methods

Norwest geologists have been active in assisting EPM with its Sevier Lake Playa field drilling and sampling programs starting on August 1, 2011, and ending with the last campaign of resource drilling in April, 2013. During that period, Norwest observed the field data collection procedures that included drilling methods, core logging, and brine sampling. In addition, Norwest assisted in the transportation of the sediment samples from the site to AWAL labouratories and IGES labouratories in Salt Lake City. The locations of 25 percent of the drill holes were independently verified using a handheld global positioning system (GPS) device by Norwest field geologists.

12.2 Surface Mapping

Norwest evaluated the playa boundary mapping completed by Sunrise Engineering in April of 2011 and used the playa boundary sourced from the public domain Automated Geographic Reference Center (AGRC) website (AGRC.utah.gov) in the geologic model. The EPM-mapped playa boundary tracked the AGRC boundary without any materially significant differences. There was only a 0.7 percent difference in the playa area between the AGRC data and the EPM mapped boundary.

12.3 Database

All field exploration data were entered into Excel table's onsite or at temporary residences located in nearby towns. Norwest was actively involved in compiling field data. Data from labouratories were supplied in digital and printed form. Comparisons were conducted by Norwest between the digital and printed assay certificates and no errors or omissions were observed. The field data and the labouratory data were integrated into a single Excel database that was used for geologic modeling and resource estimation purposes.

12.4 Labouratory Analyses

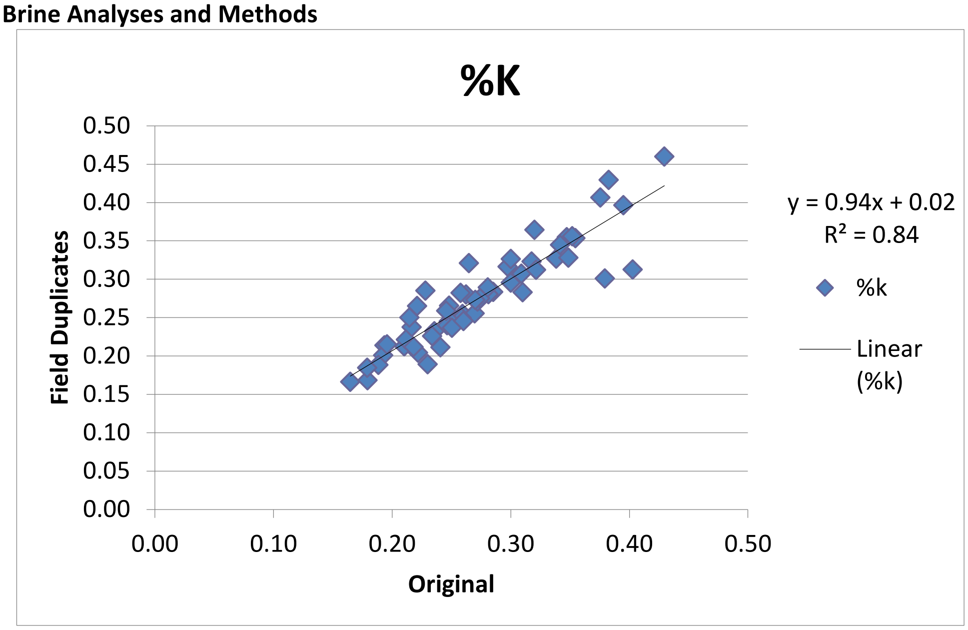
AWAL labouratories (for brine analyses) and IGES labouratories (for sediment analyses) were observed by Norwest to have their own internal QA/QC procedures. The relatively low-nugget effect observed in the geostatistical analysis of the brine sample results indicated that the sample values are repeatable within labouratory detection limits. Splitting of sediment samples for duplicate testing was determined to be impractical due to the unconsolidated nature of the sample material.

The largest deviation in analytical values occurred in the sulphate and chloride results, both analytes having values determined by ion chromatography. An investigation into alternative methods is recommended for these analytes, particularly given the more repeatable results determined by the barium precipitation method. Since potassium is the key element concentration controlling in-situ resource quantity (sulphate occurs in quantities over five times the amount required for SOP crystallization), the effects of these variations are deemed to be insignificant to the resource estimate. The resource estimate is considered conservative given that the values determined by AWAL were used in the model and are 4 to 9 percent less than those determined by Hazen.

For QC, blind field duplicates were submitted at the rate of one per 10 samples. AWAL labouratories, as required by its NELAP certification, ran method blanks, labouratory control samples, and MS/MSDs at the rate of one per 20 samples. Common control limits for the relative percent difference is ±20 percent or ± the reporting limit.

Comparison of original samples to blind field duplicates shows a slight but acceptable range of deviation for potassium assays, as illustrated in Figure 12-1. The area of greatest difference is in the higher potassium levels, possibly exhibiting a slight nugget effect at these higher concentrations. This may be caused by the logistics of obtaining a repeat sample of a liquid material as opposed to a solid. The repeatability, however, is generally good with a coefficient of determination (R^2) of 0.84.

FIGURE 12-1
Brine Analyses and Methods



The author is satisfied that the recorded data have been properly acquired and that sufficient quality control measures have been performed to make it acceptable for use in the estimation of current brine mineral resources.

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SECTION 13

Mineral Processing and Metallurgical Testing

EPM intends to convert Sevier Lake Playa brine into SOP using standard unit processes common to the potash and soda ash industries. Process test work completed to progress the understanding of the metallurgical properties of the Project and predict the overall grade and recovery included the following:

- Identification of major, minor, and deleterious species
- Pond crystallization modeling and evaporation tests
- Generation of feed stock for vendor testing
- Flotation tests
- Crystallization tests

In addition, analyses were performed to characterize better the mineralogy of the sediments in Sevier Lake Playa as described in Section 24. Section 11 includes a discussion of field sampling methods, QC (field duplicates and blind control samples), and analytical methods related to the identification of elements in the brine.

Results of the test work were used to update and refine the process designs. Flotation tests were performed to evaluate possible reagents and recovery. Tests were also performed to assist with predicting the potential purity of the final SOP product, as well as to estimate recoveries.

Table 13-1 summarizes the test work performed, the labouratories used, the test objectives, and the test results. All tests were completed using industry-standard methods, where applicable.

TABLE 13-1
Mineral Processing and Metallurgical Test Summary

Test	Labouratory	Objective	Dates of Testing	Status	Results
Identification of major, minor, and deleterious species	AWAL, Hazen	Data were used in process models and to refine the flow sheets; quantified potential variability of salts in solar evaporation ponds.	Aug 2011 – Aug 2013	Testing completed; additional testing recommended.	Testing showed considerable variations in species and ion balance with the exception of potassium and magnesium.
Pond crystallization modeling	Swenson	Determined evaporation characteristics of brine and suitability of pond designs.	Apr – Aug 2013	Modeling completed	Model showed primary potassium bearing mineral would be leonite.

TABLE 13-1
Mineral Processing and Metallurgical Test Summary

Test	Labouratory	Objective	Dates of Testing	Status	Results
Pond crystallization simulation	Swenson	Used vacuum crystallization to confirm that leonite would be produced under conditions predicted by the numerical model.	Apr – Aug 2013	Testing completed	The potassium crystallization steps of solar pond evaporation produced leonite as predicted.
Pond crystallization simulation	Hazen	Used environmental chamber to simulate pond evaporation; determined evaporation characteristics of brine and minerals crystallized.	Dec 2012 – Aug 2013	Testing completed	Evaporation to 9% Mg in brine resulted in the production of a variety of potassium minerals.
Preliminary leonite crystallization test	Hazen	Developed synthetic leonite for use in flotation testing.	Jun 2013	Testing completed	Filterable crystals of synthetic leonite were successfully produced. Recovery was 54%.
Flotation tests	Hazen	Used synthetic mineral blend to determine flotation reagent and reagent dosages, required flotation time, and establish relationship between grade and recovery.	Jul 2013	Testing completed; additional testing recommended.	Rougher flotation produced 80% recovery at 39% SOP. Scavenger flotation recovered an added 17% at a lower grade.
Leonite crystallization tests	Swenson	Evaluated crystal structure and sizes in relation to process parameters.	Jun – Aug 2013	Testing completed; additional testing recommended	Leonite was produced in four stages of crystallization. Analytical results are pending.

13.1 Identification of Major, Minor, and Deleterious Species

Analytical results from over 800 samples of brine were reviewed to provide information on the expected variation of salts in the solar evaporation ponds. There was considerable variation in the AWAL analyses for the individual species due to labouratory dilutions of concentrated brine associated with the analytical method used. A subsequent analysis by Hazen using an alternative method (barium precipitation and gravimetric analysis) yielded more-accurate results for sulphate, a key anion, and produced a set of analyses that were ionically balanced.

The concentrations of positive and negative ions were checked to help determine the accuracy of the analyses. Balanced charges are an indication that major ions have been identified and are accurate for the purposes of the study. When the AWAL analyses were checked in this way, the resulting ion balance was found to have an average error of 17 percent and a standard deviation of 26 percent. The AWAL analyses matched information found in the literature for other evaluations of Sevier Lake Playa brine, but those analyses were found to have similar ion balance errors. As mentioned, these are likely a result of the analytical method and the required dilutions.

A subsequent analysis by Hazen resulted in a more-accurate charge balance. The Hazen analytical results yielded a charge balance with 94 percent agreement and, because they were the best available data, were used for preliminary process modelling work. The Hazen results are provided in Table 13-2 to provide an example of the balance calculations.

TABLE 13-2
Results of Hazen Analysis: Concentration of Ions

ION	Concentration grams/L	Concentration moles/L	Ion Concentration equivalents/L
Na^{+}	73.9	3.2	3.213
Mg^{+2}	4.15	0.17	0.341
Ca^{+2}	0.69	0.017	0.034
K^{+}	3.28	0.084	0.084
TOTAL POSITIVE			*3.672*
SO_4^{-2}	23.8	0.25	0.496
Cl^{-}	121.3	3.5	3.421
TOTAL NEGATIVE			*3.917*
ION balance, percent			93.7

Table 13-2 shows the ion balance calculation for the composite brine. The concentration of each ion (Column 2) was divided by the atomic or molecular weight to get the concentration of the ion in moles/L (Column 3). That value was multiplied by the charge of the ion (indicated in Column 1) to get the charge equivalent of the ions (Column 4). When the sum of the positive ions (3.672 equivalents/L) is divided by the sum of the negative ions (3.917 equivalents/L) the result is a 93.7 percent ion balance.

Additional samples were collected from the Sevier Lake Playa and submitted to Hazen for duplicate, confirming analyses. In addition, a synthetic brine sample was compounded from reagents to be submitted as a blind check of the analytical techniques. The synthetic brine was included as a blind sample with the Sevier Lake Playa brine samples taken in the May 2013 sampling event. Analytical results were consistent and generally within 5 percent of the known concentrations of ions in the synthetic brine. The Hazen analysis of the “average lake brine” used in modelling work and the average analytical values from the 2013 samples analyzed by AWAL are shown in Table 13-3.

TABLE 13-3
Summary of Analytical Values Used in Modeling

ION	Concentration (g/L)		
	Hazen Analysis of Composite Sevier Playa Brine	Average of 20 Samples (2013)	
		Hazen	AWAL
Na^+	73.9	74.1	67.7
Mg^{+2}	4.15	3.92	3.64
Ca^{+2}	0.69	0.64	
K^+	3.28	3.05	2.92
SO_4^{-2}	23.8	20.7	24.5
HCO_3^-		0.54	
Cl^-	121.3	115	100

The average analysis performed by Hazen of the 20 samples collected in 2013 support the composition of the composite sample that had been used for thermodynamic modeling. Previous analyses of samples from the same locations had been analysed by AWAL and showed appreciably different concentrations.

13.2 Pond Crystallization Modeling

Minerals produced in the solar ponds drive the operation of the plant and also influence the optimal plant design. A simulation of the ponds was obtained in the following three-stage process:

1. Numerical modeling by Swenson
2. Limited pond simulation using artificial brine by Swenson
3. Pond simulation by Hazen

13.2.1 Numerical Modeling

The numerical modeling was performed using ESP software leased from OLI Systems of Morris Plains, New Jersey, and brine analyses provided by Hazen. The software used a proprietary database compiled by Swenson from the literature and their experience to predict crystal formation based on thermodynamic stability. The numerical model did not include information on reaction kinetics. The information from the numerical model was used to predict the potassium mineral expected to precipitate in the final production pond, information that is critical to the process design.

The model predicted the crystallization of a variety of salts as water was removed by evaporation, including the precipitation of potassium as leonite. The model included seven crystallization events, with events five and six representing the materials likely to be produced in the potassium production ponds. Results are shown in Table 13-4.

TABLE 13-4
Pond Crystallization Numerical Modeling Results

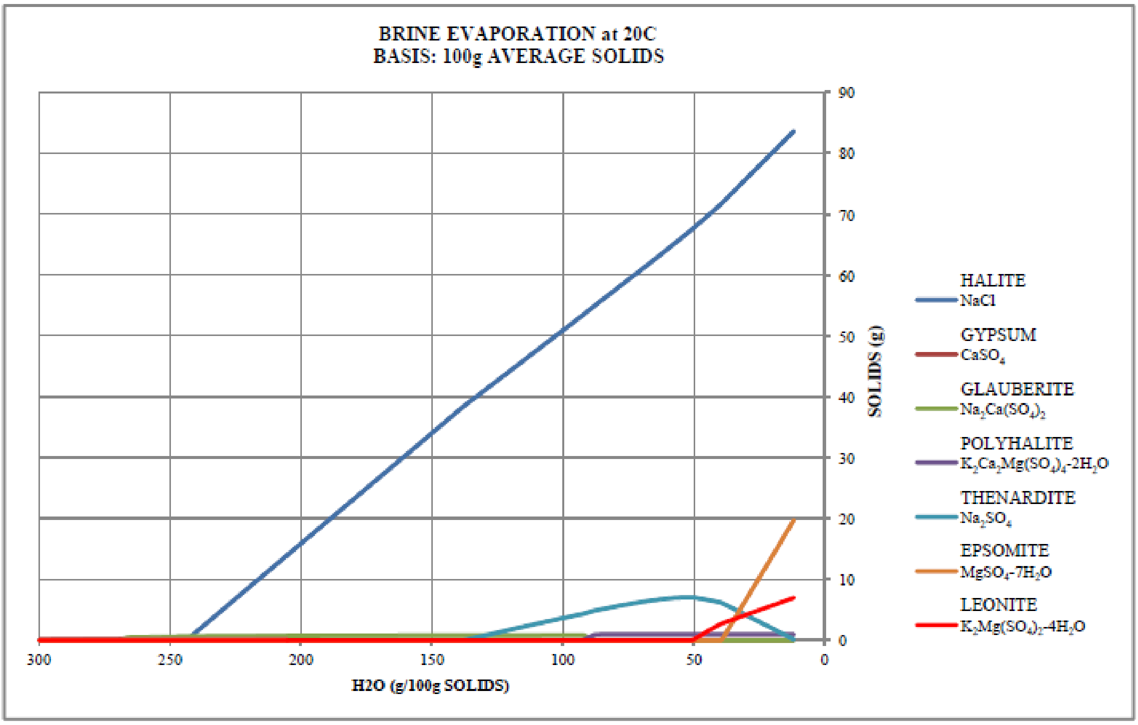
Stream	Brine Concentration (percent Mg by mass)	Remaining Water (percent of original mass)	Mineral Crystallized
Initial feed	0.35	100	
Event #1	0.51	61	Glauberite
Event #2	1.13	27	Halite Glauberite
Event #3	1.69	18	Halite Thenardite
Event #4	2.77	7.6	Halite Astrakanite (Na2SO4-MgSO4-4H2O)
Event #5	5.00	3.4	Halite Leonite
Event #6 (Sodium sulphate [Na_2SO_4] addition)	7.83	3.4	Halite Leonite
Event #7	6.58	2.3	Halite Leonite

Table 13-4 shows that halite precipitation begins in the preconcentration ponds and continue through all remaining ponds. Pond design criteria included maximum precipitation of halite in the preconcentration ponds to minimize the amount of halite cocrystallizing with the potassium minerals in the production ponds. This would reduce halite concentration and increase potassium concentration of the flotation plant feed resulting in increased potassium recovery.

Event #6 in Table 13-4 involved the addition of sodium sulphate to the brine to increase sulphate concentration. This causes the thermodynamic model to predict that additional leonite would be produced. This is similar to the proposed recycling of bitterns from the final production pond to this crystallization stage discussed in “Material Balances and Concentration Path of Sevier Lake Brine as it is Evaporated” by David Butts. In that case, the high-magnesium bitterns increases the concentration of potassium minerals in the pond product.

Simulation of solar evaporation indicates that crystallization of glauberite begins first, followed by halite, calcium sulphate, polyhalite, sodium sulphate, epsomite, and leonite as shown in Figure 13-1. Early precipitation of halite would increase potassium yield in the crystallizers. Since halite can increase unwanted formation of magnesium sulphate, both materials must be removed by means of a purge stream, which would also contain some potassium.

FIGURE 13-1
Simulation of Solar Evaporation of Sevier Dry Lake Salts



13.2.2 Pond Simulation – Swenson

Swenson performed a limited simulation of pond crystallization using artificial brine. At Swenson, synthetic brine was produced from labouratory chemicals based on the numerical model's prediction of the composition of feed to the production ponds. The brine was evaporated at temperatures expected to occur in the solar ponds. Vacuum was applied to increase evaporation rates without changing the crystallization conditions. Swenson's report "Test Report on Crystallization of Leonite for CH2M HILL/ Peak Minerals" issued August 30, 2013, noted that the crystals produced in the test were analyzed and shown to be halite and leonite and that they were filterable and had an average crystal size around 500 micrometers (0.02 in), a reasonable size for dewatering and handling equipment.

13.2.3 Pond Crystallization Simulation – Hazen

Hazen performed a solar pond simulation to verify the numerical model and to evaluate the following:

1. Determine the reaction kinetics
2. Estimate evaporation rates
3. Provide information for use in refining pond modeling and design work

Sevier Lake Playa brine was evaporated in a controlled environment with brine makeup for approximately 9 months to establish evaporation rates. No additional brine was added after 6 months. The temperature was controlled between 21°C and 32°C (70°F and 90°F) to simulate summertime temperatures. Crystals were separated from the brine when the magnesium reached approximately 2, 4, 6, and 8 percent. Table 13-5 shows the amount of each ion left in the crystals in each of Hazen's simulated ponds (H1, H2, H3, and H4).

TABLE 13-5
Hazen Pond Crystallization Test Results

Final Mg percent	Pond	Recovery of Ion to Crystals, percent							
		Ca	K	Li	Mg	Na	Br	Cl	SO_4
0.30	Feed		0.0						
2.16	H1	96.2	13.5	13.4	12.0	82.8	>100(1)	83.3	19.6
4.23	H2	3.6	34.0	5.3	12.3	12.9	27.4	12.3	23.4
6.50	H3	0.1	12.3	4.9	9.5	0.3	<6 (2)	0.4	5.4
8.23	H4	0.1	15.5	6.2	12.0	0.3	7.3	0.5	6.8
	Total	**100.0**	**75.4**	**29.9**	**45.8**	**96.4**	**>100(1)**	**96.5**	**55.1**

(1) Indicated recovery to crystal was over 100 percent due to difficulty in bromine analysis in high-chlorine brine.

(2) Indicated recovery was less than 6 percent. This was due to the bromine analysis being below the limit of detection in one or more product.

The materials produced were identified by X-ray diffraction (XRD) and are summarized in Table 13-6. A second column shows the crystals formed when clear pond brine was refrigerated to 2.78°C (37°F) to duplicate winter conditions. Minerals in bold were found in concentrations above 5 percent in the solids.

TABLE 13-6
Hazen Pond Crystals

Pond	Solids from Summer Simulation	Solids from Winter Simulation (37°F)
H1	Halite	Halite
	Gypsum	Gypsum
	Hexahydrite	Hexahydrite
H2	Hexahydrite	Hexahydrite
	Sylvite	Sylvite
	Halite	Halite
	Picromerite (Schoenite) (K2Mg(SO4)2-6H2O)	Picromerite
		Starkeyite (Cranswickite)

TABLE 13-6
Hazen Pond Crystals

Pond	Solids from Summer Simulation	Solids from Winter Simulation (37°F)
H3	Halite	Halite
	Cranswickite (Starkeyite)	Cranswickite (Starkeyite)
	Starkeyite	Starkeyite
	Picromerite (Schoenite)	Picromerite
	Sylvite	Sylvite
	Leonite	Carnallite
	Carnallite	Pentahydrite
	Pentahydrite	Epsomite
	Kainite	Calcite
H4	Halite	Halite
	Sylvite	Carnallite
	Carnallite	Starkeyite
	Kainite	Bischofite
	Starkeyite	Hexahydrite
	Bischofite	Magnesium Chloride
	Hexahydrite	Picromerite
		Korshunovskite
		Anhydrite

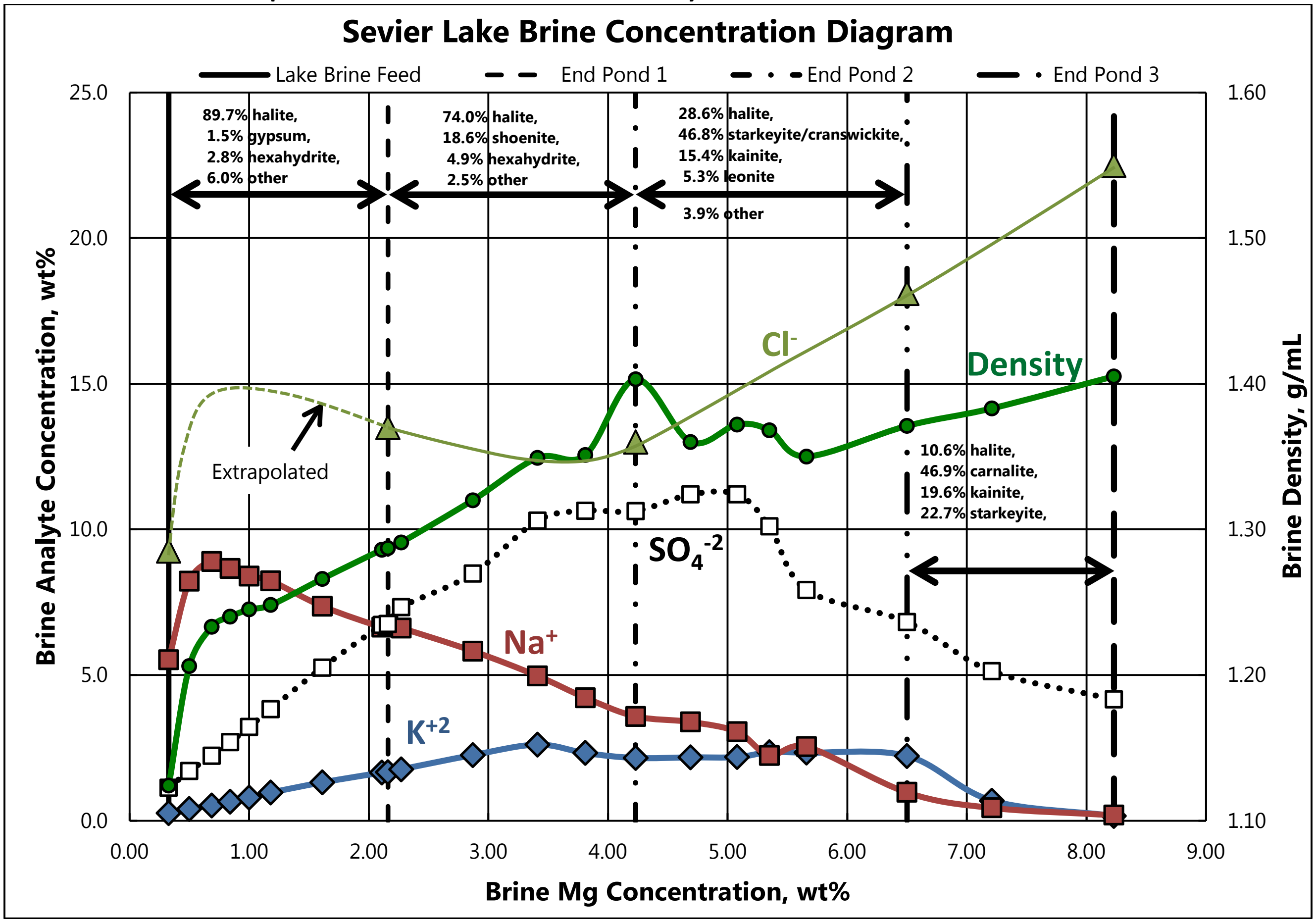
Figure 13-2 shows the major minerals and approximate magnesium concentrations from the data derived using evaporation tests performed at Hazen.

The test work at Hazen was a straight-forward evaporation of the brine. The test results deviated from the thermodynamic model in producing chloride salts of potassium. Further, this was a deviation from the model produced by Swenson. Probable reasons for the difference include the following:

1. The thermodynamic model was based on the initial Hazen composite fresh brine analysis supported by additional sample analyses in May 2013, while the later pond simulation was performed with actual brine containing lower brine sulphate levels from older, stored samples.
2. The thermodynamic model evaluated sodium sulphate addition to increase leonite production while David Butts' evaporation work anticipated recycling brine to modify ion levels. The Hazen work had no additions or recycles to provide baseline information.

Future work is recommended to verify the range of compositions expected to enter into the pond system and the benefits of either the addition of sodium sulphate, as suggested by Swenson, or the back-mixing of brine, as suggested by David Butts.

FIGURE 13-2
Test Results of Solar Evaporation Simulation of Sevier Lake Playa Brine



13.3 Preliminary Leonite Crystallization Tests

Based on the results of numerical pond crystallization modeling performed by Swenson using OLI software and a proprietary data base, feed to the plant from the solar ponds is expected to consist primarily of leonite and other interlocking minerals. One of the key operations in the SOP recovery process is the production of leonite from the flotation feed and SOP mother liquor. This would be accomplished by the evaporation of water under controlled conditions of temperature and dissolved salt concentrations.

Preliminary test work was performed by Hazen in a rotary vacuum crystallizer. The preliminary crystallization tests focused on demonstrating leonite crystallization, determining its physical properties, and obtaining material for flotation tests.

A synthetic brine was constituted that matched the concentration of the different minerals derived from simulated pond evaporation. The brine was then subjected to the following tests to simulate plant operation:

1. Heating to 75°C (167°F)
2. Evaporation under vacuum for about 12 hours resulting in evaporation of approximately 60 percent of the initial water
3. Filtration to recover air dried leonite crystals

Recovery was 54 percent of the starting potassium, much lower than would be expected in four stages of crystallization as the plant would be designed. The crystal size was approximately 45 percent passing a 0.420 mm standard sieve (U.S. Sieve Size No. 40, or 35 Tyler mesh) and 18 percent passing a 0.149 mm standard sieve (U.S. Sieve Size No. 100, or 100 Tyler mesh). The test showed that leonite could be produced from brine under the recommended process conditions. The particle sizes indicated that solids could readily be separated from residual brine by filtration or by centrifuge.

Leonite synthesized by Hazen labouratories was used in subsequent flotation testing. The synthesized leonite was similar in composition to materials likely to be generated from the solar ponds but differed in crystal size. This difference was mitigated by grinding samples to an appropriate size distribution prior to flotation testing.

13.4 Flotation Tests

Flotation testing was performed using synthetic feed crystals composited from the synthesized leonite, commercially available halite, and epsomite, since information in the literature suggests that epsomite would be produced in the solar ponds in addition to leonite and halite. The composition of the flotation feed crystals was designed to contain:

- Leonite – 36 percent
- Halite – 43 percent
- Epsomite – 21 percent

The combined materials were crushed to 210 micrometers (U.S. Sieve Size No. 70, or 65 Tyler mesh) before conditioning and flotation.

Brine was made to simulate recirculating brine, similar to that expected in the mineral processing area of the plant. Brine was synthesized for flotation testing using labouratory reagents at concentrations consistent with the numerical model's predicted concentrations for the final production pond. Brine concentrations used in flotation testing are shown in Table 13-7.

TABLE 13-7
Synthetic Brine Concentrations Used in Flotation Testing

Compound	Percent by Mass
Water	68
Halite	2
Magnesium sulphate	3
Magnesium chloride	24
Potassium Chloride (Sylvite)	3

Parameters evaluated during the flotation tests included the following:

1. Reagents
2. Dispersants/depressants
3. Recovery

The goal of the testing was to determine applicable flotation reagents and approximate reagent dosages, estimate the required flotation time, and approximate the recovery and resulting potassium mineral grade. Flotation conditions, chemical assays for potassium, ERD analyses to determine crystal size, and potassium distributions for each experiment were documented during the testing.

The flotation work was performed at Hazen with selected results as shown in Table 13-8. The flotation brine was not supersaturated with respect to the mineral mixture resulting in dissolution of epsomite and halite into the brine. A recommendation for future test work is to establish brine equilibrium for the mineral mixture being floated.

TABLE 13-8
Selected Flotation Test Results

Test No.	Flotation Reagent	Reagent Type	Stage	Potassium Recovery (%)	K_2SO_4 Concentration (%)
23	Sodium dodecyl sulphate	Anionic collector	Rough	80	39
			Scav	17	20
			Total	97	33
			Assumed Rougher and Cleaner	94	39
24	Flomin F-853, sodium petroleum sulfonate	Anionic collector	Rough.	66	46
			Scav	12	47
			Total	78	47
			Assumed Rougher and Cleaner	74	46
4	Nansa LSS 38/AS	Anionic collector	Rough	80	31

TABLE 13-8
Selected Flotation Test Results

Test No.	Flotation Reagent	Reagent Type	Stage	Potassium Recovery (%)	K_2SO_4 Concentration (%)
			Scav	9	31
			Total	89	31
			Assumed Rougher and Cleaner	87	31

Results from Flotation Test 23 indicate that recoveries of 80 percent at a grade of 39 percent SOP are possible in rougher flotation. Additional recovery was obtained when waste material from rougher flotation was subjected to additional flotation time in scavenger flotation. In the scavenger concentrate, an additional 17 percent of the potassium was recovered, but at a lower-grade of 20 percent SOP. The scavenger concentrate would be reprocessed to purify it in cleaner flotation. Using the recovery in rougher flotation as a guideline, it is estimated that 80 percent of the SOP in the scavenger concentrate would be recovered in the cleaner stage at the same concentration as the rougher concentrate for a total recovery of 94 percent at 39 percent SOP. Additional flotation testing is recommended to verify recoveries assumed for cleaner flotation and to experiment with combining reagents to achieve recoveries as close to 100 percent as possible and, as closely as possible, approaching 43 percent potassium sulphate in the form of pure leonite.

13.5 Crystallization Tests

Leonite crystallization had been demonstrated at Hazen as described in Section 13.3. The test produced materials that were readily separated from the residual brine by filtration.

Swenson was contracted to test multiple effect crystallization to produce leonite. These tests were performed at the Swenson labouratory in June 2013. The test work was reported in "Test Report on Crystallization of Leonite for CH2M HILL/Peak Minerals" issued by Swenson on August 30, 2013. The report states that a retention time of 4 hours in each effect crystallizer yielded a product with an average particle size of about 500 micrometers (32 Tyler mesh), "which is a reasonable size for dewatering and handling equipment."

13.6 Throughput Calculations

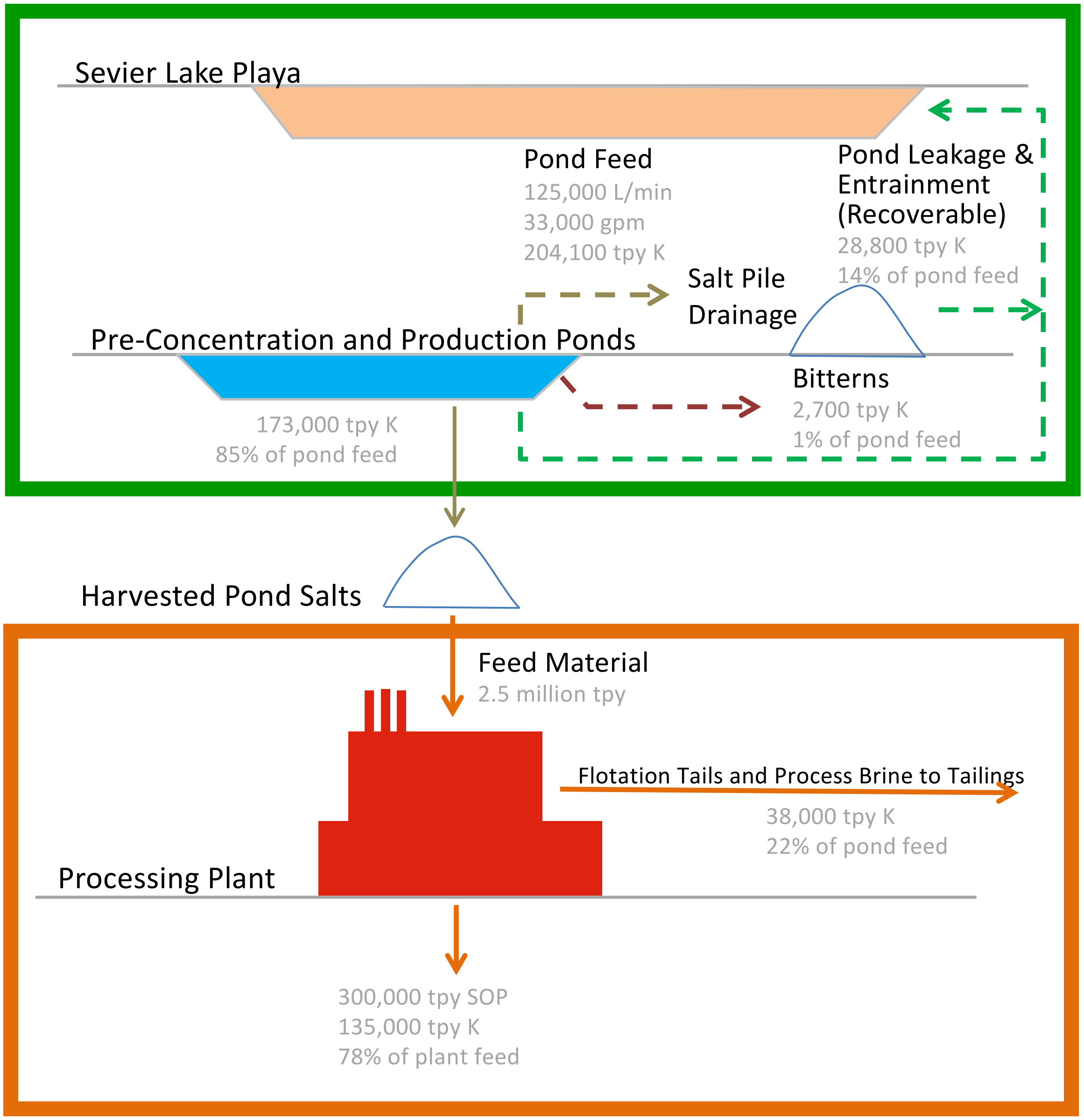
Figure 13-3 illustrates the brine balance throughout the process cycle from the solar evaporation ponds through the processing plant. Approximately 300,000 tonnes (330,693 tons/yr) of SOP would be produced assuming 125,000 L/min (33,000 gpm) of brine pond feed to the preconcentration and production ponds. Recoverable losses include the following:

1. Brine leakage through the bottom of the ponds that will re-enter the brine aquifer

2. Entrainment (brine that is present as moisture in the pond solids) that would drain back to the production ponds

A total of 125,000 L/min (33,000 gpm) of brine is pumped into the evaporation ponds, 2.5 million tpy (2.7 million tons/yr) of potash salts are harvested and stockpiled as feed material and processed to yield 300,000 tpy (330,693 tons/yr) of SOP. Of the total quantity of 204,000 tpy 224,871 tons/yr) of potassium that enters the evaporation ponds, 85 percent (173,000 tpy [190,700 tons/yr]) is harvested as feed material. Loss to bitterns (solution drained from the final pond) would be 1 percent (3,000 tpy [3,307 tons/yr]). The remaining 14.0 percent (29,000 tpy [31,967 tons/yr]) is leakage and entrainment and is considered recoverable. From the flotation feed material, 78 percent (135,000 tpy [149,000 tons/yr] potassium) is processed into saleable SOP product. The remaining 22 percent (38,000 tpy [42,000 tons/yr]) reports to tailings. Investigations are planned to evaluate methods that would allow some or all of the material to be either recycled into the process, returned to the lake, or subjected to alternative product recovery.

FIGURE 13-3
Potassium Balance



The brine in the Sevier Lake Playa basin is not homogenous; variations exist from the north feed end to the south feed end. Differences also exist between surface and near-surface brine and deeper brine. These differences may become more pronounced as brine is withdrawn from the aquifer and is replaced with recharge water. Therefore, brine collected from different parts of the lake or at different times may contain different ion concentrations. This difference would be mitigated by a robust pond design that preferentially precipitates specific salts and by allowances in the process design to accommodate variances in feed. Mechanisms to accommodate variations in feed composition will be detailed in later stages of the design process.

13.7 Deleterious Elements

Over 800 samples were analyzed for a variety of ions including magnesium, sodium, chloride, calcium, and bicarbonate. There were no deleterious materials present in concentrations that cannot be accommodated by the process design.

13.8 Estimated Recovery

Flotation recoveries were estimated based on test work performed at Hazen. Assuming recoveries in the rougher banks will be similar to results from Flotation Test 23, as shown in Table 13-8, total flotation recovery should be approximately 94 percent as shown in Table 13-9.

TABLE 13-9
Estimated Flotation Recovery

Stage	Recovery, %
Rougher flotation	80
Scavenger flotation	17
Cleaner flotation (17 × 80%)	13.6*
Total recovery (rougher + cleaner)	**94**

* Estimated, but not tested

Process recoveries were based on modeling by Swenson. The crystallization model predicts potassium recovery of about 83 percent in leonite and SOP crystallization. The combined recovery of potassium from pond crystals to SOP would be about 78 percent (94 percent × 83 percent = 78 percent).

13.9 Conclusions

In the opinion of the CH2M HILL QPs, the following conclusions are appropriate:

- Test work was performed by recognized testing facilities and the tests performed were appropriate to the resource type.
- Samples selected for testing were representative of the overall brine resource and the type of mineral to be processed.
- Test work has established the leonite-into-SOP process as the most economical for conversion of Sevier Lake Playa brine.
- Assumed life-of-mine SOP recovery assumptions are based on appropriate test work and the potassium recovery averages from 78 percent.

- Elements posing a potential for concern related to product recovery include sodium chloride. There were no other elements or minerals noted in the sampling that would cause decreased recovery or penalties against EPM.
- No other processing factors were identified from the metallurgical test work that would have a significant impact on extraction.

Mineral Resource Estimates

14.1 Overview

The brine resource estimate was prepared by Norwest Project Manager Derek Loveday, P.Geo., Pr Sci. Nat.; and Norwest geologist Brandon Alger under the supervision of Norwest Vice President Geologic Services Lawrence Henchel, P.Geo., PG. Mr. Henchel is the QP for the resource estimate.

Brine occurrences are not "solid mineral deposits" as defined under the 2010 Canadian Institute of Mining, Metallurgy and Petroleum (CIM) definition standards. However, there are sufficient similarities to mineral deposits that the guidelines published by CIM and referenced in NI 43-101 provide a useful guide to brine estimation reporting. Norwest used the principle of the NI 43-101 disclosure standards, the general format of Form NI 43-101F1 in preparing the report on the estimate, and considered recommendations in CIM best practice guidelines when preparing the estimate[2].

The brine resource estimate was developed using MineSight® 3D block modeling software. The geological model (3DBM) from which the brine resources are reported is based on the analyses and descriptions of brine and aquifer sediment samples taken at regular depth intervals from vertically orientated drill holes collared on the playa surface.

14.2 Model Database

The geologic model database comprises three components—topography, surface mapping, and drill hole data. Each component is described separately as follows.

14.2.1 Topography

The playa surface represents the top surface limit of the brine aquifer. To the unaided eye, the playa surface appears flat with little or no obvious changes in elevation across the lakebed. To obtain an accurate measure of the elevation of the playa surface, the surveyed drill hole collar locations and playa survey points were used to define the playa surface elevation for brine resource modeling purposes. Dense survey control of the playa margin was used to delimit the brine resource area.

[2] CIM Best Practice Guidelines, Estimation of Mineral Resources and Mineral Reserves and CIM Best Practice Guidelines for Resource and Reserve Estimation for Lithium Brines.

14.2.2 Surface Mapping

There was no geological mapping of the playa surface because of the generally uniform nature of the playa surface geology. Surface mapping was limited to the surveying of the playa surface and boundary, as described previously.

14.2.3 Drill Hole Data

The following principal brine resource parameters were acquired from drill hole sampling of brine and host sediments:

- Penetrometer measurements (kilogram per square centimeter [kg/cm^2])
- Gravimetric moisture content in weight percent
- SG of brine and host sediments
- Cation in mg/L brine for ions (Mg^{2+}, Na^+ and K^+)
- Anion in mg/L brine for chlorine and sulphate (SO_4^{2-})

Additional ancillary brine geochemical parameters were analyzed, including lithium, barium, bromide, and TDS. Each of the above principal resource parameters is discussed as follows:

14.2.3.1 Penetrometer Measurements

The penetrometer results provided an indirect and relative field measure of moisture content. The lower values (0 to 1.95 kg/cm^2 27.7 lbs/in^2]) generally represented intervals of elevated moisture content while the higher values (greater than 1.95 kg/cm^2[27.7lbs/in^2]) generally represented intervals of low moisture content of approximately 30 Wt% or less. Penetrometer results, together with lithologic descriptions, were used for field assessment of relative moisture content and corroboration of assayed values prior to modeling. Penetrometer measurements, along with lithologic descriptions, were used to determine the transition from the URZ to the LRZ and to delineate the bottom of the total brine aquifer.

14.2.3.2 Moisture Content

The gravimetric moisture content was measured for all sediment samples and this value can be used to directly calculate porosity given that all lakebed sediment samples were observed to be 100 percent saturated and the unit weights of the solids and brine are known. The univariate statistics for modeled moisture content is listed in Table 14-1.

TABLE 14-1
Sediment Moisture Content Univariate Statistics

Parameter	No. Samples n	Minimum (Wt%)	Maximum (Wt%)	Mean (Wt%)	Median (Wt%)	Standard Deviation
Gravimetric moisture	2,489	6.02	75.58	43.66	43.38	8.93

14.2.3.3 Specific Gravity

SG of the brine was measured for all brine samples together with the cation and anion analyses. The dry SG of the host sediments was not determined for all samples and was limited to a representative group randomly distributed across the property. The univariate statistics for brine and sediment SG is listed in Table 14-2. The average sediment SG, together with modeled brine SG and sediment moisture content, is used to calculate the brine resource tonnes using the formula:

$$\text{Brine Tonnes} = BV * BSG = \frac{AV*MC*BSG}{MC*BSG+(\frac{1}{SGS-(BSG-1)})}*BSG$$

Where:

BV = brine volume (m^3)

BSG = brine SG

AV = aquifer volume (m^3)

MC = gravimetric sediment moisture content (Wt%/100)

SGS = dry host sediment SG

TABLE 14-2
Specific Gravity Univariate Statistics

Parameter	No. Samples n	Minimum	Maximum	Mean	Median	Standard Deviation
Brine SG	839	1.0	1.21	1.10	1.10	0.03
Sediment SG	25	2.75	2.99	2.88	2.88	0.06

14.2.3.4 Cation and Anion Analyses

The purpose of measuring the most commonly occurring cations and anions in the brine samples is for use in determining the theoretical salt products, including potash, either SOP or potassium chloride, that could be precipitated from brine in solar evaporation ponds. To calculate the relative proportion of cations and anions in the lakebed brine deposit, all cation and anion analyses were converted to Wt% equivalent values from the labouratory reported mg/L units. Univariate statistics for the modeled cations and anions are listed in Table 14-3.

TABLE 14-3
Cation and Anion Univariate Statistics

Parameter	No. Samples n	Minimum	Maximum	Mean	Median	Standard Deviation
Magnesium	839	0.08	1.6	0.34	0.33	0.11
Sodium	839	2.37	16.67	6.83	6.70	1.64
Potassium	839	0.06	0.76	0.27	0.27	0.07
Chloride	839	2.61	26.24	8.22	7.77	2.70
Sulphate	839	0.64	6.77	2.24	2.06	0.86

14.3 Database Verification

Prior to modeling, the master database was subjected to the following standard checks for inconsistencies:

- Drill hole sample depth intervals and survey locations
- Drill hole collar elevations against regional public domain survey data
- Lakebed boundary mapping versus regional public domain lakebed mapping
- Anomalous values in moisture content, SG, and brine chemistry
- Comparison between penetrometer results and moisture content
- Comparison between labouratory assay certificates and electronic records

All observed inconsistencies and apparent errata were resolved following checks of the base data or consultation with the concerned parties; namely EPM, consultant services, drilling contractors, and labouratories.

14.4 Geologic Model

The brine resources were reported from a 3DBM that covers the extent of the Sevier Lake Playa boundary. All spatially referenced data used in the model have been converted from the source Central Utah North American Datum of 1983 State Plane coordinate system to the metric UTM Zone 12 WGS84 datum system. All elevation and depth data have been converted from the source U.S. Customary Units (in feet) to metric units.

14.4.1 Spatial Correlation

The geometry of the brine aquifer was determined from the correlations of drill hole lithologic descriptions, penetrometer results, and moisture content measurements. The brine aquifer is confined to within the boundary of the lakebed surface and resource estimates to within controlled lease boundaries. Along the lakebed boundary, there is a clear transition from surface soil to a gypsum-halite duricrust. Below the duricrust, the upper and lower brine horizons (URZ and LRZ) have been correlated. The contact between the

URZ and LRZ can be distinguished lithologically; however, from a hydrologic and brine chemistry perspective, the contact is interpreted to be gradational.

The URZ has generally high moisture content, averaging approximately 42 percent moisture and with penetrometer readings below the minimum detection limit. The LRZ has slightly lower moisture content, averaging approximately 39 percent moisture and typically exhibits penetrometer readings above the minimum detection limit. The contact between the two horizons is often identified lithologically as a thin layer of stiff clay, approximately 0.15 to 0.3 m (6 to 12 in) thick, with penetrometer readings averaging 2.4 kg/cm^2 (34.1 lb/in^2). The basal limit of the LRZ is characterized by a transition from moderately moist sediments to a stiff, dry clay with penetrometer results beyond the maximum detection limit (greater than 4.64 kg/cm^2 [66.0 lb/in^2]). Additionally, there was often a colour change in the sediments from medium olive grey in the lower brine horizon to a reddish-brown colour in the underlying consolidated clay.

The URZ averages 6.24 m (20.47 ft) thick and is generally consistent across the lakebed as indicated in Table 14-4 (brine horizon thickness statistics generated from the drill hole records). The LRZ is penetrated by fewer drill holes, as indicated in Table 14-4, and is interpreted to average 15.13 m (49.64 ft) thick. The total combined brine resource averages 21.37 m (70.11 ft) in thickness.

TABLE 14-4
Upper and Lower Brine Horizon Thickness

Brine Aquifer	No. Intercepts n	Minimum (m)	Maximum (m)	Mean (m)
Upper	416	1.52	12.19	6.24
Lower	40	4.88	26.52	15.13

Wireframe surfaces were constructed of the upper and lower brine horizon contact using grid estimates of topography and aquifer thickness from the drill hole records. The top contact for the upper brine horizon is represented by a wireframe surface of the lakebed topography sourced from grid estimates of drill hole collar and lakebed surveys. The brine floor elevation wireframe surfaces were generated from grid estimates of upper and lower brine thickness that were subtracted from the reference topography grid. The lakebed topography and brine grid estimation parameters are listed in Table 14-5.

TABLE 14-5
Model Grid Estimation Parameters

Parameter	Description
Grid spacing	100 m (X), 100 m (Y)
Estimation algorithm	Topography – Triangulation
	Brine thickness – Inverse distance power 2
	Brine floors – Topography less brine thickness

Cross sections illustrating the subsurface extent of the top and bottom brine horizons are illustrated in Figure 14-1. Colour contour plots of the brine horizon thickness are illustrated in Figure 14-2 and brine horizon floor elevations are illustrated in Figure 14-3. The top and bottom brine horizon contact surfaces were used to construct wireframe solids that were in turn used to code the 3DBM with ore versus waste blocks using a majority code. The 3DBM parameters are outlined in Table 14-6.

TABLE 14-6
Block Model Parameters

Parameter	Description
Coordinate system	UTM Zone 12 WGS84 datum
Units	metric
Block size	100 m (X), 100 m (Y), 1.5 m (Z)
Model easting (X) range	304,400 to 330,000
Model northing (Y) range	4,285,800 to 4,332,000
Model elevation (Z) range	1,335 to 1,383

14.4.2 Moisture and Brine Grade Interpolation

The estimation of moisture content and brine grade (cations and anions) and SG into the 3DBM was influenced by the results of geostatistical analyses of the source drill hole sample data as well as by differences in sampling method and results between direct-push and sonic holes.

Frequency distribution plots (histograms) of sample moisture content and brine chemistry were used to identify outliers in the sample data. The moisture and brine grade histograms are illustrated in Figure 14-4. Three-dimensional semi-variogram analyses charts with three-dimensional grade trend plots are illustrated in Figure 14-5.

FIGURE 14-1
Resource Model Cross Section Views

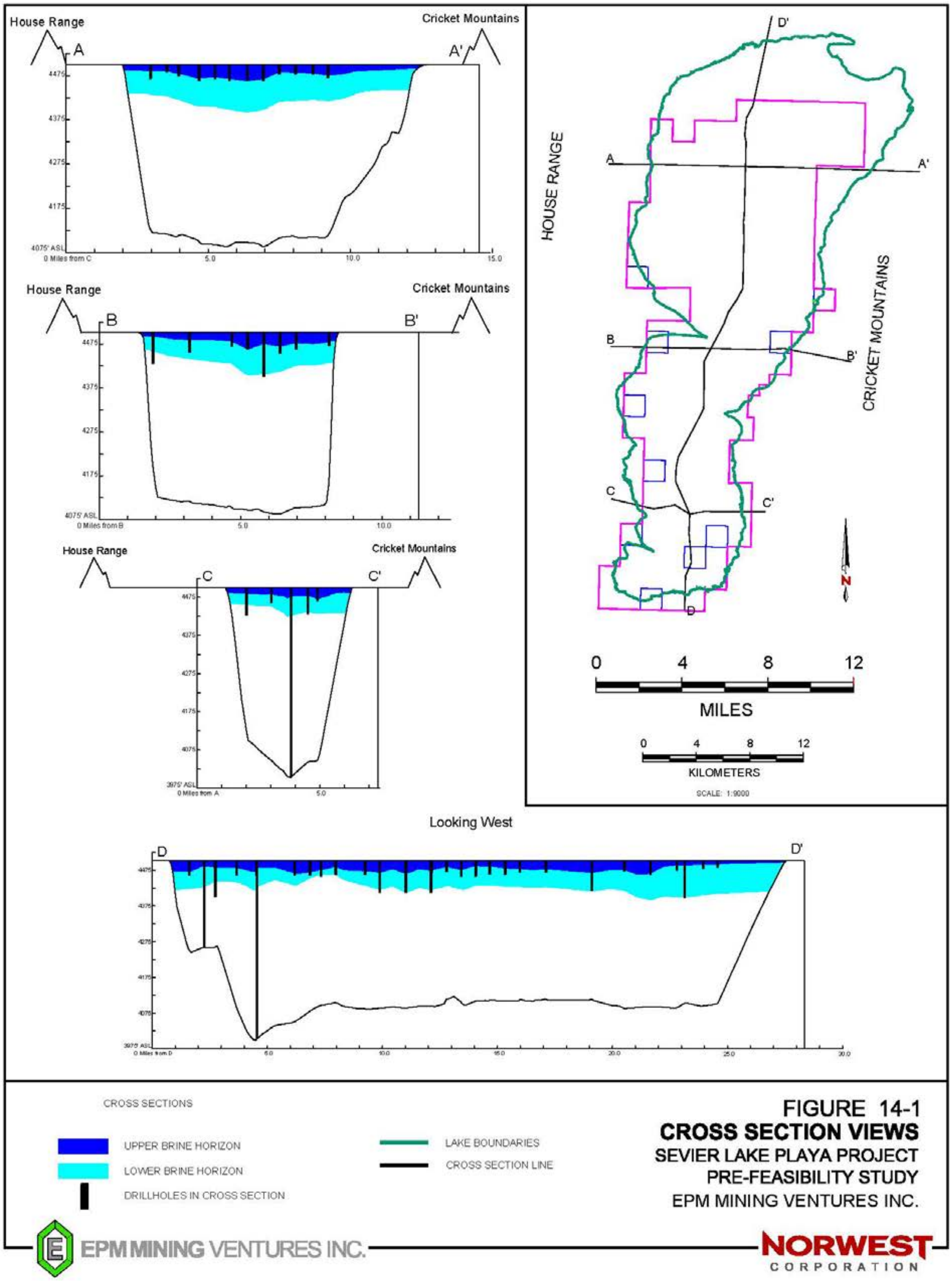


FIGURE 14-2
Brine Aquifer Thickness

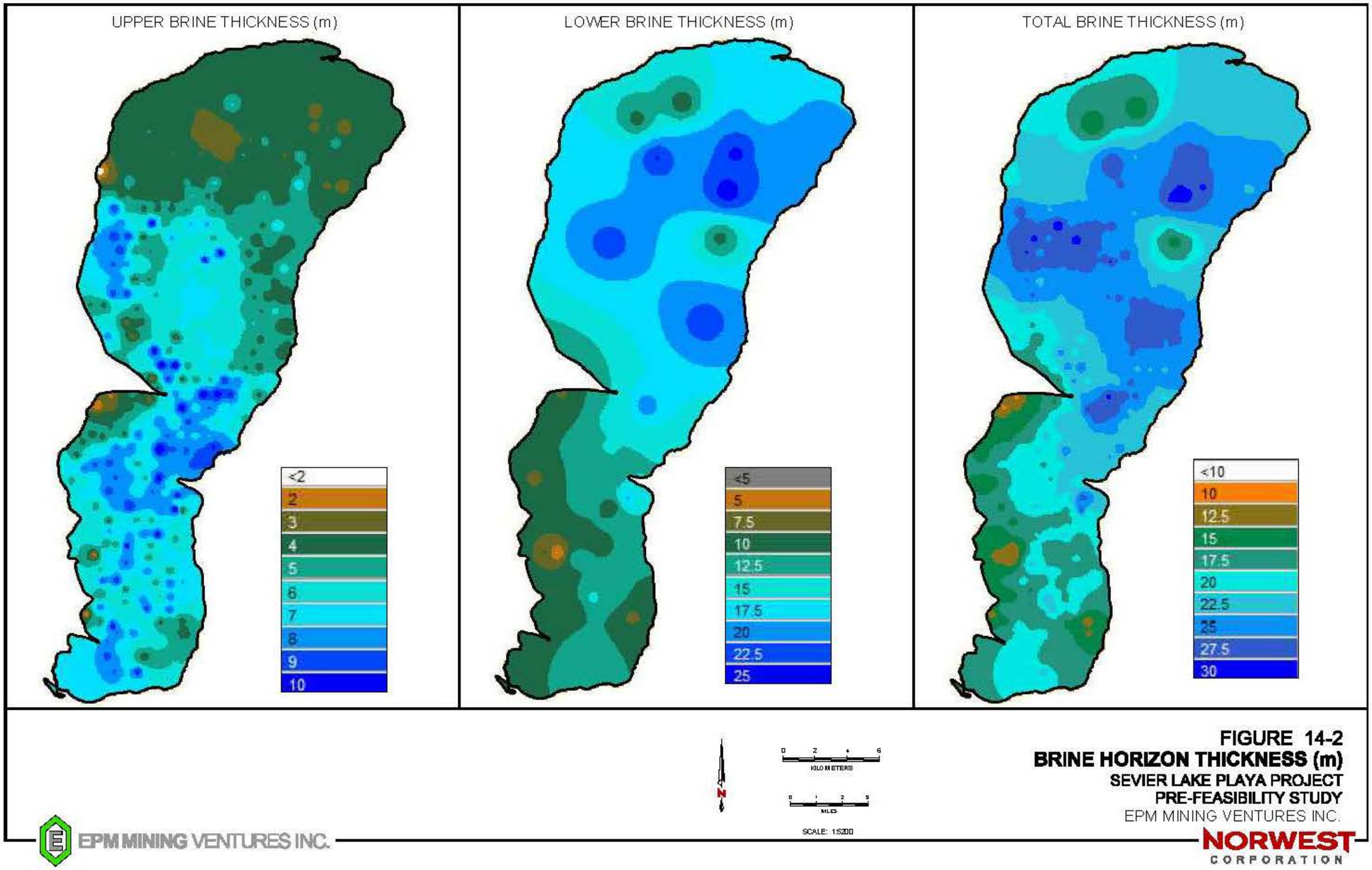


FIGURE 14-3
Brine Aquifer Floor Elevation

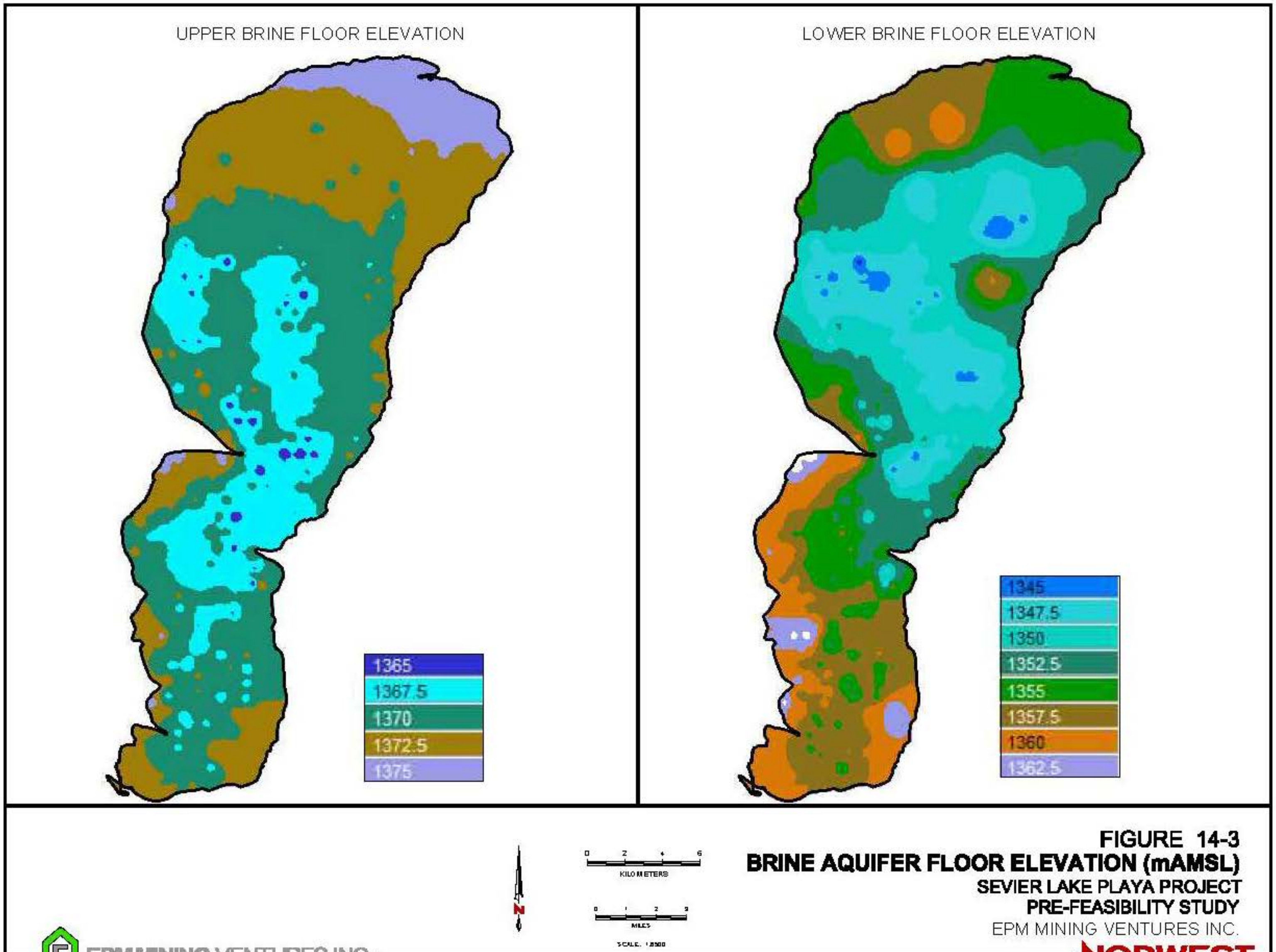


FIGURE 14-4

Histograms of Assays and Moisture

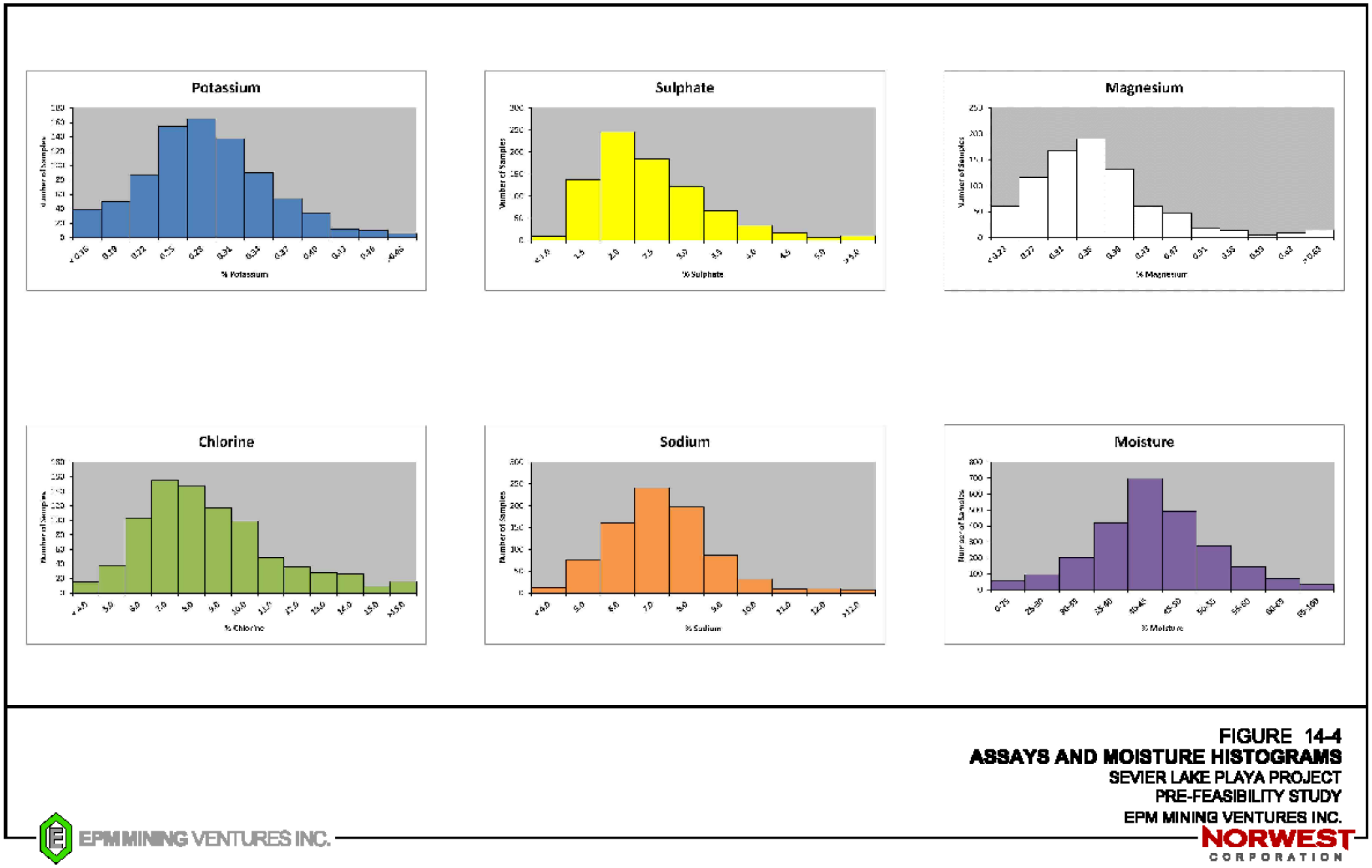


FIGURE 14-5
Semi-Variograms and Grade Trend Ellipses

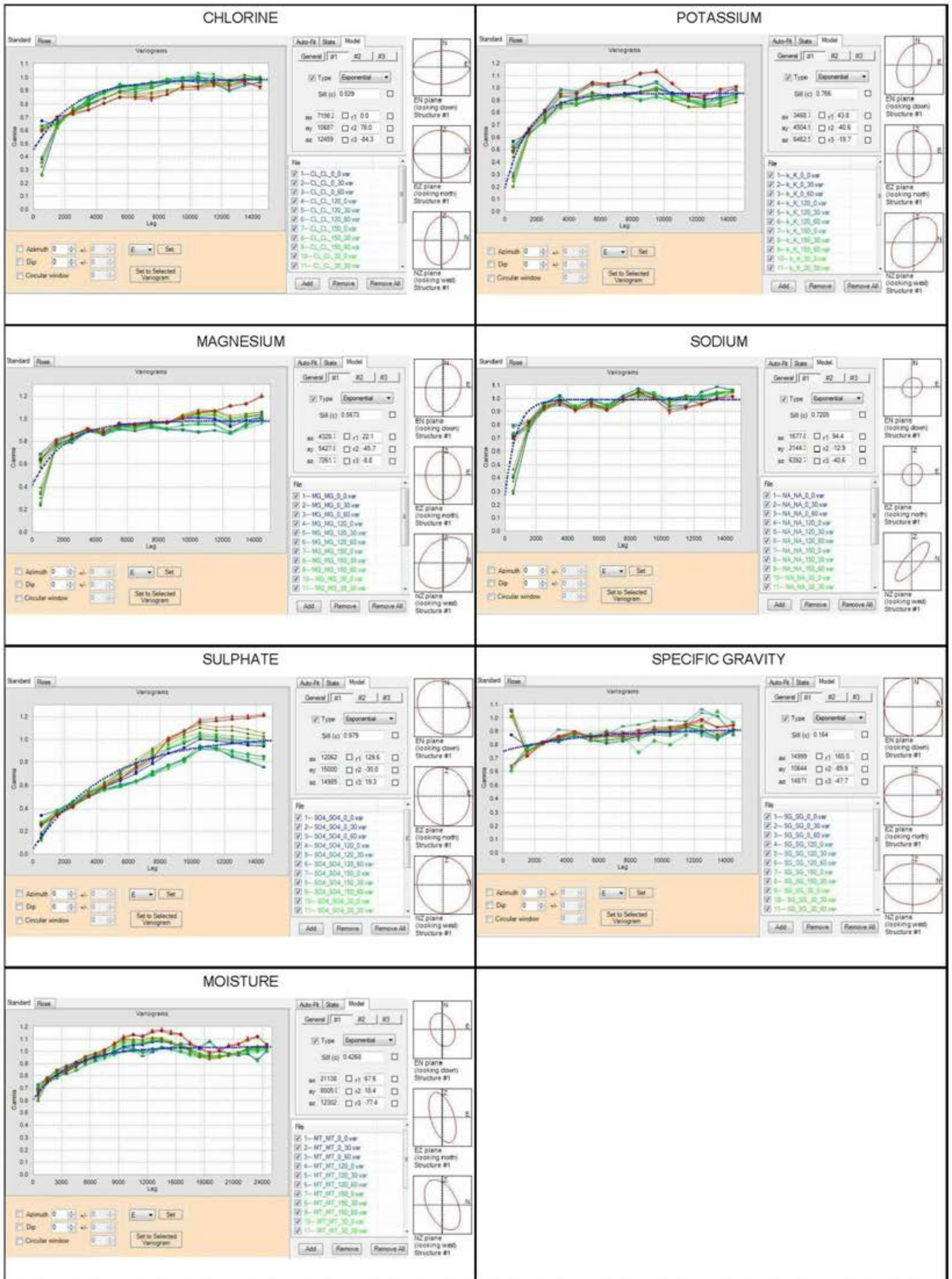


FIGURE 14-5
SEMI-VARIOGRAMS AND GRADE TREND ELLIPSES
SEVIER LAKE PLAYA PROJECT
PRE-FEASIBILITY STUDY
EPM MINING VENTURES INC.

EPM MINING VENTURES INC.
NORWEST CORPORATION

14.4.3 Moisture and Brine Grade Interpolation

The estimation of moisture content and brine grade (cations and anions) and SG into the 3DBM was influenced by the results of geostatistical analyses of the source drill hole sample data as well as by differences in sampling method and results between direct-push and sonic holes.

Frequency distribution plots (histograms) of sample moisture content and brine chemistry were used to identify outliers in the sample data. The moisture and brine grade histograms are illustrated in Figure 14-4. Three-dimensional semi-variogram analyses charts with three-dimensional grade trend plots are illustrated in Figure 14-5.

The histogram and semi-variogram analyses of the sediment and brine sample data have been used as a guideline to determine appropriate estimation algorithms, top cuts, and ranges for brine resource classification. The semi-variogram analyses of the sample data using 1.5-m-thick (5-ft-thick) regular composites indicate a low nugget affect for the sample data and generally isotropic grade trends as indicated in the semi-variogram charts in Figure 14-5. Table 14-7 outlines the moisture and brine grade estimation methods used for the 3DBM.

TABLE 14-7
Geologic Model Estimation Methods

Parameter	Resource Classification	Minimum No. Samples (n)	Maximum No. Samples (n)	Maximum Search Distance (m)
First pass estimates	Measured	3	50	1,500
Second pass estimates	Indicated	3	100	3,000
Third pass estimates	Inferred	1	200	9,000

The brine resource classification is influenced by the results of the semi-variogram analysis of the brine cation and brine anion sample data. The best-fit experimental variogram illustrated in Figure 14-5 indicates a maximum range to sill of approximately 3,000 m (9,842 ft) beyond which the relationship between sample grade pairs is viewed as random or inferred. The search ranges outlined in Table 14-7 are also used to tag the block estimates as measured (first pass), indicated (second pass), or inferred (third pass).

The moisture estimates were matched with respective upper and lower brine horizons due to the close association between drill core lithology and moisture content. The brine grade estimates were not matched with respective upper and lower brine horizons due to the interpreted gradational contact in brine chemistry between the URZ and LRZ. A narrow initial vertical search radius has been used to simulate the vertical stratification of both moisture content and the gradational trends in brine grade as reflected in the sample data. The distribution in estimated moisture content composited across both upper and lower brine horizons is illustrated in Figure 14-6. Similarly, the distribution of brine cation and anion estimates composited for both horizons is illustrated in Figures 14-7 through 14-11.

14.4.4 Model Validation

The block model estimates were validated against the source drill hole sample database by comparing the drill hole sample data against the nearest block estimates. This comparison is best illustrated with the aid of swath plots that compare the mean drill hole sample grades with mean block estimates at regular intervals across the model area. The north-south-oriented swath plots are illustrated in Figure 14-12 and east-west-orientated swath plots are illustrated in Figure 14-13. No overestimation or underestimation trends were observed in any of the plots.

A concern arose during the data and model validation process that there was a potential skewing of grade estimates due to the nature of direct push versus sonic hole completions. The vast majority of the completions, over 90 percent, were direct push holes that terminated at the firmer clay contact between the URZ and LRZ, effectively isolating the URZ horizon. The sonic holes were either isolated in the LRZ or were open completions bridging both upper and lower horizons. It was determined that the URZ grade estimates were better represented by excluding the open-completion sonic holes.

The limited number of completions in the LRZ compared to the URZ prevented accurate statistical determination of possible effects of the set of sonic hole open-completions. Although sampling was conducted using low-volume peristaltic pumps and care was taken not to disturb the brine column between sampled intervals, it is possible that brine from the URZ may have comingled with brine produced from the LRZ after purging. Therefore, there is the potential that the LRZ grade determinations may have been skewed slightly by the higher average grade brine of the URZ.

Areas in the 3DBM influenced by the open completions have been limited to indicated and inferred resource assurance categories due to the relative uncertainty of sampling in these wells. Norwest believe an indicated classification for the lower brine resource in proximity to these wells is warranted due to the interpreted gradational contact and the definitive data that was produced, including empirical moisture content data used for resource volumetrics and accurate delineation of the base of the brine aquifer. The 17 sonic holes with isolated completions in the LRZ have been assigned measured, indicated, and inferred classifications based on the geostatistical determinations described in Section 14.4.2.

FIGURE 14-6
Brine Sediment Moisture Content

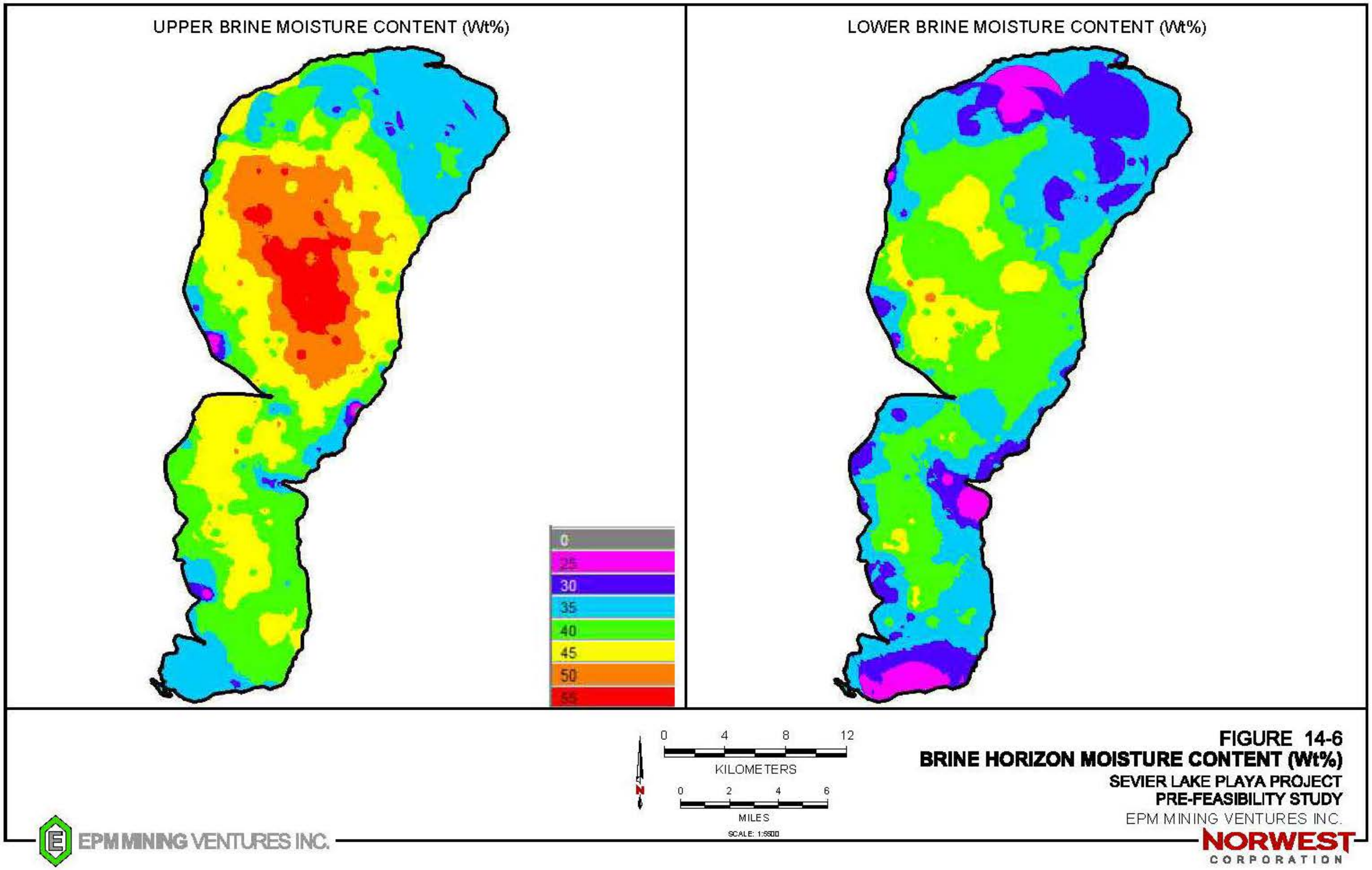


FIGURE 14-7

Brine Aquifer Potassium

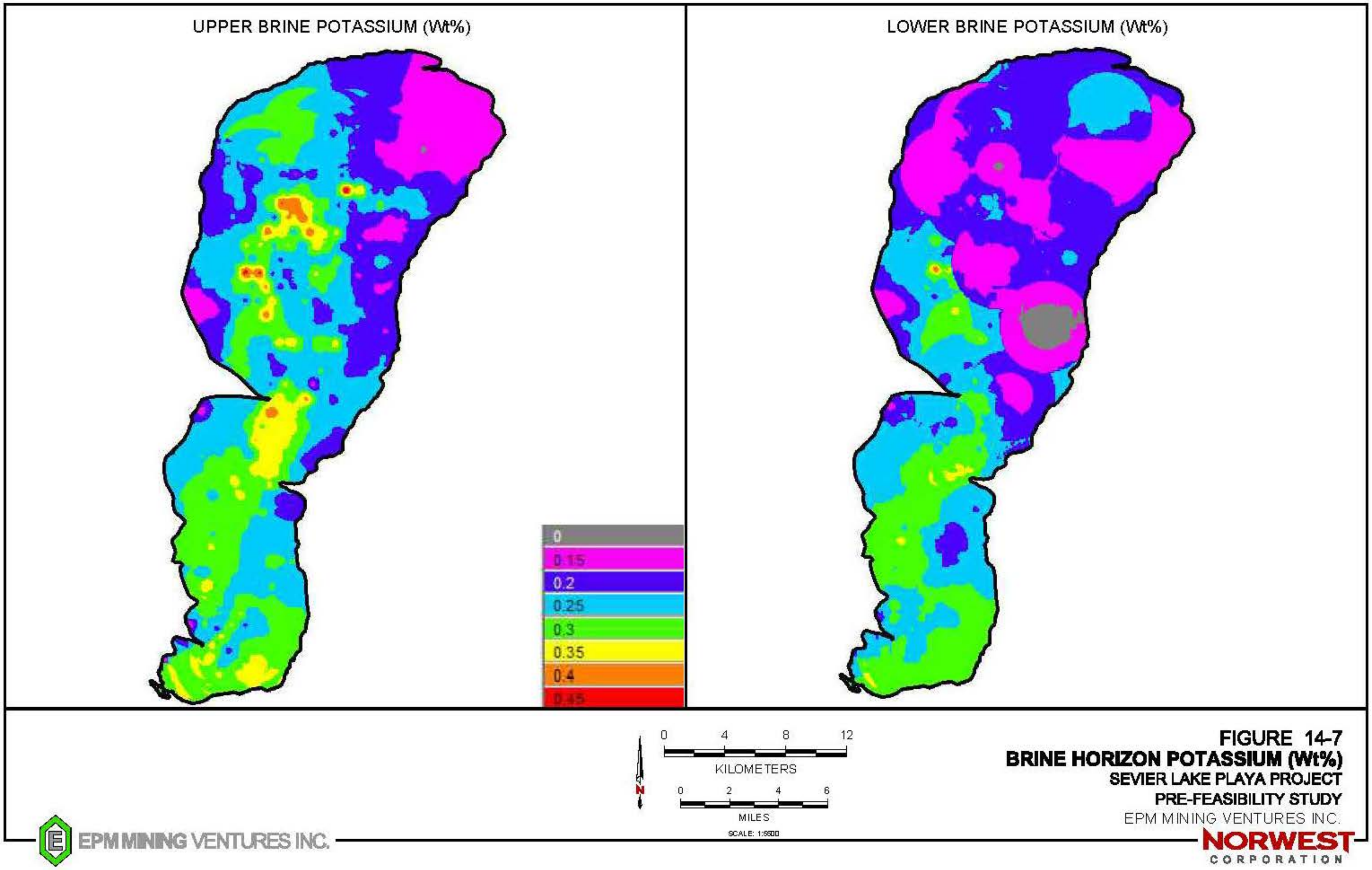


FIGURE 14-8
Brine Aquifer Sulphate

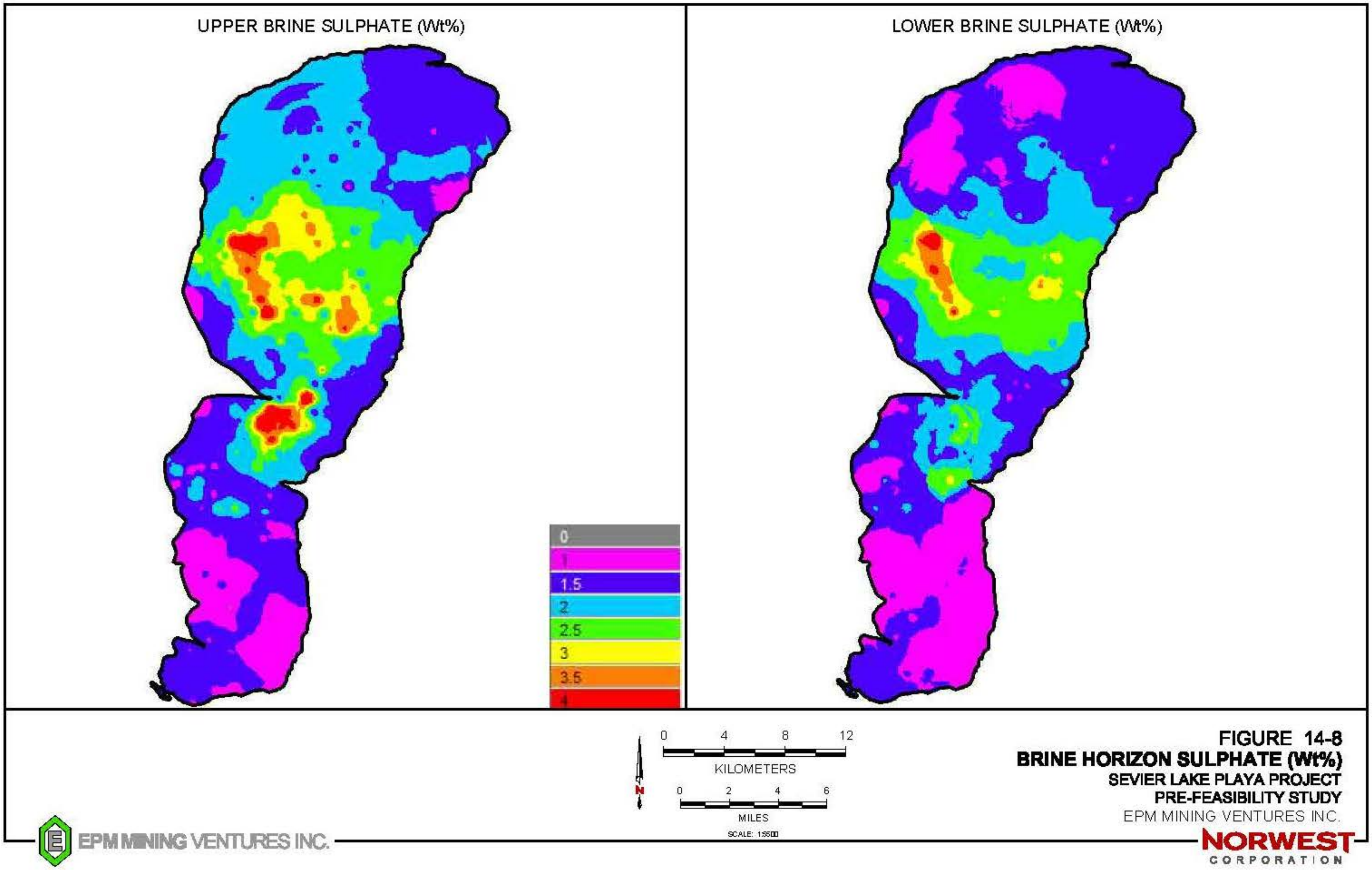


FIGURE 14-9
Brine Aquifer Chlorine

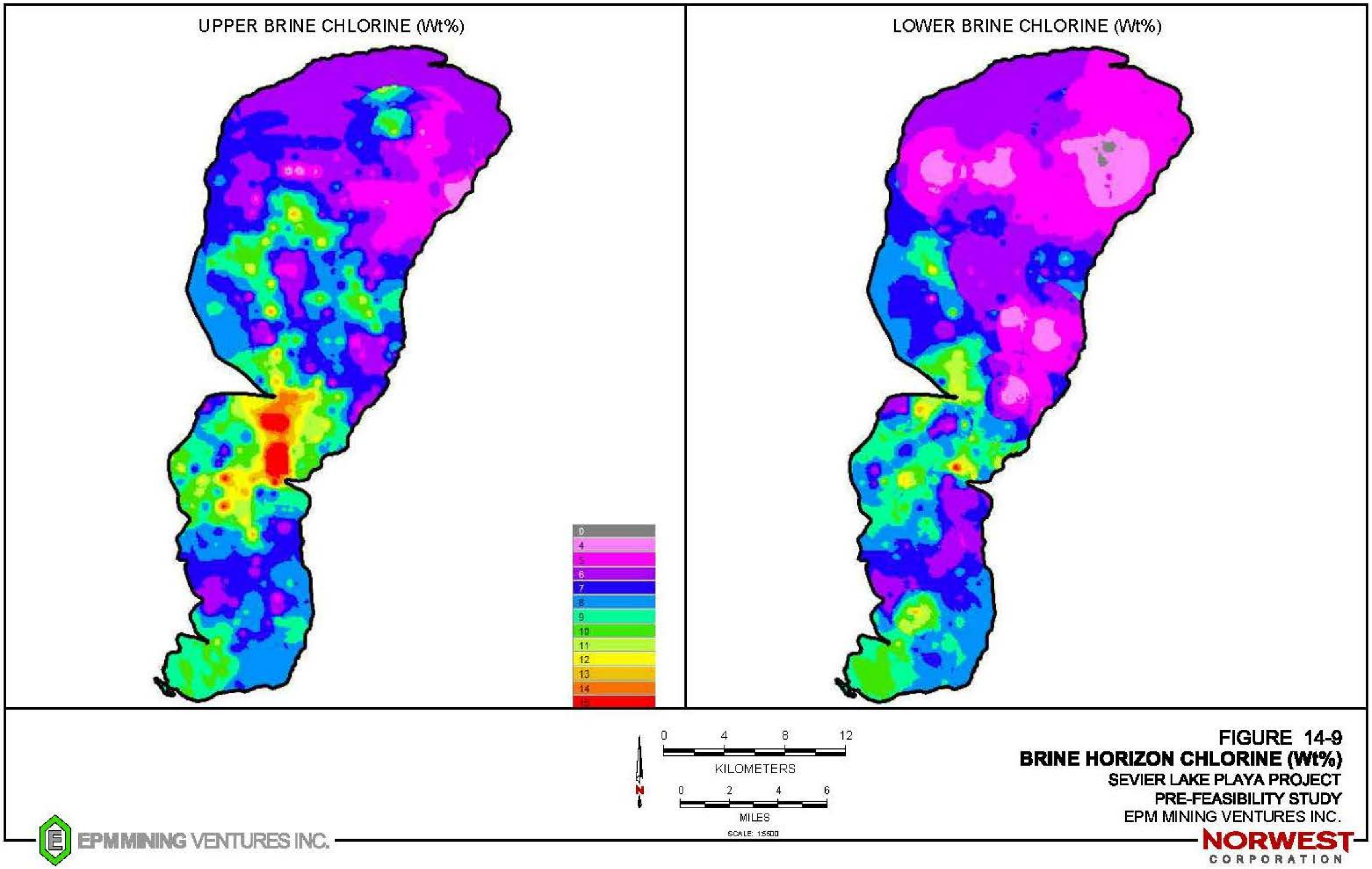


FIGURE 14-10
Brine Aquifer Sodium

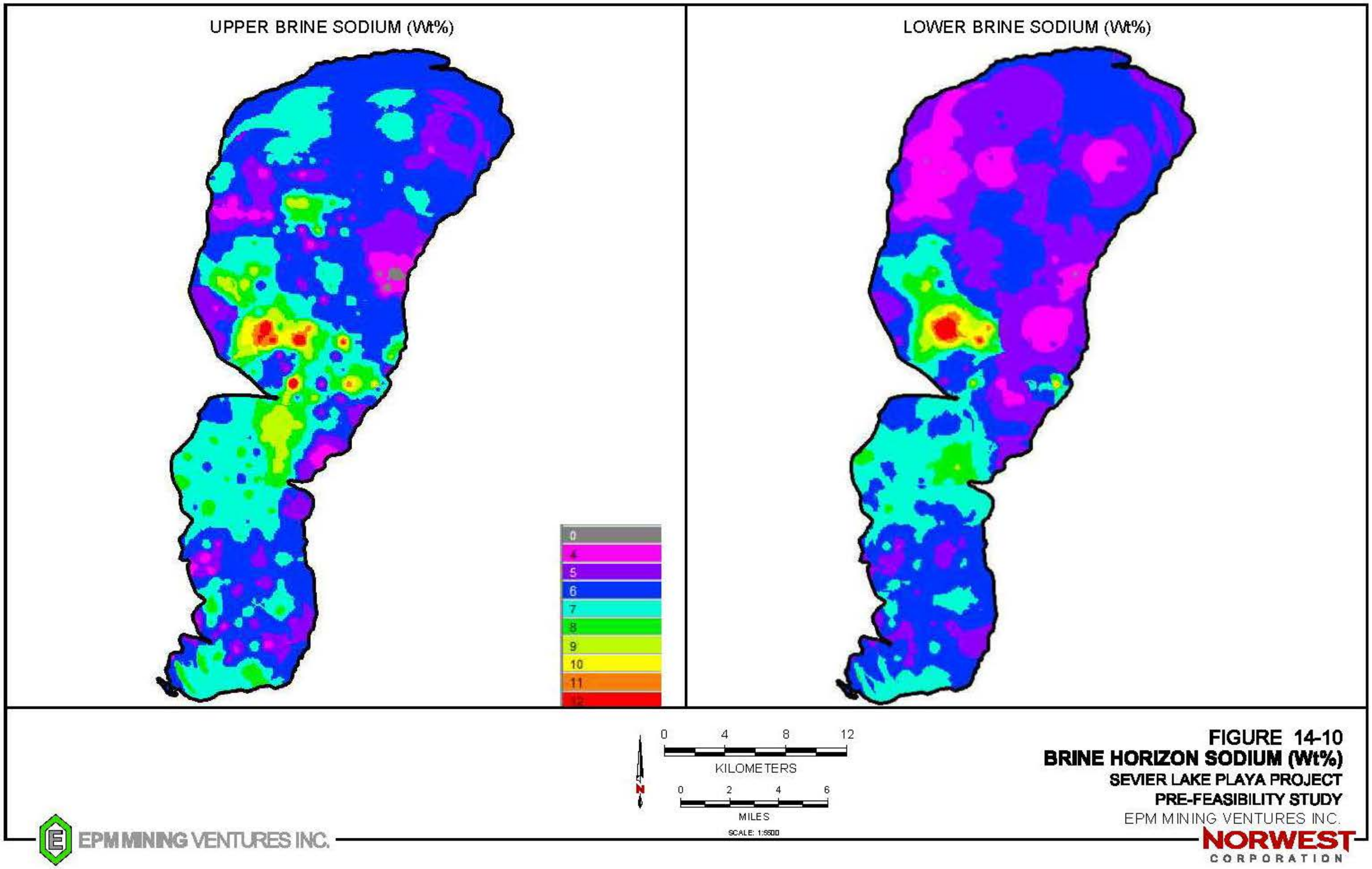


FIGURE 14-11

Brine Aquifer Magnesium

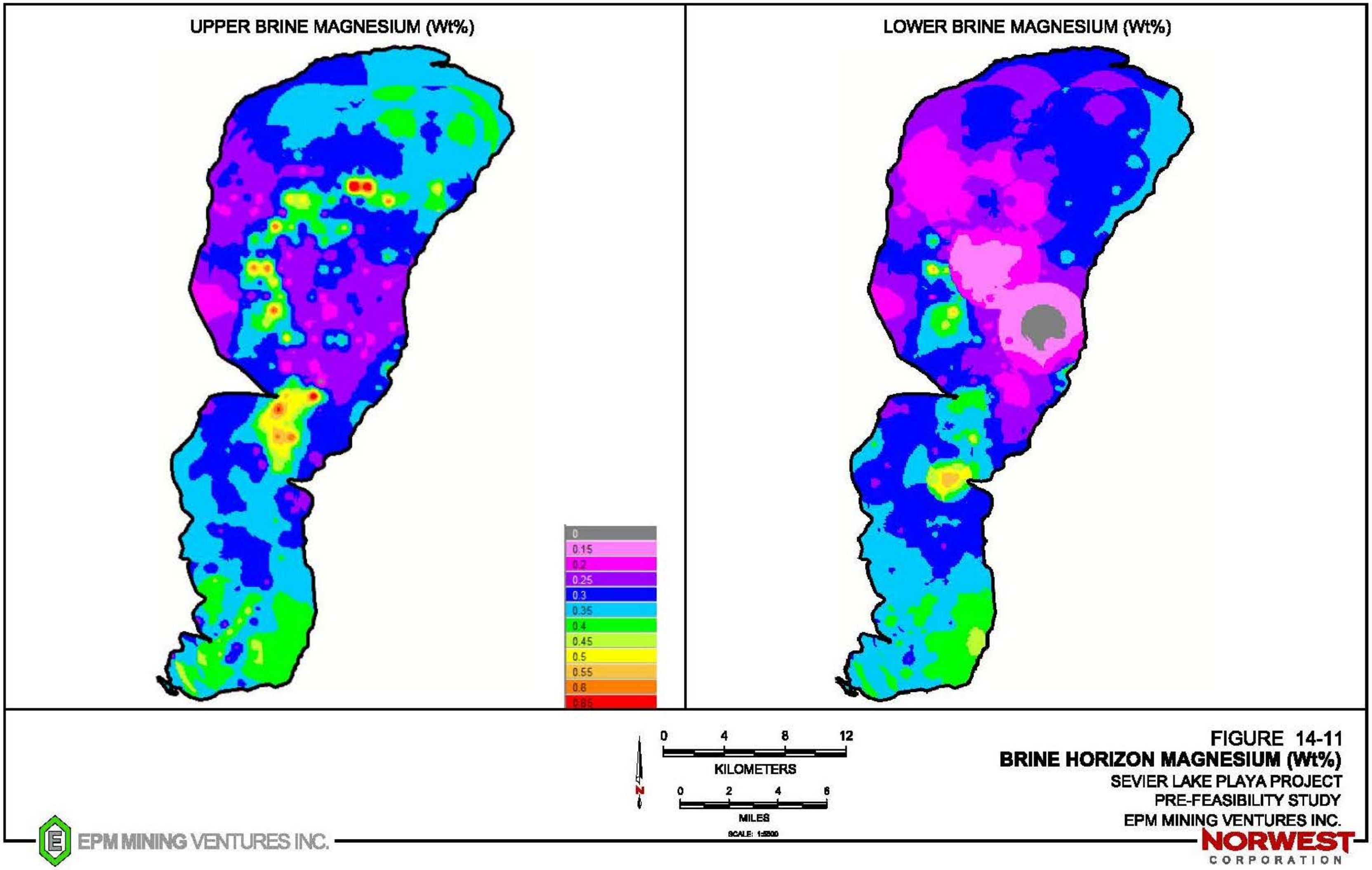


Figure 14-12
Swath Plots North-South Intervals

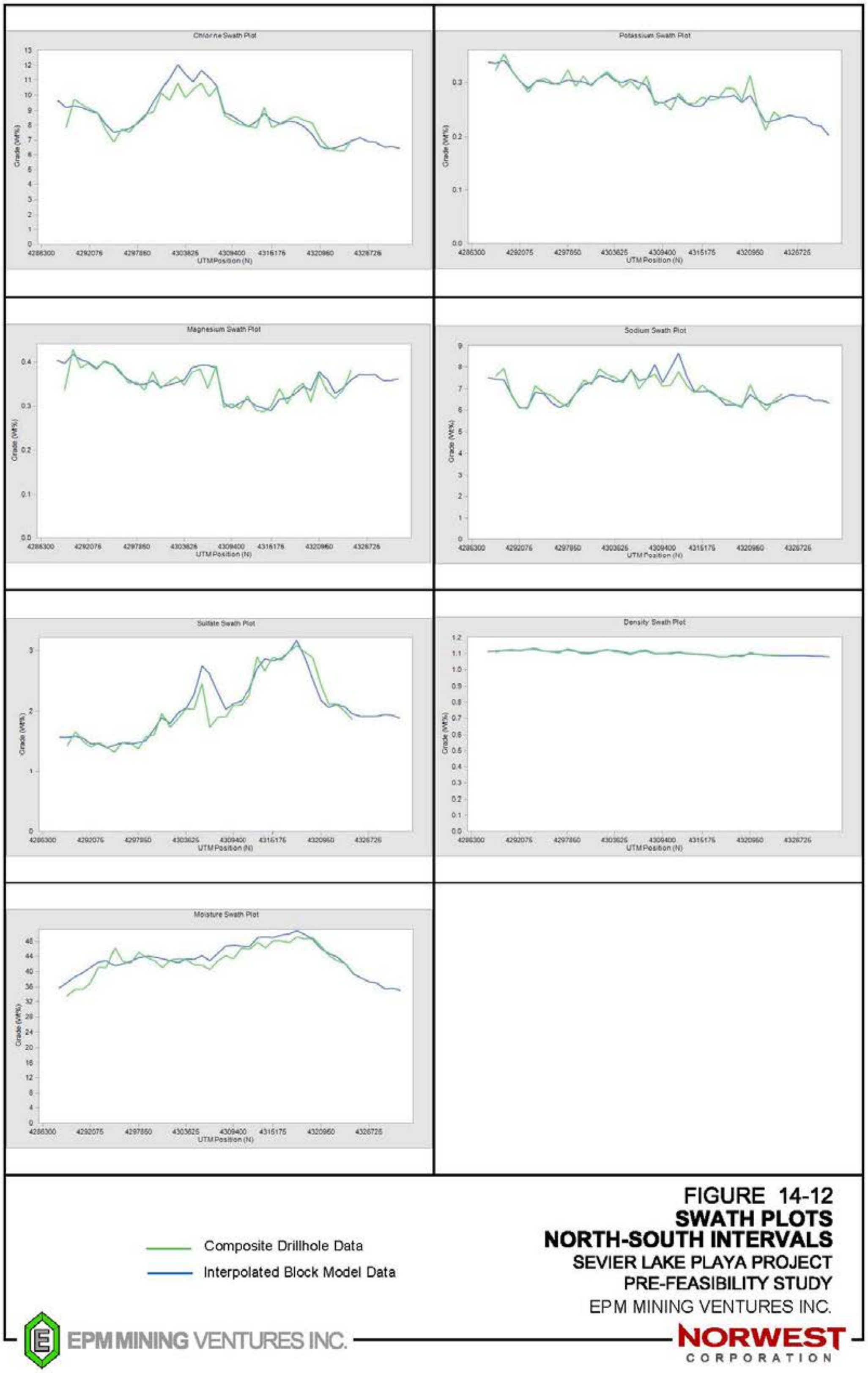
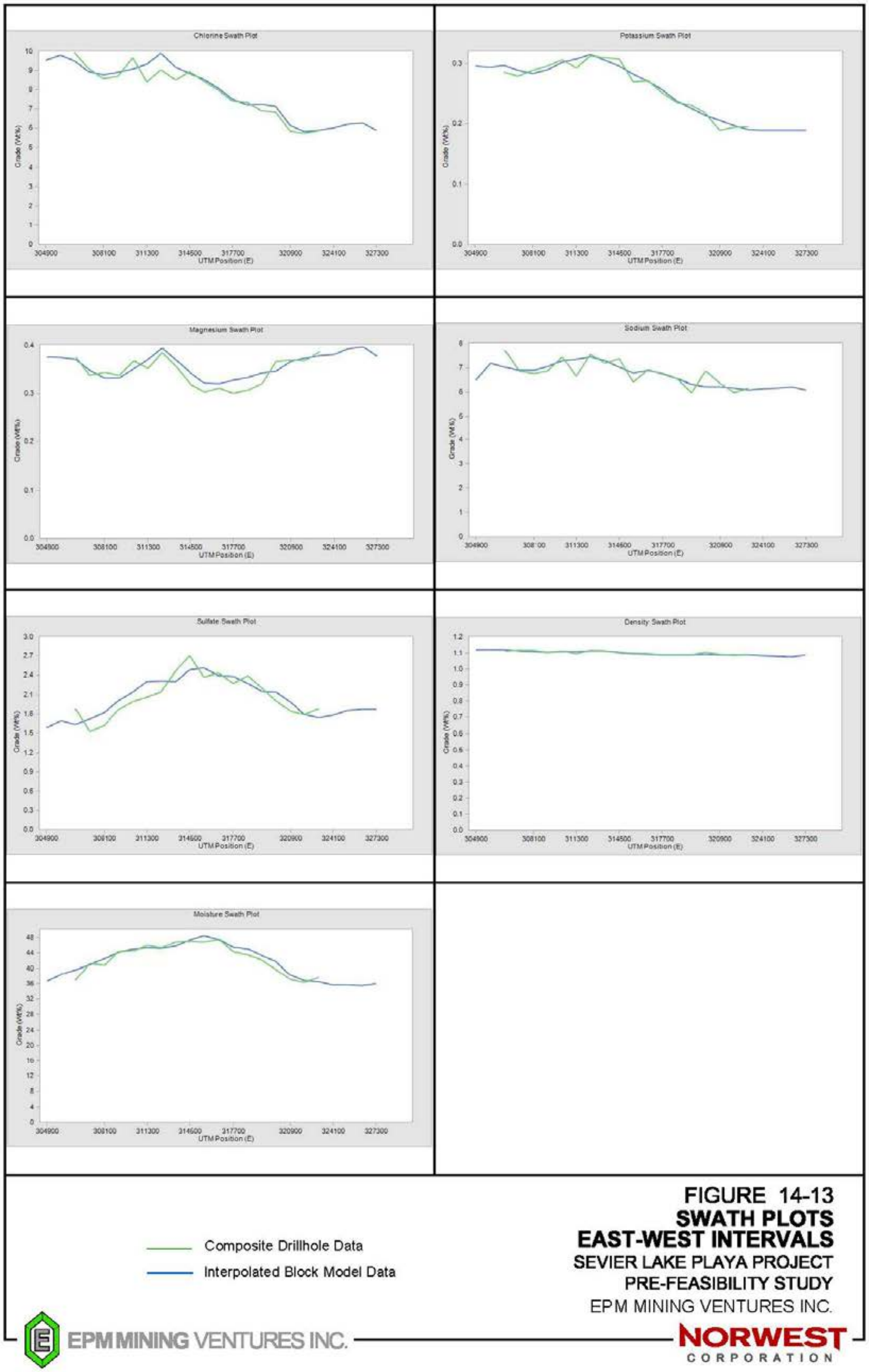


FIGURE 14-13
Swath Plots East-West Intervals



14.5 Resource Statement

Brine resource estimates were derived from the 3DBM of the Sevier Lake Playa that was created using EPM's current drilling and analytical data. The estimated brine resources and associated major dissolved cations and anions for the upper and lower brine horizons are listed in Table 14-8. Resource plans illustrating the distribution of brine resources by levels of assurance for the upper and lower brine horizons are illustrated in Figure 14-14. Table 14-9 outlines tonnages of mineral equivalent compounds that could be created using the available cations and anions in the brine resource. A total measured plus indicated in-place brine resource is estimated to be 5,691 Mt (6,273 Mton). Given that sufficient sulphate is present in the brine to use all the potassium ions, equivalent SOP from the measured plus indicated brine is calculated to be approximately 31.5 Mt (34.7 Mton). An inferred brine resource is estimated at 476 Mt (524 Mton) with an SOP equivalent of 2.6 Mt (2.9 Mton).

The equivalent compounds outlined in Table 14-8 are based on in-place brine tonnages and do not factor in any recovery percentages.

The measured plus indicated resources for available brine tonnes has increased from the 4,938 Mt (5,443 Mton) reported in the PEA (2012) to 5,691 Mt (6,273 Mton) as outlined in Table 14-8, a difference of 753 Mt (830 Mton)or 15.3 percent. The inferred resources for available brine tonnes has decreased from 1,653 Mt (1,822 Mton) reported in the PEA (2012) to 476 Mt (525 Mton), a difference of 1,177 Mt (1,297 Mton) or 71.2 percent. The material change in the resource estimates from the PEA estimates to the current PFS estimates is due to the drilling of 17 additional holes on the lakebed during the 2013 drilling project and the addition of samples from 17 new drill holes that were previously unsampled.

TABLE 14-8
Estimated Brine Resources and Major Dissolved Cations and Anions (Effective Date October 25, 2013)

Classification	Brine Horizon	Lease	Moisture (Wt%)	Volume Aquifer (Mm^3)	Sediment SG	Brine SG	Volume Brine (Mm^3)	Tonnes Brine (Mt)	Potassium (K) Wt%	Potassium (K) Mt	Sulphate (SO4) Wt%	Sulphate (SO4) Mt	Chloride (Cl-) Wt%	Chloride (Cl-) Mt	Sodium (Na) Wt%	Sodium (Na) Mt	Magnesium (Mg) Wt%	Magnesium (Mg) Mt
Measured	Upper	State	42.66	87	2.88	1.121	49	55	0.293	0.163	1.510	0.837	8.508	4.717	6.670	3.698	0.368	0.204
		Federal	46.21	2,063	2.88	1.104	1,209	1,335	0.286	3.818	2.282	30.463	8.893	118.728	7.078	94.496	0.349	4.662
		LUMA	40.54	87	2.88	1.094	48	52	0.240	0.126	1.928	1.010	6.962	3.649	6.670	3.496	0.370	0.194
		Total	45.83	2,237	2.88	1.104	1,307	1,443	0.285	4.107	2.239	32.311	8.808	127.094	7.047	101.689	0.351	5.060
	Lower	State	40.84	6	2.88	1.068	3	3	0.186	0.006	1.504	0.048	4.879	0.156	5.324	0.170	0.243	0.008
		Federal	40.96	757	2.88	1.078	410	442	0.194	0.857	2.010	8.876	5.889	26.008	5.469	24.152	0.253	1.118
		LUMA	29.61	98	2.88	1.090	45	49	0.190	0.093	1.264	0.619	6.276	3.075	4.782	2.343	0.276	0.135
		Total	37.61	860	2.88	1.079	458	494	0.000	0.956	0.000	9.543	0.000	29.238	0.000	26.664	0.000	1.261
	Combined	State	42.43	92	2.88	1.118	52	59	0.289	0.168	1.510	0.885	8.392	4.873	6.611	3.868	0.364	0.212
		Federal	44.14	2,820	2.88	1.097	1,619	1,777	0.269	4.676	2.220	39.339	8.353	144.735	6.750	118.647	0.331	5.780
		LUMA	33.34	184	2.88	1.092	93	101	0.219	0.219	1.676	1.630	6.648	6.724	5.912	5.838	0.331	0.329
		Total	43.35	3,097	2.88	1.098	1,764	1,937	0.261	5.063	2.161	41.854	8.072	156.332	6.627	128.353	0.326	6.321
Indicated	Upper	State	35.70	8	2.88	1.118	4	5	0.336	0.015	1.620	0.074	9.535	0.438	7.542	0.346	0.395	0.018
		Federal	40.45	70	2.88	1.111	39	43	0.305	0.131	1.848	0.792	9.222	3.950	7.091	3.037	0.376	0.161
		LUMA	37.51	134	2.88	1.088	71	77	0.238	0.184	1.929	1.493	6.945	5.375	6.666	5.159	0.375	0.290
		Total	38.37	211	2.88	1.097	114	125	0.265	0.330	1.890	2.359	7.822	9.762	6.844	8.542	0.376	0.469
	Lower	State	35.91	200	2.88	1.115	105	117	0.276	0.323	1.439	1.683	7.762	9.080	6.476	7.576	0.351	0.410
		Federal	39.88	4,948	2.88	1.097	2,717	2,980	0.241	7.170	2.099	62.562	7.367	219.543	6.432	191.683	0.303	9.018
		LUMA	34.51	957	2.88	1.088	490	533	0.228	1.213	1.653	8.810	5.823	31.026	5.768	30.732	0.310	1.649
		Total	38.85	6,104	2.88	1.096	3,311	3,630	0.240	8.706	2.013	73.055	7.153	259.649	6.336	229.991	0.305	11.077
	Combined	State	35.90	208	2.88	1.115	109	122	0.279	0.338	1.446	1.757	7.844	9.517	6.523	7.922	0.352	0.428
		Federal	39.89	5,017	2.88	1.097	2,755	3,023	0.242	7.301	2.096	63.354	7.400	223.493	6.443	194.720	0.304	9.178
		LUMA	34.86	1,090	2.88	1.088	561	610	0.229	1.398	1.693	10.303	5.989	36.401	5.897	35.891	0.319	1.939
		Total	38.83	6,315	2.88	1.096	3,425	3,755	0.241	9.036	2.009	75.414	7.175	269.411	6.353	238.533	0.308	11.546
Measured plus Indicated	Upper	State	42.03	95	2.88	1.121	54	60	0.297	0.178	1.519	0.911	8.595	5.155	6.744	4.044	0.370	0.222
		Federal	46.01	2,133	2.88	1.104	1,248	1,378	0.287	3.949	2.271	31.255	8.903	122.678	7.078	97.533	0.350	4.823
		LUMA	38.67	220	2.88	1.090	119	130	0.239	0.310	1.928	2.503	6.952	9.023	6.668	8.654	0.373	0.484
		Total	45.13	2,448	2.88	1.104	1,420	1,568	0.283	4.437	2.211	34.670	8.729	136.856	7.031	110.231	0.353	5.529
	Lower	State	35.99	205	2.88	1.114	108	120	0.274	0.329	1.441	1.731	7.714	9.235	6.451	7.745	0.349	0.418
		Federal	39.77	5,705	2.88	1.095	3,126	3,422	0.236	8.027	2.088	71.438	7.211	245.551	6.325	215.835	0.297	10.135

TABLE 14-8

Estimated Brine Resources and Major Dissolved Cations and Anions (Effective Date October 25, 2013)

Classification	Brine Horizon	Lease	Moisture (Wt%)	Volume Aquifer (Mm³)	Sediment SG	Brine SG	Volume Brine (Mm³)	Tonnes Brine (Mt)	Potassium (K) Wt%	Potassium (K) Mt	Sulphate (SO4) Wt%	Sulphate (SO4) Mt	Chloride (Cl-) Wt%	Chloride (Cl-) Mt	Sodium (Na) Wt%	Sodium (Na) Mt	Magnesium (Mg) Wt%	Magnesium (Mg) Mt
		LUMA	33.85	1,055	2.88	1.088	535	582	0.225	1.307	1.628	9.429	5.864	34.101	5.698	33.074	0.307	1.784
		Total	38.69	6,964	2.88	1.094	3,769	4,124	0.234	9.663	2.003	82.599	7.006	288.887	6.224	256.655	0.299	12.337
	Combined	State	37.79	300	2.88	1.116	161	180	0.282	0.507	1.468	2.642	8.029	14.390	6.552	11.789	0.356	0.640
		Federal	41.36	7,837	2.88	1.097	4,374	4,800	0.252	11.976	2.144	102.693	7.775	368.229	6.559	313.368	0.314	14.958
		LUMA	34.64	1,275	2.88	1.089	654	712	0.228	1.616	1.691	11.932	6.091	43.124	5.899	41.729	0.321	2.268
		Total	40.26	9,412	2.88	1.097	5,189	5,691	0.248	14.099	2.060	117.268	7.480	425.743	6.446	366.886	0.314	17.866
Inferred	Upper	State	0.00	0	2.88	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Federal	38.78	14	2.88	1.120	8	9	0.311	0.027	1.608	0.141	9.294	0.814	6.876	0.602	0.392	0.034
		LUMA	37.81	105	2.88	1.090	56	61	0.227	0.139	2.009	1.231	6.654	4.078	6.415	3.931	0.351	0.215
		Total	37.92	119	2.88	1.094	64	70	0.238	0.166	1.959	1.372	6.984	4.892	6.472	4.533	0.356	0.249
	Lower	State	41.28	1	2.88	1.111	1	1	0.244	0.002	1.729	0.012	8.251	0.056	6.711	0.046	0.311	0.002
		Federal	43.19	305	2.88	1.102	174	191	0.270	0.517	2.492	4.765	8.280	15.832	7.478	14.299	0.318	0.608
		LUMA	36.25	374	2.88	1.090	196	214	0.217	0.464	1.799	3.844	5.873	12.552	6.023	12.873	0.340	0.728
		Total	39.20	680	2.88	1.096	370	406	0.242	0.982	2.125	8.621	7.011	28.440	6.710	27.218	0.330	1.337
	Combined	State	41.28	1	2.88	1.111	1	1	0.244	0.002	1.729	0.012	8.251	0.056	6.711	0.046	0.311	0.002
		Federal	42.98	319	2.88	1.103	181	200	0.272	0.544	2.467	4.906	8.330	16.646	7.454	14.902	0.322	0.642
		LUMA	36.59	479	2.88	1.090	252	275	0.219	0.603	1.850	5.075	6.064	16.629	6.115	16.804	0.343	0.942
		Total	39.01	799	2.88	1.095	434	476	0.241	1.148	2.101	9.993	7.007	33.332	6.675	31.751	0.334	1.586

TABLE 14-9
Mineral Equivalent Compounds from Brine Resource (Effective Date October 25, 2013)

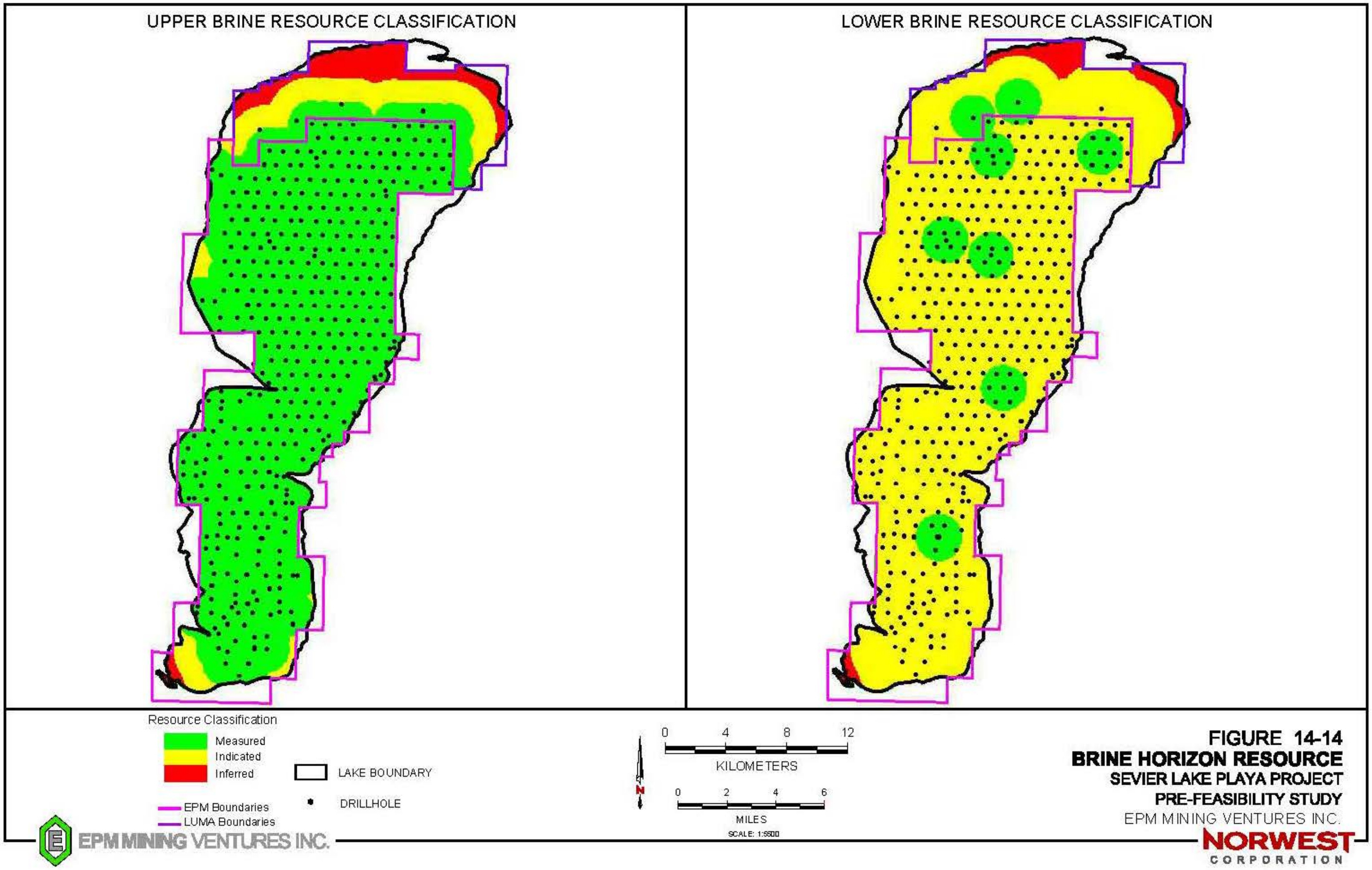
		Tonnes (Mt)				
		Potash	Bitterns	Bitterns	Salt Cake	Halite
Lease Area	Classification	K_2SO_4	$MgCl_2$	$MgSO_4$	Na_2SO_4	NaCl
State	Measured	0.376	0.416	0.526	0.384	7.524
	Indicated	0.754	0.840	1.061	0.732	14.653
	Measured plus Indicated	1.130	1.256	1.586	1.115	22.177
	Inferred	0.004	0.004	0.005	0.008	0.087
Federal	Measured	10.471	11.391	14.391	32.981	225.649
	Indicated	16.272	17.998	22.738	53.577	346.196
	Measured plus Indicated	26.744	29.389	37.129	86.558	571.846
	Inferred	1.212	1.259	1.591	4.389	25.889
LUMA	Measured	0.497	0.657	0.830	1.067	10.492
	Indicated	3.116	3.803	4.804	7.027	55.327
	Measured plus Indicated	3.613	4.460	5.634	8.094	65.819
	Inferred	1.344	1.848	2.335	3.654	25.137
Total	Measured	11.344	12.464	15.746	34.432	243.666
	Indicated	20.142	22.641	28.604	61.335	416.176
	Measured plus Indicated	31.486	35.104	44.350	95.768	659.841
	Inferred	2.560	3.111	3.931	8.051	51.113

The author is not aware of any environmental, permitting, legal, title, taxation, socioeconomic, marketing, political, or other factors that could materially affect the resource estimate, other than the continued validity of the Cooperative Development Agreement with LUMA. The current estimate is dependent on the continued renewal of the Cooperative Development Agreement with LUMA, which is in effect through July 15, 2014.

The accuracy of resource and reserve estimates is, in part, a function of the quality and quantity of available data and of engineering and geological interpretation and judgment. Given the data available at the time this Technical Report was prepared, the estimates presented herein are considered reasonable. However, they should be accepted with the understanding that additional data and analysis made available subsequent to the date of the estimates may necessitate revisions that could be material. There is no guarantee that all or any part of the estimated resources will be recoverable.

Mineral resources that are not mineral reserves do not have demonstrated economic viability.

FIGURE 14-14
Resource Classification



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Mineral Reserve Estimate

There are no declared mineral reserves at present. Mineral reserves will be claimed after completion of the work detailed in the recommendations specified in Section 26. Among other aspects stated in Section 26.1, a full-scale long-term demonstration trench test will be used to validate the hydrogeologic model on which the PFS is based. (See Appendix A.) The full-scale long-term demonstration trench test is necessary because there is no documented commercial mining example based on trench production and trench recharge in similar geologic conditions. The work will validate the brine flow and concentrations over an extended period and allow refinement of the extraction trench and recharge trench geometry as well as construction sequencing. The brine resource is contained in porous media of seemingly low permeability and effective porosity, yet these media produce ample flow to support the proposed processing plant.

A sophisticated dual-porosity model was used as part of the geohydrological modeling to support long-term maintenance of the brine grade. A number of parameters used in the dual-porosity model are not well constrained so until that is achieved, the authors of this Technical Report believe it prudent to wait for completion of additional field data before claiming reserves.

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Mining Method

16.1 Introduction

The proposed mining method for the production of SOP at the Project would comprise the collection of naturally occurring brine from the sedimentary basin of Sevier Playa using extraction trenches and wells that would collect and divert the brine into a series of solar evaporation and concentration ponds located on the surface of the playa, ultimately resulting in a dry, potassium-rich salt. This method is used throughout the world for the collection and concentration of salt-type brines. In general, the larger preconcentration ponds would be located in the northern portion of the Sevier Playa with the production ponds located in the southern portion of the Sevier Playa. Brine extraction is expected to occur predominately within the middle portion of the playa south of the preconcentration ponds and north of the production ponds. Existing site conditions are presented in Figure 16-1.

16.2 Mine Method Overview

Based on the nature of the deposit and the types of materials containing the salts, the most feasible method to gather the brine is using gravity-fed extraction trenches located within the upper fissured-clay resource zone and by pumped extraction wells for the brine located in the LRZ. To reduce the volume of brine that needs to be processed to extract the ore, the brine collected in the extraction trenches and wells is expected to flow through a series of solar evaporation ponds to increase potassium concentration. This method should optimize the production process by increasing the concentration of potassium in the ore that is delivered to the plant, thus reducing the amount of tailings produced.

16.3 Mine Layout and Design

The proposed layout of the mine facilities is illustrated in Figure 16-2. One significant difference between what was presented in the PEA and what is presented in this Technical Report is the location and extent of the preconcentration ponds. The total area required for the preconcentration ponds is slightly smaller and the ponds are now located in the north end of the Sevier Playa on the LUMA leases.

In general, the mine design consists of the following three major components: (1) a brine extraction system consisting of canals, trenches, and wells; (2) a recharge system consisting of canals and trenches; and (3) a series of evaporation ponds. Supplemental analysis in support of the following mine design concepts are provided in several reports and technical memoranda (See Reference Section for AAI, 2013a, 2013b, 2013c, and 2013d; CH2M HILL, 2012, 2013a, and 2013b; IGES 2012a, 2012b, and 2013; Whetstone, 2013).

FIGURE 16-1

Site Map—Existing Conditions

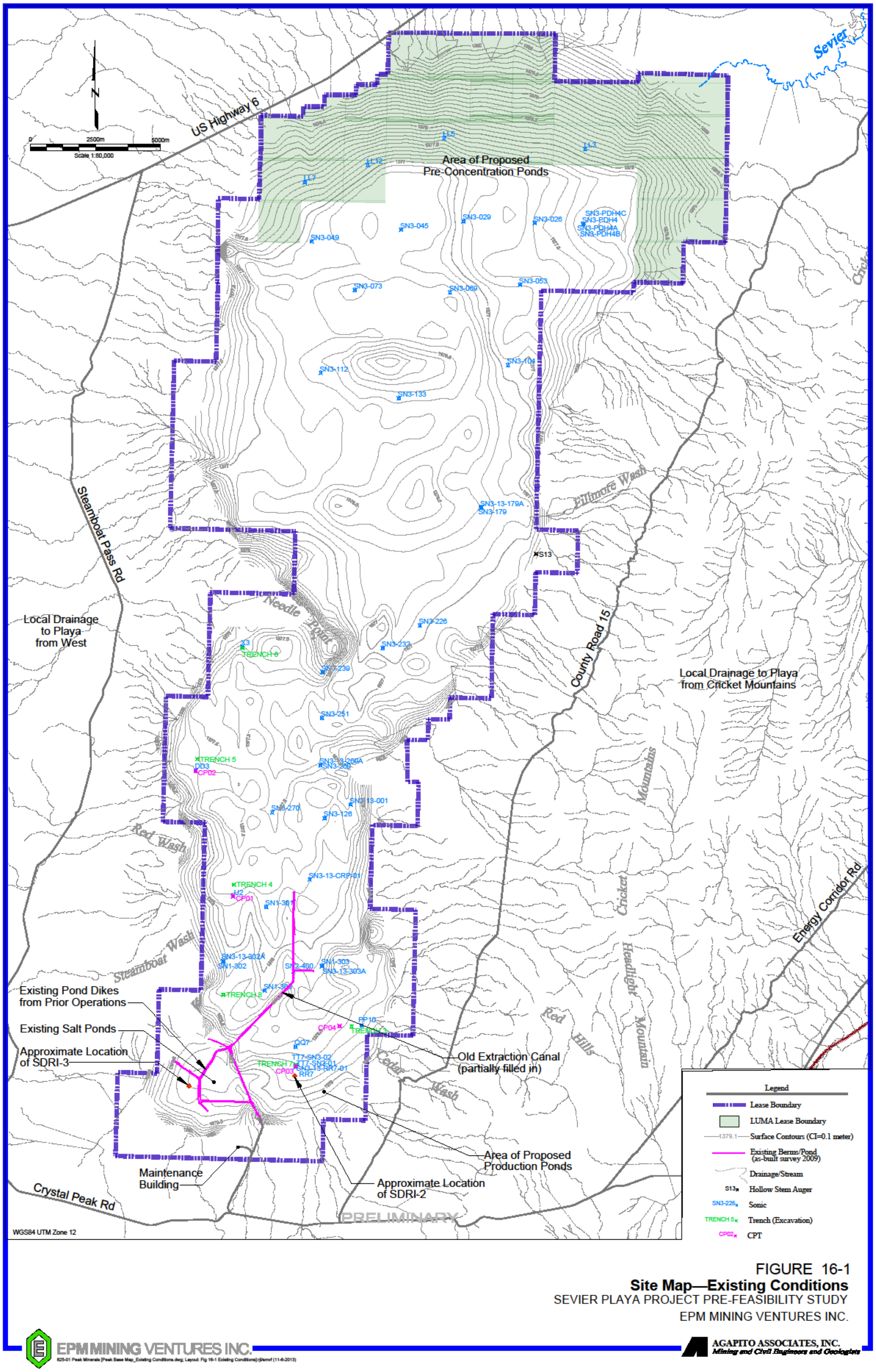
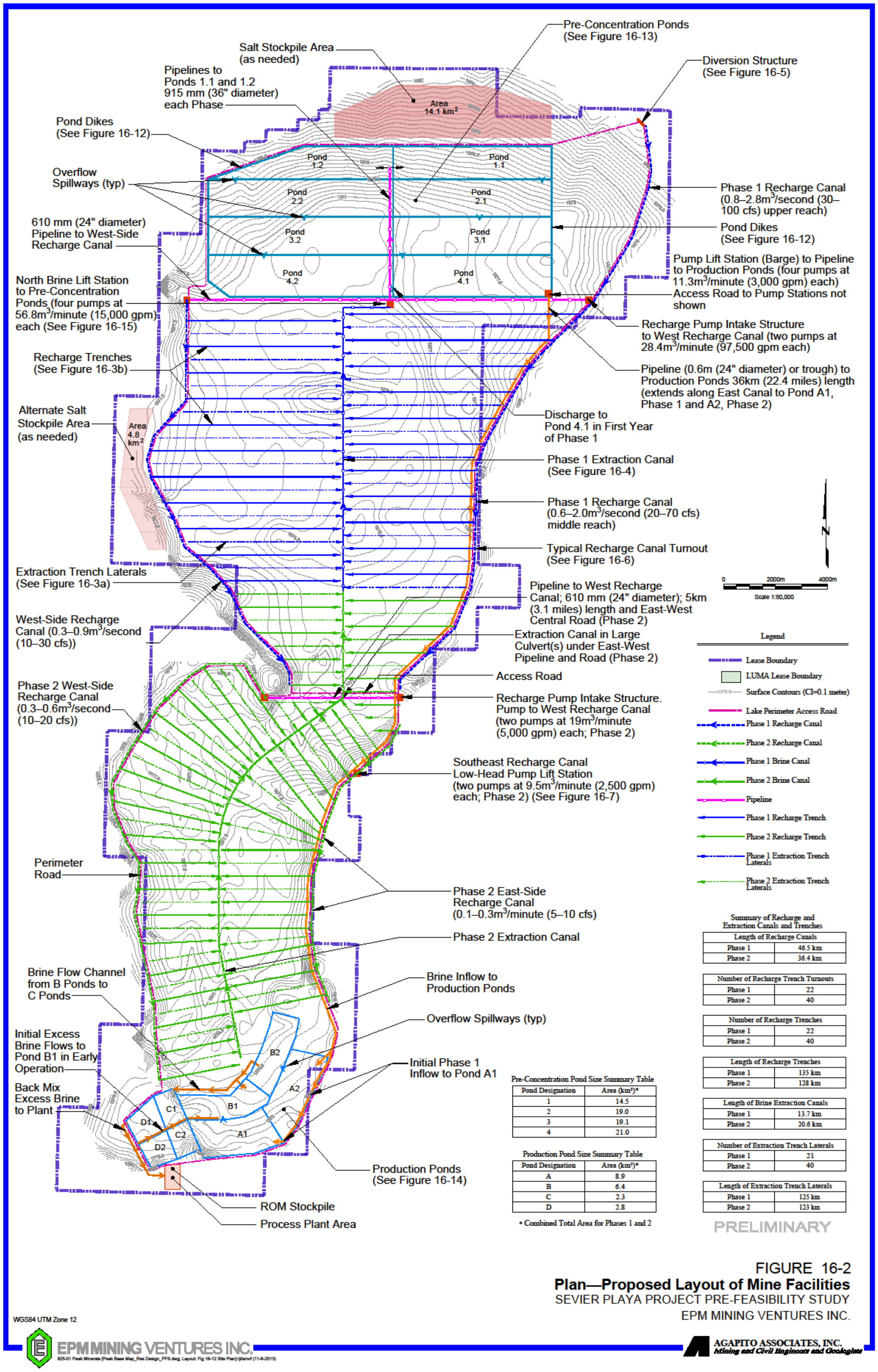


FIGURE 16-2

Plan – Proposed Layout of Mine Facilities



Pre-Concentration Pond Size Summary Table

Pond Designation	Area (km²)*
1	14.5
2	19.0
3	19.1
4	21.0

Production Pond Size Summary Table

Pond Designation	Area (km²)*
A	8.9
B	6.4
C	2.3
D	2.8

* Combined Total Area for Phases 1 and 2

Summary of Recharge and Extraction Canals and Trenches

Length of Recharge Canals	
Phase 1	46.5 km
Phase 2	36.4 km

Number of Recharge Trench Turnouts	
Phase 1	22
Phase 2	40

Number of Recharge Trenches	
Phase 1	22
Phase 2	40

Length of Recharge Trenches	
Phase 1	135 km
Phase 2	128 km

Length of Brine Extraction Canals	
Phase 1	13.7 km
Phase 2	20.6 km

Number of Extraction Trench Laterals	
Phase 1	21
Phase 2	40

Length of Extraction Trench Laterals	
Phase 1	125 km
Phase 2	123 km

Extraction trenches would include collection headers, also referred to as brine canals, which would be fed by brine collection lateral trenches. Recharge would include distribution canals from the Sevier River that would feed trench laterals branching off the main recharge canals. The recharge trench system would provide means by which raw water would be introduced into the system to maintain continuous brine extraction over time. The brine aquifer would be recharged primarily with water from the Sevier River, precipitation, groundwater flow, and local runoff.

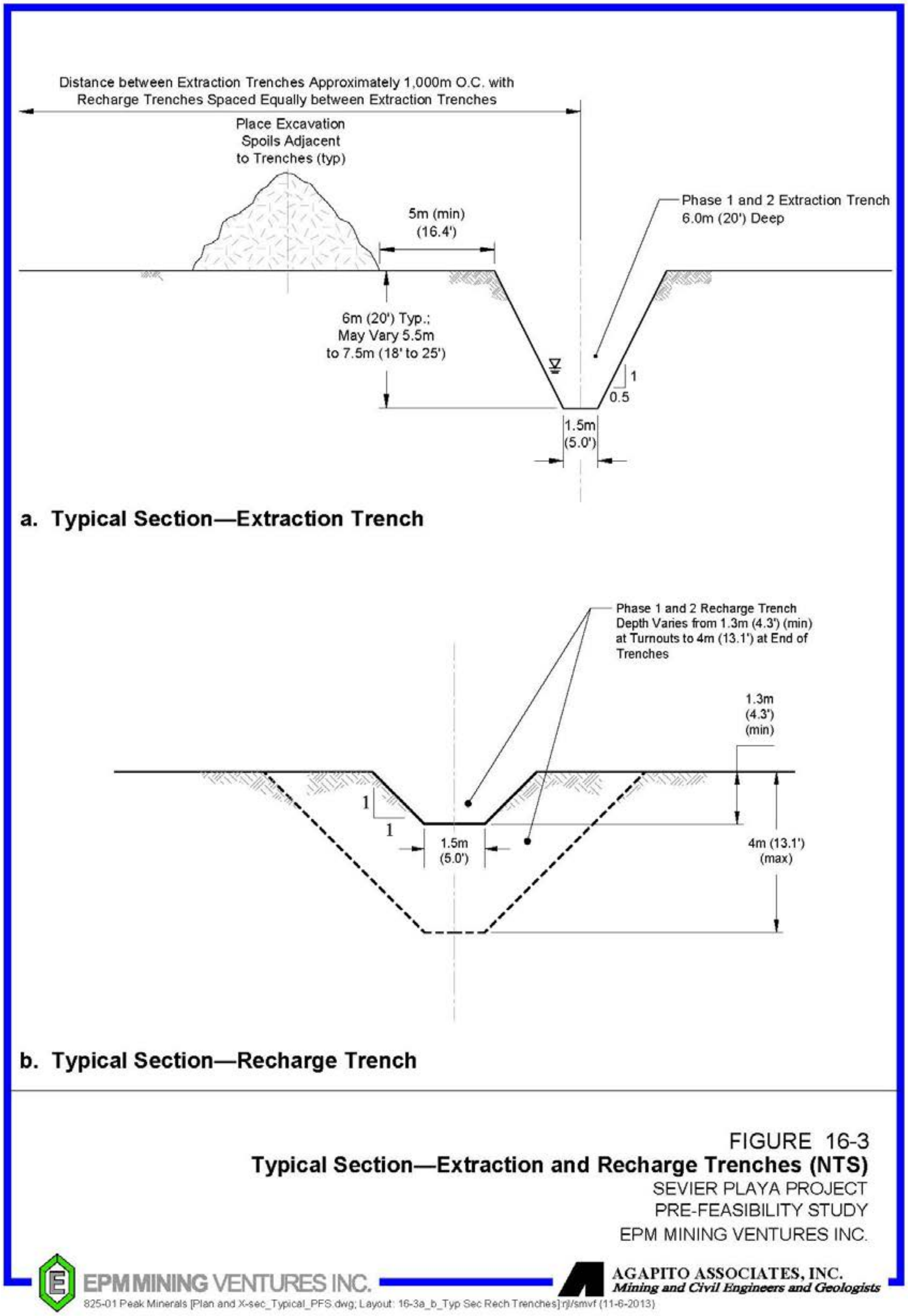
The Sevier River is expected to produce approximately 13.58 million cubic meters per year (m^3/yr) (11,000 acre-feet per year [ac-ft/yr]) during nonsurplus years and approximately 61.7 million m^3/yr (50,000 ac-ft/yr) during surplus years into the Sevier Playa. In addition to the existing water flows, EPM plans to lease up to 33.3 million m^3/yr (27,000 ac-ft/yr) of water rights from Sevier River water users.

A probabilistic reservoir model was developed for the Sevier Playa (CH2M HILL, 2013a) using GoldSim software (GoldSim Technology Group, version 10.5, 2011) to evaluate the likelihood of availability of recharge water. This model simulated variations in inflows including river inflow, runoff to the Sevier Playa, precipitation directly onto the surface of the playa, and mountain block recharge, as well as outflow including extraction and evaporation. A river surplus event probability was incorporated into the model with assumed input values from the base case, the model predicted a 0.86 probability of sufficient recharge water to sustain extraction of 6,414 hectare meters per year (32,200 gpm) of brine for 30 years. Modeling results indicate that supplementing the system with an additional 3,700 hectare meters per year (18,600 gpm) of water from the Sevier River improves the probability of sufficient volume to 0.90. Because the input parameters that were used in the model incorporate variability in each parameter, these probability estimates seem reasonable.

16.3.1 Extraction Canals and Trenches

Brine from the URZ, which extends from approximately 0 m to a maximum of 12 m (0 to 40 ft) bgs, would be collected via extraction trenches that allow for gravity drainage to a depth of approximately 6 m (20 ft), with trench depths likely varying between 5.5 and 7.5 m (18 to 25 ft). Extraction trenches would be spaced every 1,000 m (3,280 ft) with recharge trenches mid-way between them. Side slopes of the extraction trenches would typically be 0.5:1 (horizontal: vertical) with 1.5 m (5 ft) bottom widths as shown in s 16-3A-B. Stability analysis of various trench depths and geometries were performed and indicate that 0.5:1 (horizontal: vertical) side-slopes for a 6-m-deep (20-ft-deep) excavation would be stable during short- and long-term operations. Optimization of these preliminary designs should be performed following additional materials testing and stability analyses in subsequent phases.

FIGURE 16-3A-B
Typical Section—Extraction/Recharge Trench (NTS)



Extraction rates from the trenches were determined in part from the field testing conducted during 2013 (Whetstone, 2013), along with previously reported values (CH2M HILL, 2012). Based on the results of the pumping tests and finite-difference modeling, it is estimated that between 0.80 and 1.2 L/min per m (0.06 to 0.09 gpm per ft) can be extracted from the 6 m (20 ft) deep trenches. To provide the required 125,000 L/min (33,000 gpm), or 72.2 Mt (79.59 Mton) of brine, a minimum of approximately 120 km (75 miles) of extraction trenches would need to be constructed across the Sevier Playa to satisfy the production goal of 300,000 tpy (330,693 tons/yr) of SOP. Design of the Phase 1 extraction trenches includes a total length of approximately 125 km (78 miles) and the Phase 2 extraction trenches total approximately 123 km (77 miles).

Extraction trenches would initiate approximately 250 to 300 m (820 to 984 ft) from the edge of the Sevier Playa boundary and terminate at the junction of the brine extraction canal. Based on the groundwater modeling simulations (Whetstone, 2013), each phase of the extraction trenches, when recharged, is expected to provide sufficient brine for approximately 9 to 10 years. Based on this time sequence, extraction would occur in phases. The construction and implementation of the recharge and extraction phases is discussed in more detail in Section 16.5.

Extraction trench laterals would discharge brine into a main north-south extraction canal, which would convey brine to a pump lift station at the south end of the preconcentration ponds. A profile of the main brine extraction canals for Phase 1 is presented in 16-4. To maintain a continuous flow rate of 125,000 L/min (33,000 gpm), three 57,000-L/min (15,000-gpm) pumps would need to operate approximately 75 percent of the time.

Construction of the extraction trench systems would most likely precede construction of the recharge trench systems to provide earlier transport of brine to the pond system. Recharge would begin once initial drawdown of brine commences within an area.

16.3.2 Recharge Trenches

To manage and control recharge of the brine aquifer from Sevier River flows, the preliminary design includes a low-diversion structure across the river at the inlet to the Sevier Playa. River flow can initially be diverted to the east side of the Sevier Playa for approximately 31 km (19 miles). Water that is initially captured and routed to the east side of the playa would be conveyed to the west side of the playa at two locations by means of pumping stations and pipelines. The northern east-to-west pump and pipeline system is expected to be constructed in Phase 1 while the southern east-to-west pump and pipeline system would be constructed in Phase 2. The preliminary layout of the Sevier River diversion canal and trench system is presented in Figure 16-2. The northern east and west recharge canal systems are expected to be constructed in the early phases while the southern recharge canal systems would be constructed in later phases.

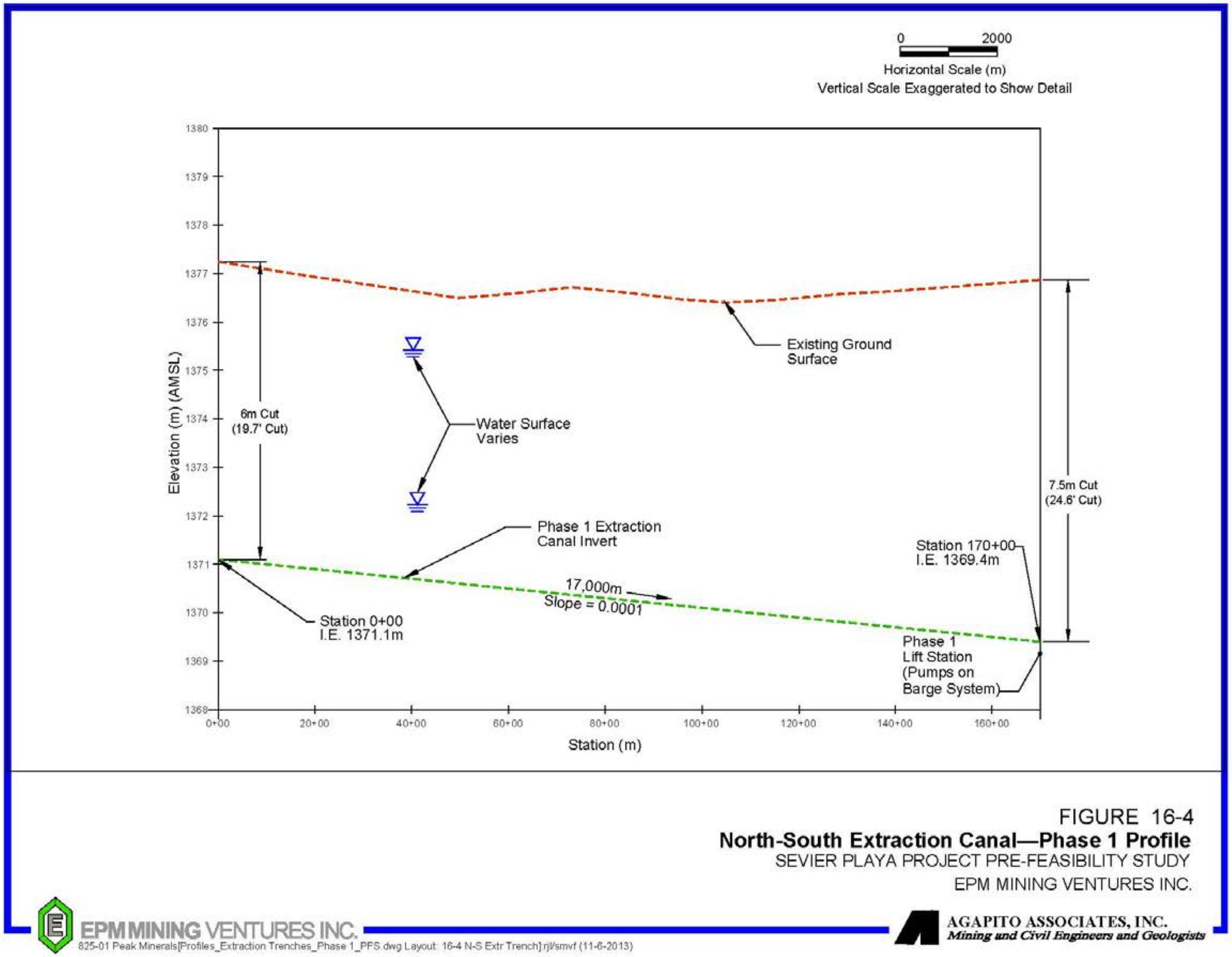
Recharge trench laterals should penetrate the fat clay layer that extends to a depth of 3.7 m (12 ft) and, therefore, should initially be constructed to a terminal depth of at least 4 m (13.1 ft) and deepened to 6 m (20 ft) as necessary in subsequent phases. Typical sections illustrating the recharge trench designs are presented in Figure 16-3A-B.

16.3.3 Recharge Canals

It is assumed that 100 percent of the Sevier River inflow would be diverted via canals, pumps, and piping along the east and west sides of the Sevier Playa. Assuming flows are averaged over the full year, an approximate flow rate of 0.86 to 1.15 m^3/second (s) (30 to 40 ft^3/s) would result during nonsurplus years with higher rates during Sevier River surplus water years. Maximum flows in the initial reach of the recharge canal are expected to be approximately 2.9 m^3/s (100 ft^3/s). Details of the recharge canal designs are presented in AAI's (2013c) Technical Memorandum 12. A plan and section of the Sevier River diversion structure is presented in Figure 16-5. In section, the geometry of the recharge canal excavations are expected to range between 10 m (3.3 ft) to 3.4 m (11.2 ft) deep with flat bottom widths that range from 2.0 m (6.6 feet) to 3.65 m (12.0 ft) with 2:1 (horizontal: vertical) side-slopes. A profile of a typical turnout from the recharge canal to a recharge trench is presented in Figure 16-6.

The west diversion canal in the north recharge area is anticipated be fed by a pipeline that extends approximately 15.5 km (9.7 miles) from the east canal diversion structure to the west along the south side of the preconcentration ponds. The pump structure is expected to consist of a rectangular concrete vault housing two vertical turbine pumps. Each pump will likely have a capacity of 28,000 L per minute (7,500 gpm). The pipeline that is to convey the recharge waters is to be connected to the vault box and will probably consist of 610-mm-diameter (24-in diameter) high-density polyethylene. The pipeline will most likely terminate at a recharge pipeline discharge structure at the head of the west recharge canal. The upper west recharge canal is expected to extend along the west side of the north recharge area to a point northwest of Needle Point. As noted in Figure 16-2, it is anticipated that a second pump station, similar to the one described above, will be required along with a diversion pipeline approximately 5.5 km (3.4 miles) long, which would be needed to provide recharge water to the southwest portion of the Sevier Playa in Phase 2.

FIGURE 16-4
North-South Extraction Trench—Canal Phase 1 Profile



It is expected that the east recharge canal would require a lift station to provide conveyance to the final 9.5-km (5.9-mile) trench along the southeast side of the Sevier Playa (Figure 16-7). A profile of the east recharge canals is presented in Figure 16-8. The profile along the west recharge canal is similar to that presented in Figure 16-8 in that a minimum slope of 0.0001 can be maintained over a distance of 18,000 m (11.2 miles) although it is anticipated the a lift station should not be required.

Recharge canals and laterals are not expected initially to be as deep as the extraction trenches since they would only distribute raw water to the upper layer of the URZ during the early phases of mine operations. The freeboard on the recharge canals and trenches would allow some flood flows to discharge through the system. However, extreme flood events could discharge over the Sevier River diversion structure and spread out over the Sevier Playa. In a future study, a recharge containment system would need to be designed to mitigate the impact of such an event.

FIGURE 16-5

Plan and Section View – Sevier River Diversion Structure

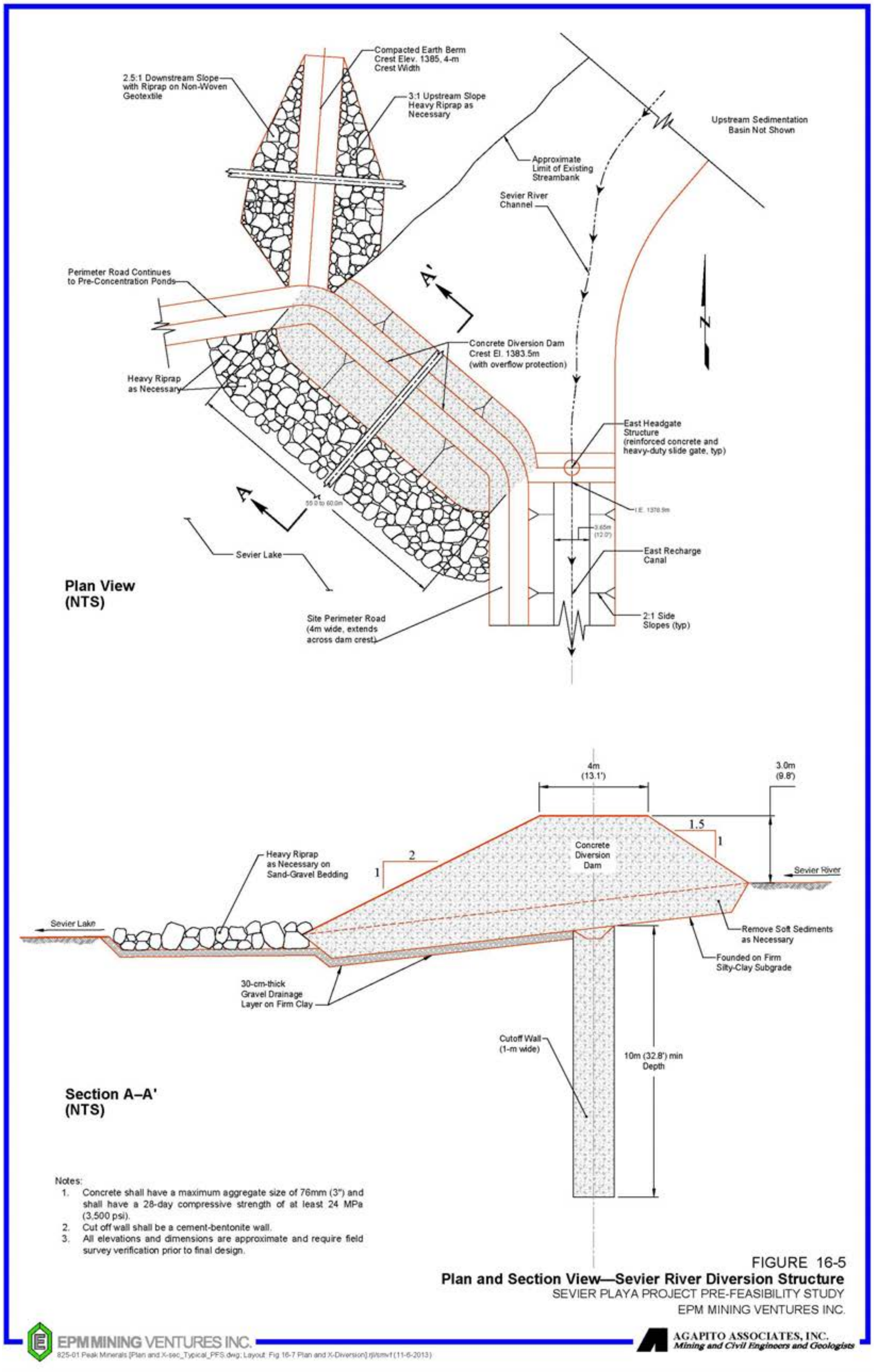


FIGURE 16-6
Typical Recharge Canal Turnout to Recharge Trench

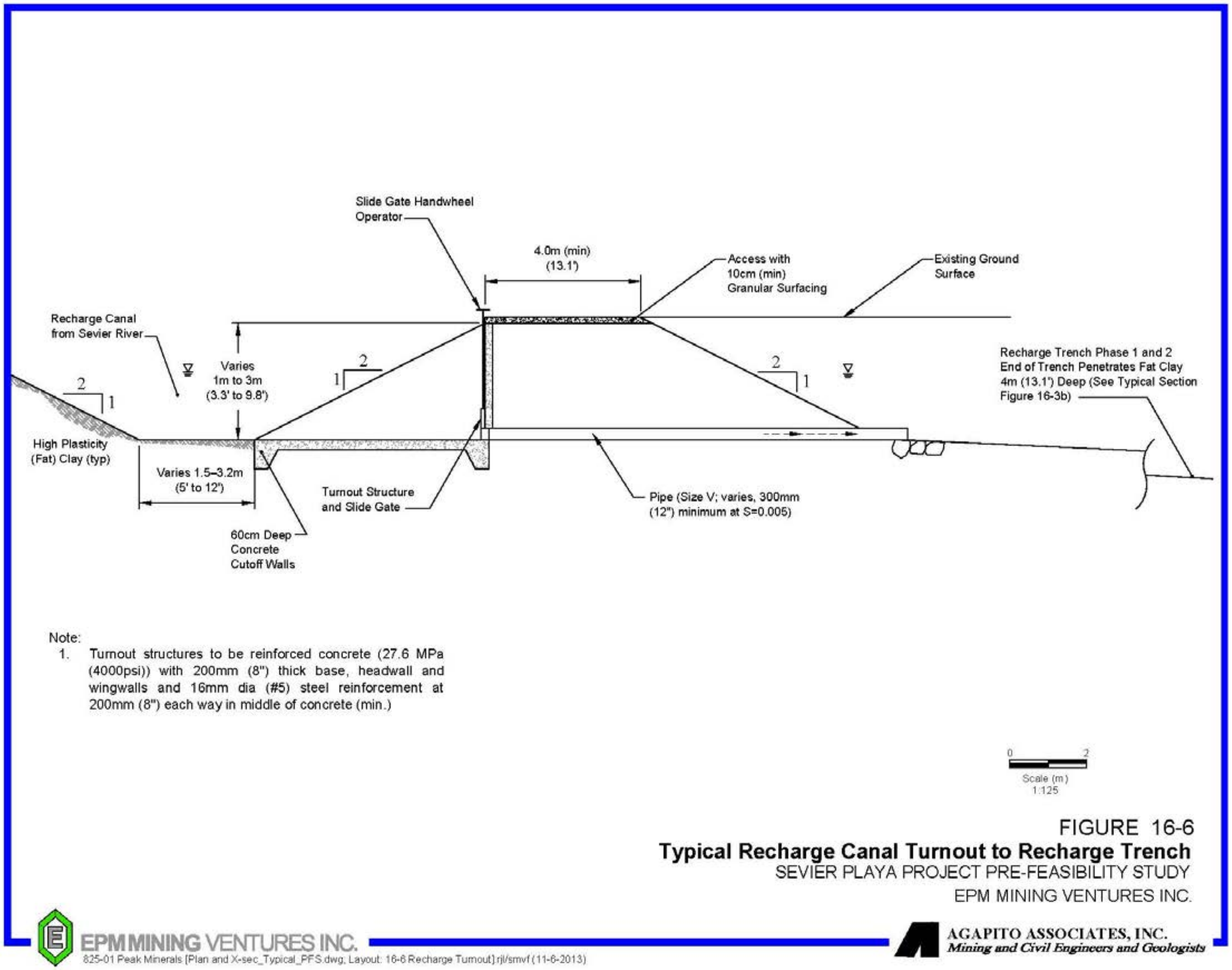


FIGURE 16-7
Southeast Recharge Canal Pump Lift Stations (NTS)

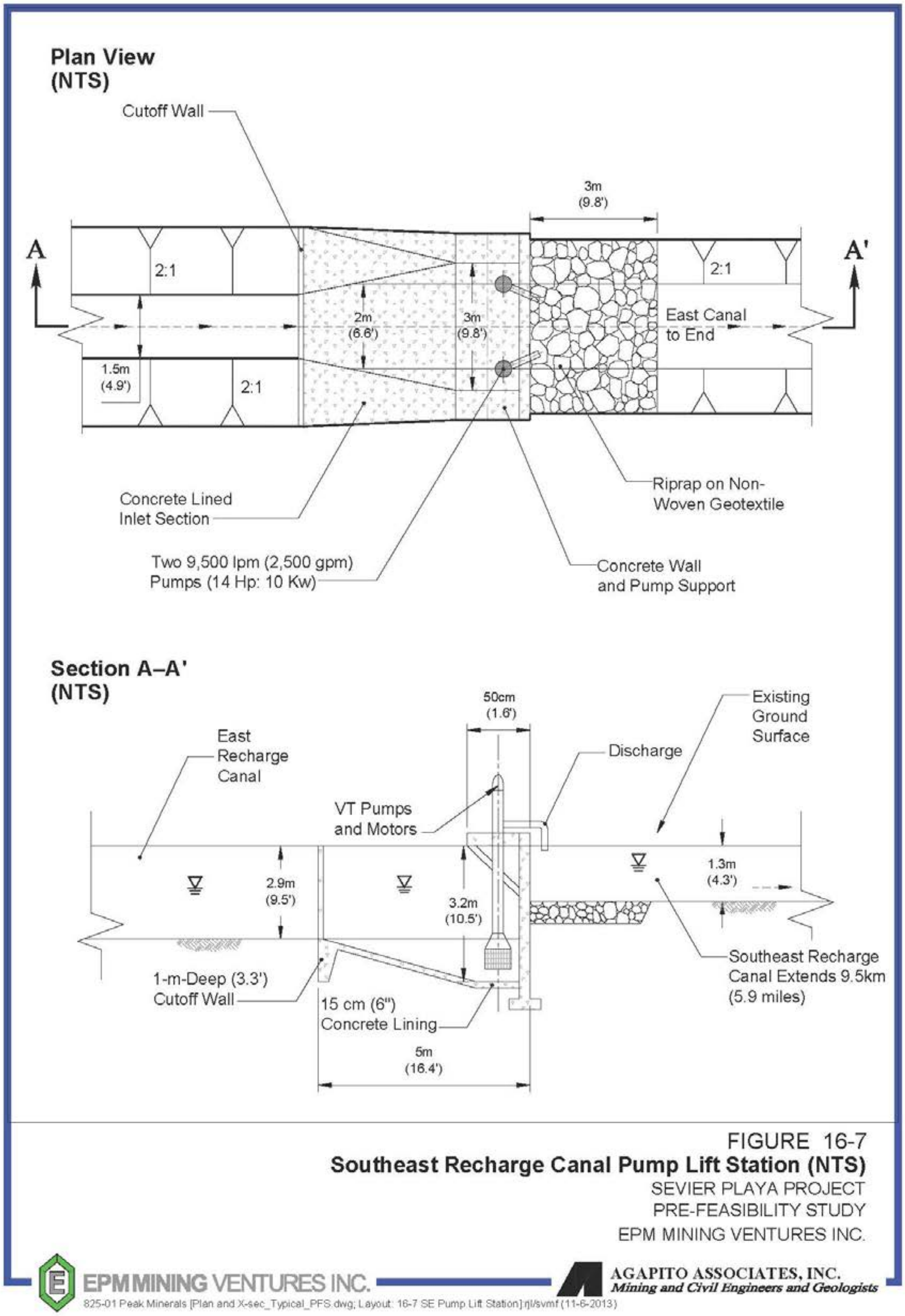


FIGURE 16-8
Profile—East Recharge Canal

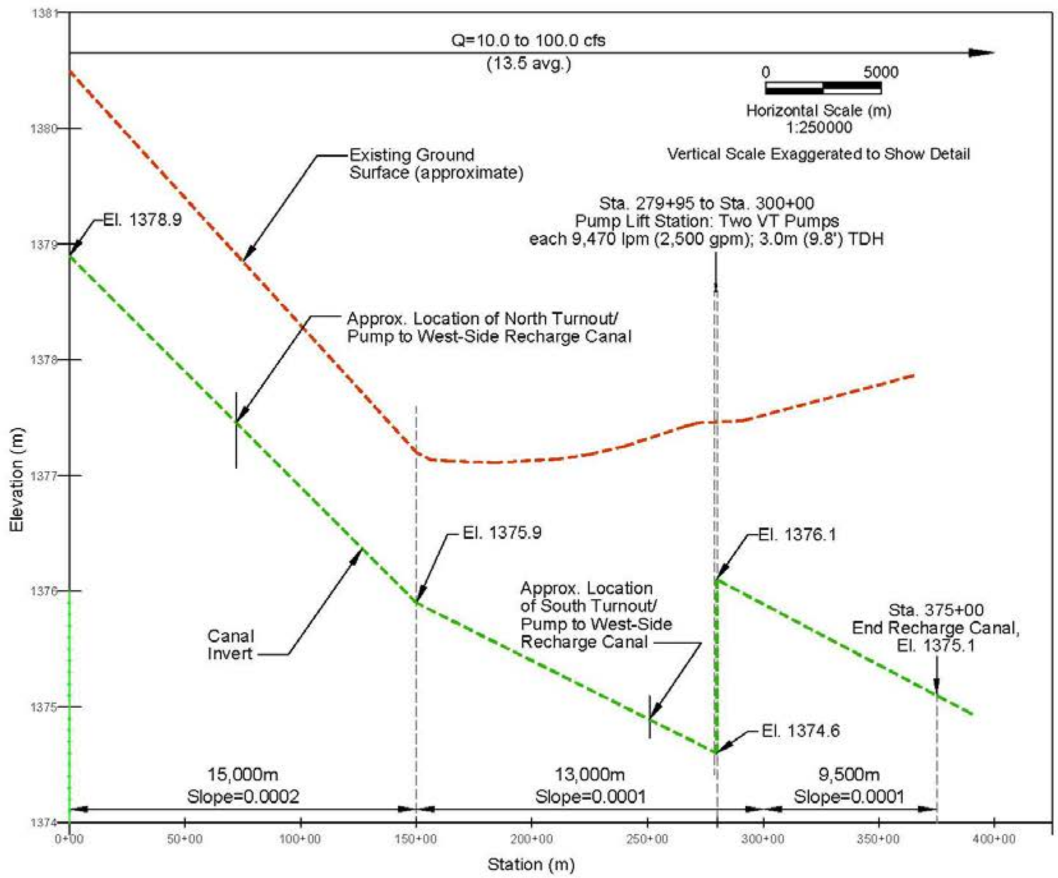


FIGURE 16-8
Profile—East Recharge Canal
SEVIER PLAYA PROJECT PRE-FEASIBILITY STUDY
EPM MINING VENTURES INC.

EPM MINING VENTURES INC.
825-01 Peak Minerals[Profiles_Diversion Canals_PFS.dwg; Layout: 16-8 Profile East Recharge Canal]:rjl/smvf (11-6-2013)

AGAPITO ASSOCIATES, INC.
Mining and Civil Engineers and Geologists

16.3.4 Extraction Wells

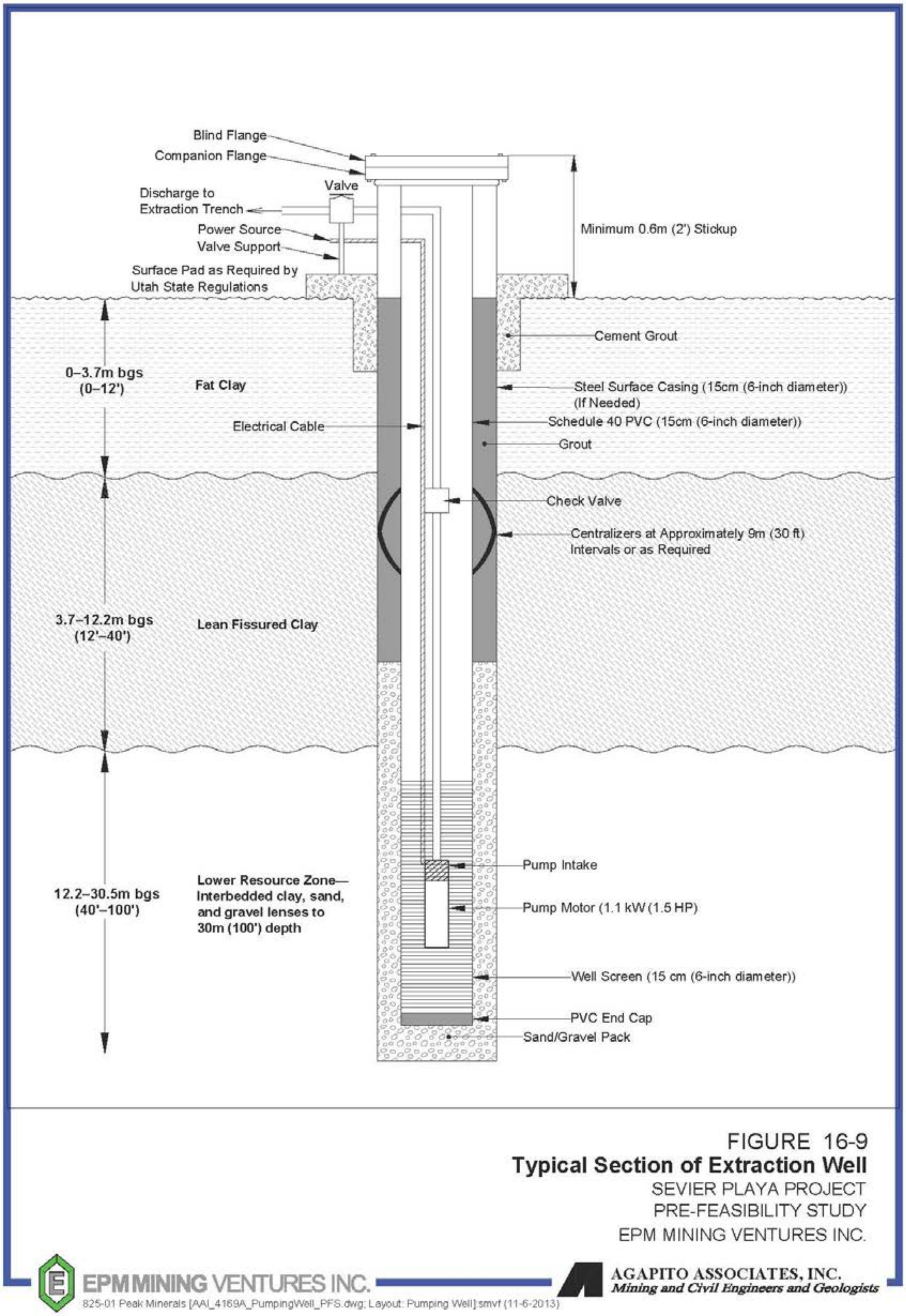
Wells would be required to extract brine from the LRZ. Analytical modeling of the URZ and LRZ was conducted based on the parameters established from field pumping tests and results from Whetstone (2013). Based on these results and the desired discharge of 125,000 L/min (33,000 gpm), a spacing of 250 to 400 m (820 to 1,312 ft) at a distance of between 250 to 300 m (820 to 940 ft) from extraction trenches is anticipated as being required to provide adequate flow in support of the brine feed rate to Pond 1. The average flow rate per well has been determined to be approximately 69 L/min (18.3 gpm); therefore, 1,800 15-cm-diameter (6-in-diameter) wells would be required.

A typical section of an extraction well is presented in Figure 16-9. The wells are expected to be located in two rows 500 to 600 m (1,640 to 1,970 ft) apart located between the production and recharge trenches. Based on maps of the total depth of the lower resource zone, it was determined that the average depth of wells would be approximately 23 m (75 ft), although it is recognized that the well depths may vary from 15 to 30 m (50 to 100 ft). The wells will likely be screened from the bottom of the URZ to the bottom of the LRZ, typically 15 m (50 ft). The extraction wells would be installed near the end of Phase 2, in Production Years 15 and 16, to provide brine feed during the third decade of the project. Additional extraction wells may be required to maintain the target production flow rate throughout the life of the project as brine grade declines.

16.3.5 Hydrogeologic Modeling and Analysis

A comprehensive groundwater modeling effort was conducted to support the mine design. Appendix A and Whetstone (2013) detail the modeling effort. The modeling included several variations designed to test different aspects of the conceptual model. Three-dimensional models of the entire playa system were developed in MODFLOW-2005 to characterize the stream-playa lake interaction and the effects of areal recharge and evaporation rates. This was followed by 2D and 3D models employing MODFLOW-SURFACT, an advanced proprietary version of MODFLOW, with the ability to simulate density-dependent flow and dual-domain transport. The models incorporated layer elevations derived from intercepts logged from over 400 boreholes and wells drilled during the exploration program. Field data incorporated into the models included estimates of hydraulic conductivity and storage coefficients based on HydroPhysical™ and aquifer stress test results from wells and trenches. Site-specific estimates of the vertical infiltration rate and evapotranspiration were also obtained. Data from labouratory testing incorporated into the modeling included unsaturated flow properties, saturated hydraulic conductivity, matrix porosity, and solute concentrations.

FIGURE 16-9
Typical Section of Extraction Well



16.3.5.1 Conceptual Model

The Sevier Lake Playa system is conceptualized as a terminal playa lake system bounded by steeply dipping faults which serve to compartmentalize flow in the vicinity of the playa. Other than the Sevier River, which seasonally flows onto the playa, the current understanding is that very little natural lateral or vertical recharge enters the playa groundwater system (CH2M HILL, 2013b). Some recharge may result from episodic run-off events originating on the watershed surrounding the playa. The bulk of groundwater discharge is through evapotranspiration via the playa surface and is self-limiting by seasonal depth to groundwater.

The playa surface is composed of low-hydraulic conductivity fat clay of variable thickness up to approximately 3.7 m (12 ft). The surficial fat clay is underlain by approximately 7.6 to 9.1 m (25 to 30 ft) of fissured clay that composes the upper flow system and hosts the upper brine resource. The fissures are thought to be osmotic features and are responsible for relatively high conductivities observed in the upper brine resource zone.

Hydraulic conductivity and an observed correlation of carbonate content that occurs contemporaneously with the fissures suggests that the fissuring in the URZ may die out with depth. The upper zone is underlain by a lower brine resource zone hosted in a thick clay aquifer to depths of up to 30 m (100 ft) bgs. Groundwater flow in the LRZ appears to be developed in silt, sand, and gravelly intervals intercalated with the clay. The top of the lower zone could be partially bound in some locations by unfissured clay between the upper flow system and the first occurrence of permeable intervals in the lower flow zone; however, the boundary is likely transitional over some distance, where permeability dominated by fissuring gives way to permeability dominated by discrete zones typical of the LRZ. In any case, aquifer testing supplemented by recent HydroPhysical™ test results did not identify a playa-wide low hydraulic conductivity barrier that would separate flow between the URZ and the LRZ. Instead, it supports the concept that flow is conducted through variable thicknesses of coarser material, which can occur at almost any depth in the LRZ.

The presence of an aquitard separating groundwater flow in the URZ from LRZ has been speculated based on observation of a zone of refusal observed at several locations during direct push sampling. The extent of the zone of refusal and its thickness is basically undocumented and its hydrogeologic characteristics are unknown. However if an aquitard exists between the URZ and the LRZ it could have a significant local impact on the expected flow and brine grade produced during mining operations. Model results indicate that recharge water will dilute brine concentrations in the URZ more quickly if an aquitard exists.

Figure 16-10 illustrates results of a 2D simulation of trench extraction for a 9.5-year period without the aquitard in place. This simulation assumes an extraction trench excavated to the bottom of the URZ which is pumped for a period of 9.5 years at the target extraction rate.

Figure 16-10 depicts concentrations at the end of pumping as a colour flood, where red indicates undiluted maximum concentration and blue indicates the maximum dilution. As shown, make-up water from the recharge trenches moves laterally toward the centrally located extraction trench. Some water also moves vertically into the LRZ from the recharge trenches and then laterally toward the extraction trench under influence of the gradient imposed by pumping. The significantly diluted water in the lower LRZ, however, stays within the vicinity of the recharge trenches.

Diffusion is expected to play an important role in transferring dissolved mass between the relatively immobile clay matrix and the fissures of the upper resource or between the clay matrix and coarse-grained seams in the lower flow zone. Therefore the dual-domain mass transport concept was incorporated into the modeling in order to account for this behavior. The dual-domain concepts account for the fact that advection-based mass transport occurs mainly within clay fissures and coarse-grained seams while diffusion accounts for mass transport within the less permeable clay matrix.

Figure 16-11 illustrates the dual-domain concept as applied to the URZ (a) and LRZ (b). The black arrows represent advective transport while the red arrows represents diffusion. As shown, advective flow takes place through fissures in the URZ, and within discrete coarse-grained intervals in the LRZ. Pore space dominated by advective flow and transport is termed the mobile porosity, or in some cases, effective porosity. The remaining porous media in the URZ or LRZ is referred to as the immobile porosity, where advective flow does not take place. At Sevier Lake, immobile porosity contains a significant percentage of the brine resource and solutes can be transferred between immobile and mobile pore space depending on the concentration gradient. Thus, the immobile porosity is expected to act as a stored resource that slowly releases brine.

Estimated model parameters that have significant uncertainty include the dual domain parameters and characteristics of the zone of refusal between the URZ and the LRZ. The model parameters characterizing the dual domain of importance include the mass transfer coefficient between the mobile and immobile domains and the percentage of the URZ and LRZ that are composed by the mobile domain (i.e., the mobile fraction). Higher mass transfer coefficients result in faster release of brine from the clay matrix and the system behaves more like a single domain aquifer with a mobile porosity approaching a value equal to the total porosity (mobile plus immobile porosity). Low-mass transfer coefficients result in slower releases of brine from the clay matrix and the system behaves like a single domain aquifer with a mobile porosity equal only to that of the mobile domain (Zheng and Bennett, 2002). The presence of an extensive aquitard separating flow in the URZ from flow in the LRZ represents risk to operations and may need to be accommodated in detailed mine planning.

Varying the percentage of mobile domain during model simulations increases the arrival time of peak dilution (i.e., delays the arrival) when the mobile fraction is high, and decreases the arrival time when it is low (Zheng and Bennett, 2002). This is because seepage velocity must increase as the pore space represented by the mobile domain decreases.

It is believed that available data are in general agreement with the dual-domain concept and that the model appropriately represents the flow and transport characteristics of the Sevier Lake aquifer system. It is believed that available data are in general agreement with the dual-domain concept and that the model appropriately represents the flow characteristics of the Sevier Lake aquifer system. However, additional fieldwork, including a pilot test, will be required to constrain the aforementioned parameters. Uncertainty associated with the estimated mass-transfer coefficient and percent mobile domain could cause the model to:

- Over or under estimate the rate at which brine can be produced from trenches.
- Over or under estimate how quickly brine concentrations will be diluted by recharge water

16.3.5.2 Simulation Objectives and Results

Brine will be extracted through a network of extraction trenches and distributed to solar evaporation ponds. Make-up water would be supplied to the groundwater system by a network of recharge trenches supplied by water diverted from the Sevier River. The objectives of the modeling effort were to characterize the degree to which the brine resource could dilute over time, determine optimum trench spacing and sustainable trench brine production rates, and support a cost-benefit analysis of extracting brine from the LRZ with either trenches or wells.

To facilitate the modeling efforts, a 45 square kilometers (km^2) (17.4 square mile [mi^2]) area of the southern lobe of the playa was selected for focused modeling to allow a finer discretization of model cell size and to obtain timely simulation results of numerous scenarios involving extraction rate and trench recharge flow requirements. This area was configured with 12 recharge trenches, a central brine canal, and 10 lateral extraction trenches to support the simulation.

Figure 16-10

Sevier Concentration Profile

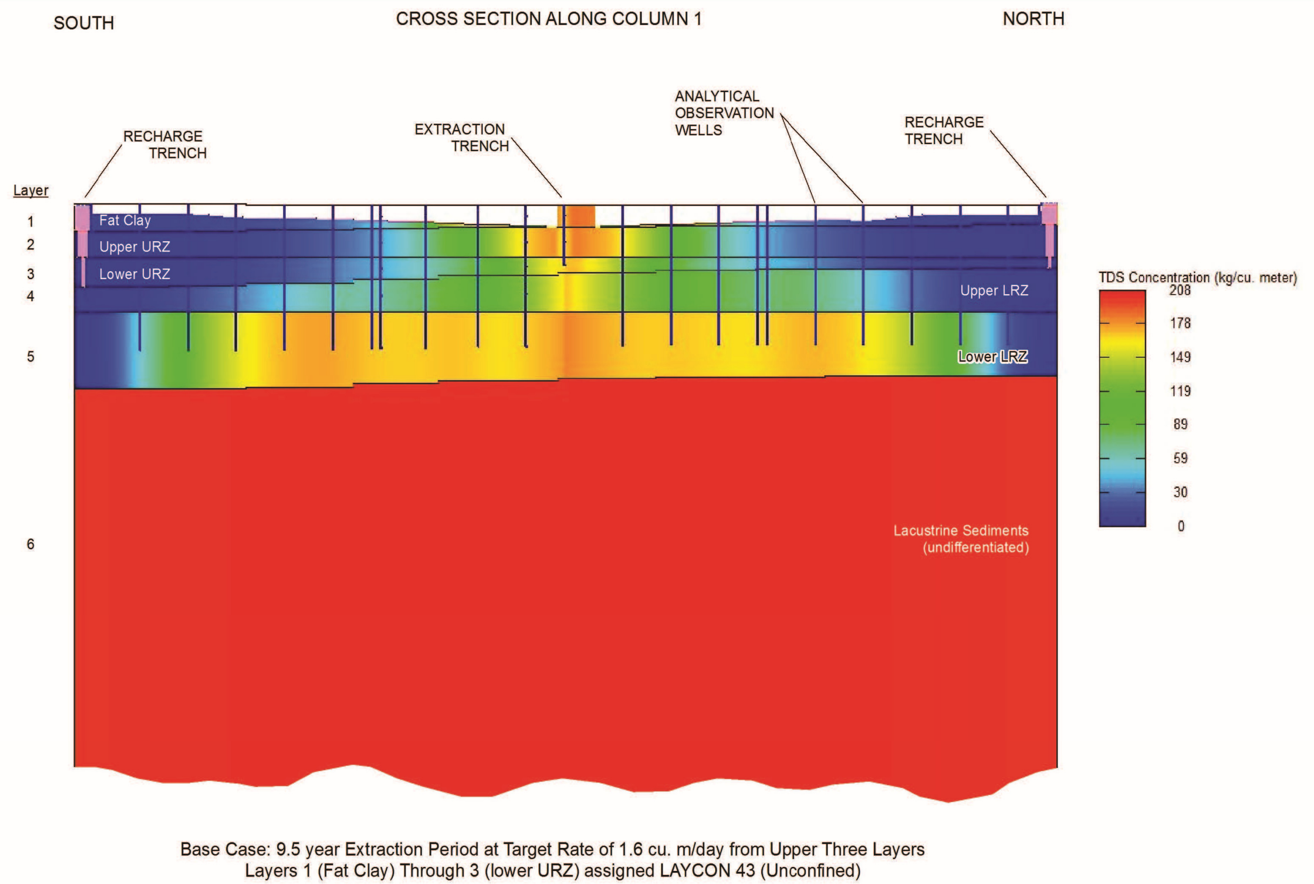


FIGURE 16-10

Sevier Concentration Profile

SEVIER PLAYA PROJECT PRE-FEASIBILITY STUDY

EPM MINING VENTURES INC.

EPM MINING VENTURES INC.

825-01 Peak Minerals [Whetstone_Sevier Concentration Profile.cdr]:smvf (11-8-2013)

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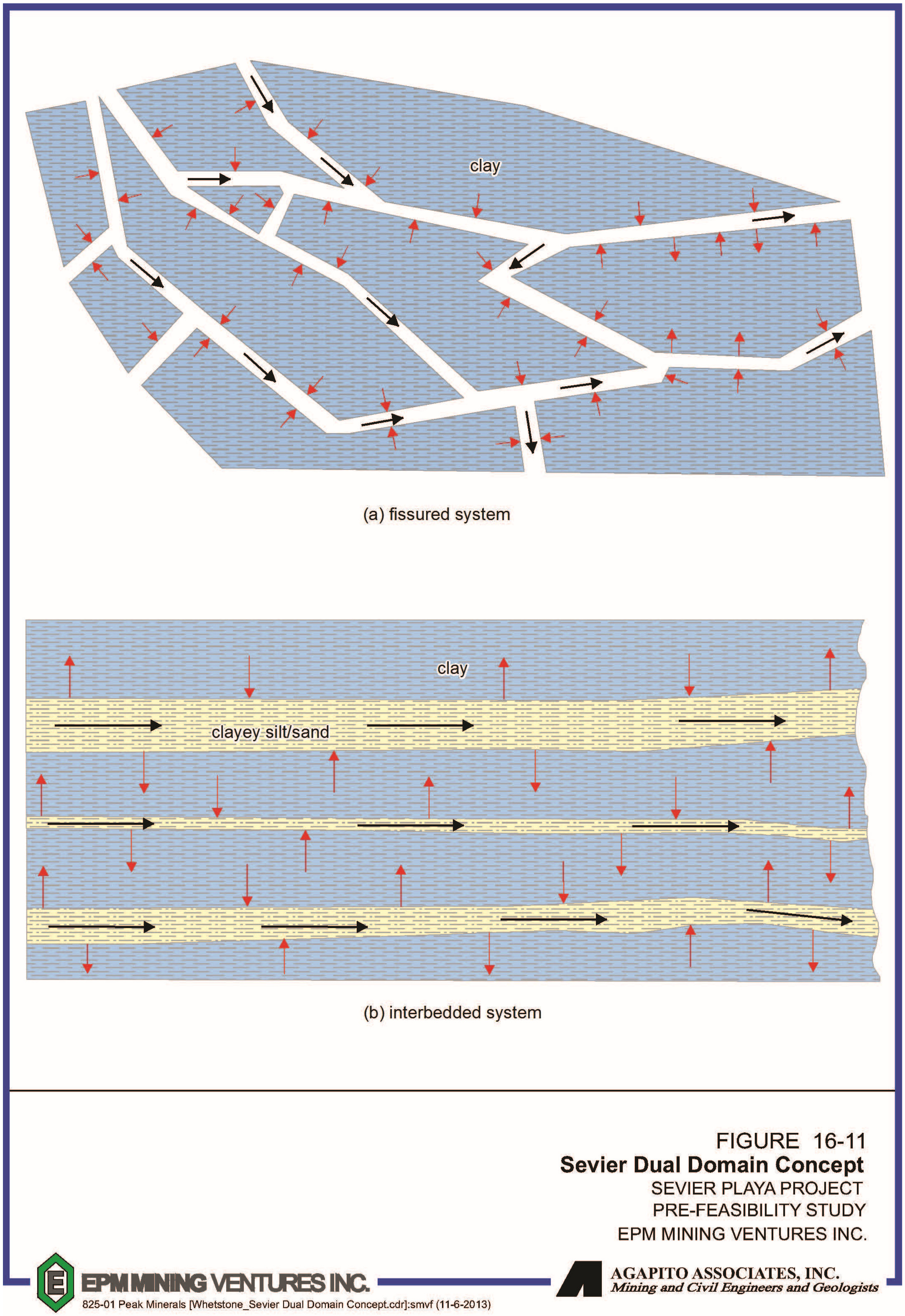
FIGURE 16-11
Sevier Dual Domain Concept



TDS was used as a surrogate for the individual solute species of interest since sodium, chloride, sulphate, potassium, and magnesium compose 95 percent of the TDS in the brine, and relative concentrations of each parameter are well characterized. TDS was modeled as a conservative solute (no adsorption, precipitation, or other chemical reactions) with density-dependent flow effects in a dual domain porous media. Initial modeling determined that the target production rate of 1.2 L/min per m (0.09 gpm per ft) of the extraction trenches could be met with a total demand of make-up recharge water of 0.42 m^3/s ±0.08 m^3/s (15 ft^3/s ± 3 ft^3/s). This modeling was followed by 2D flow and transport simulations to characterize the dilution of the brine resource by recharge water over time, to determine optimum trench spacing, and to support a cost-benefit analysis of extracting brine from the LRZ using either deepened trenches or wells. To construct the 2d models, a 1-m-wide (3.3 ft-wide) north-south profile was cut through the 3D model so that location-specific layer thicknesses and depths would be preserved. Multiple simulations incorporating trench spacing of 500, 750, and 1,000 m (1,640, 2,461, and 3,280 ft); trench flow rates; and well spacing of 100, 200, 250, and 400 m (328, 656, 820, and 1,312 ft) were conducted to simulate various designs. Results demonstrate that acceptable brine mass rates can be extracted from 6 m (20 ft) deep trenches with a spacing of 1,000 m (3,280 ft) during two 9.5 year phases as discussed in Section 16.3.1 and as illustrated in Figure 16-2. Extraction from the Phase 2 trenches can be followed by extraction from wells installed within the LRZ for an additional 9.5 year period. The use of extraction wells is discussed in the previous Section 16.3.4.

16.4 Evaporation Pond Layout and Design

To assist with the determination of the number and size of the ponds required to meet the final production target of 300,000 tpy (330,693 tons/yr) of SOP, the computer model Solar Pond Balance, Rev. 3, developed by DSB International (DSB) (2013a) was utilized. Required input parameters include the brine feed rate, the site-specific evaporation rate, leakage from the pond base, the brine entrainment contained in salt crystallization, mill recovery, and precipitation. Based on historical records and tests that have been completed to date, pond leakage, evaporation rate, and precipitation values are within an acceptable degree of accuracy (AAI 2013b and 2013d, IGES 2013). Brine entrainment was estimated based on experience with similar projects (DSB 2013b).

16.4.1 Pond Design Methodology

In total, four preconcentration ponds and four production ponds are anticipated to be required to produce salts of the concentration needed for plant processing. In addition to the input parameters listed previously, cation concentrations are also needed. Cation concentrations are necessary inputs to accurately represent the brine phase chemistry. Concentration values used in the model were based on the predicated concentration curve of Sevier Playa brine (DSB, 2013b and 2013c). Data collection relevant to concentrations and phase chemistry for further refinement of the brine phases is ongoing. The results of the pond design model are summarized as follows:

- Minimum area of preconcentration ponds: 66.8 km^2 (25.8 mi^2)
- Minimum area of production ponds: 18.5 km^2 (7.1 mi^2)
- Average continuous brine inflow to ponds: 125,000 L/min (33,000 gpm)

Brine collected from the extraction trenches and wells would be conveyed to the north lift station and pumped into preconcentration Pond 4 for the first year or two, and then into Pond 1 for the remainder of the mine life. Because the higher concentration brine resource is located primarily in the central and southern portions of the Sevier Playa, the preconcentration ponds were relocated to the northern portion of the playa. The production ponds would be located at the southern end of the playa to facilitate transport of SOP to the crystallizing plant.

16.4.2 Preconcentration Ponds

The area and pumping rates needed to produce 300,000 tpy (330,693 tons/yr) of SOP is a function of evaporation, leakage, entrainment, brine chemistry, and plant efficiency. Table 16-1 summarizes input parameters used in the preliminary design of the solar evaporation ponds.

TABLE 16-1
Design Input Parameters for Solar Evaporation Pond Design

Parameter	Value
SOP net yield	300,000 t/yr (330,693 tons/yr)
Average annual precipitation	203 mm/yr (8 in/yr)
Net average annual lake evaporation	1,219 mm/year (48 in/year)
Average net evaporation (brine, Pond 1)	683 mm/yr (27 in/yr; 0.35 percent Ca+Mg)
Pond leakage (high-plasticity clay)	0.018 mm/day (d) (0.26 in/yr)
Entrainment factor	0.30
Overall plant efficiency	78 percent

The resulting brine inflow rate to the preconcentration ponds would be approximately 72.2 Mt (79.6 Mton) per year. This requires a brine inflow rate to Pond 1 of approximately 125,000 L/min (33,030 gpm) that is maintained consistently throughout each production year. The total area of the solar evaporation ponds was increased by approximately 8 to 12 percent above the pond sizes determined by the design model, as recommended by the developer of the model, to account for contingencies in the input parameters. Therefore, the total area of the four preconcentration ponds required per design is approximately 73.6 km^2 (28.4 mi^2).

Typical cross sections of the pond dikes are presented in Figure 16-12. The dike crests are expected to include 15 cm (6 in) of salt crust layer to provide for light vehicle travel. Granular wearing course will likely be used in limited areas, such as select areas such as pump stations, to maintain trafficability of heavier equipment and provide erosion resistance. Portions of the exterior slopes may require erosion control rock, turf reinforcement mat, or other armor to protect against high water in the Sevier Playa during flood events. The production ponds are expected to constructed in the same manner as the preconcentration ponds

Clay material from the ponds would be used to construct the dikes using low-ground-pressure dozers or excavators. The upper 30 to 45 cm (12 to 18 in) of loose salt deposits are expected to be removed from the footprint of the dikes, where necessary, to provide an acceptable base for construction of the dikes. The dikes should be compressed by equipment travel to achieve compaction, increased stability, and decreased permeability.

It is anticipated that the lowest portion of each pond would fill with brine initially and it is assumed that salt accumulation would cause the pond floors to level over time. Each down-gradient pond is planned to be approximately 20 to 80 cm (8 to 32 in) lower in elevation than the upgradient pond to allow gravity flow. A typical section through the preconcentration ponds is presented in Figure 16-13 and a typical section through the production ponds is presented in Figure 16-14.

Each preproduction pond is expected to be divided into two parallel series of four ponds each. Dividing the ponds into two parallel cells each would likely provide operational flexibility by allowing flow to be shut off in one pond series while salt and SOP were removed. This system would also allow for reduced flow rates in response to operational needs. The flow rate into these ponds is expected to be approximately one-half the full development flow rate at full build-out. The production ponds are also expected to be divided into two parallel series of four ponds each.

FIGURE 16-12

Typical Cross Sections of Pond Dike

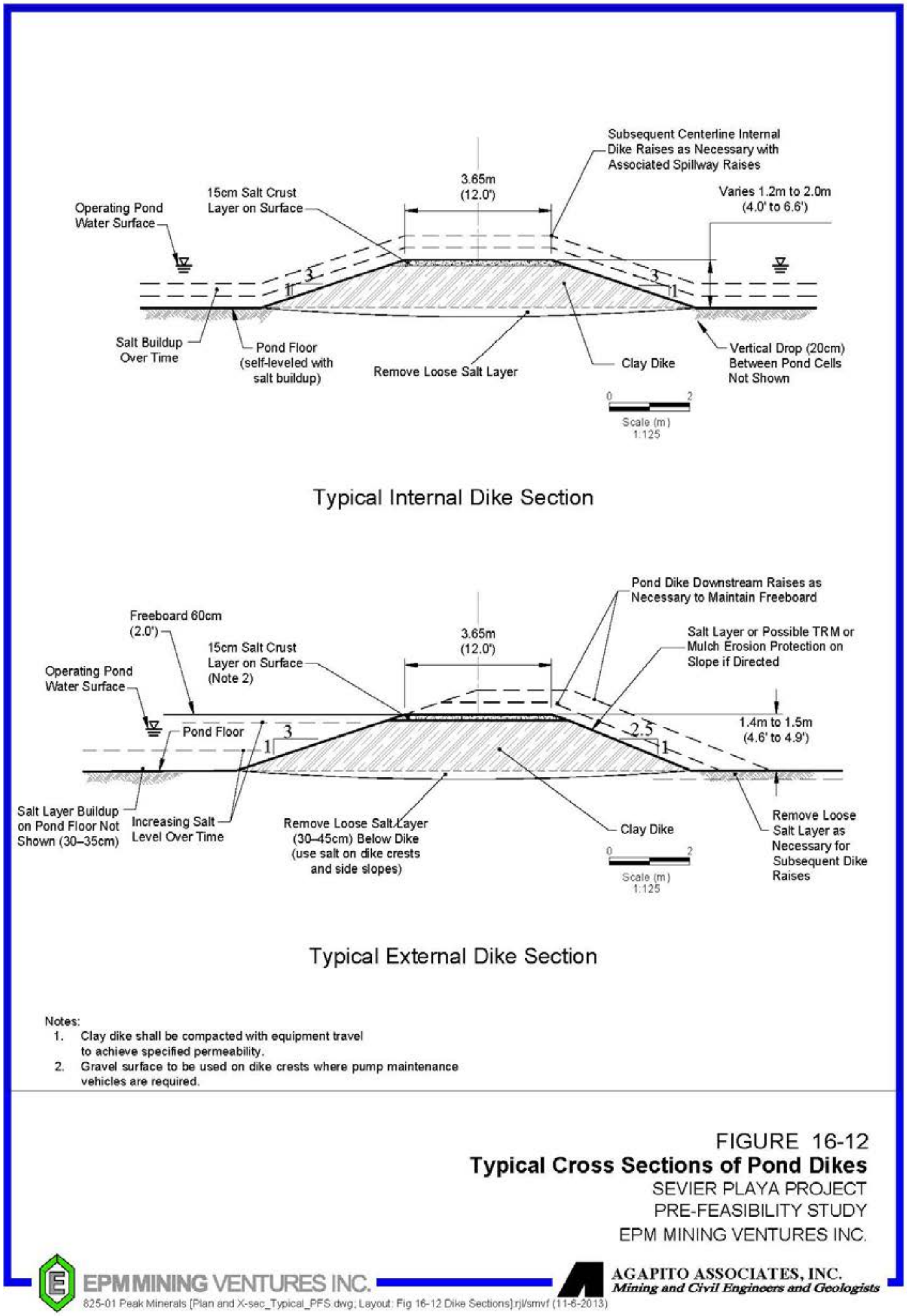


FIGURE 16-13

Typical Cross Section through Preconcentration Ponds

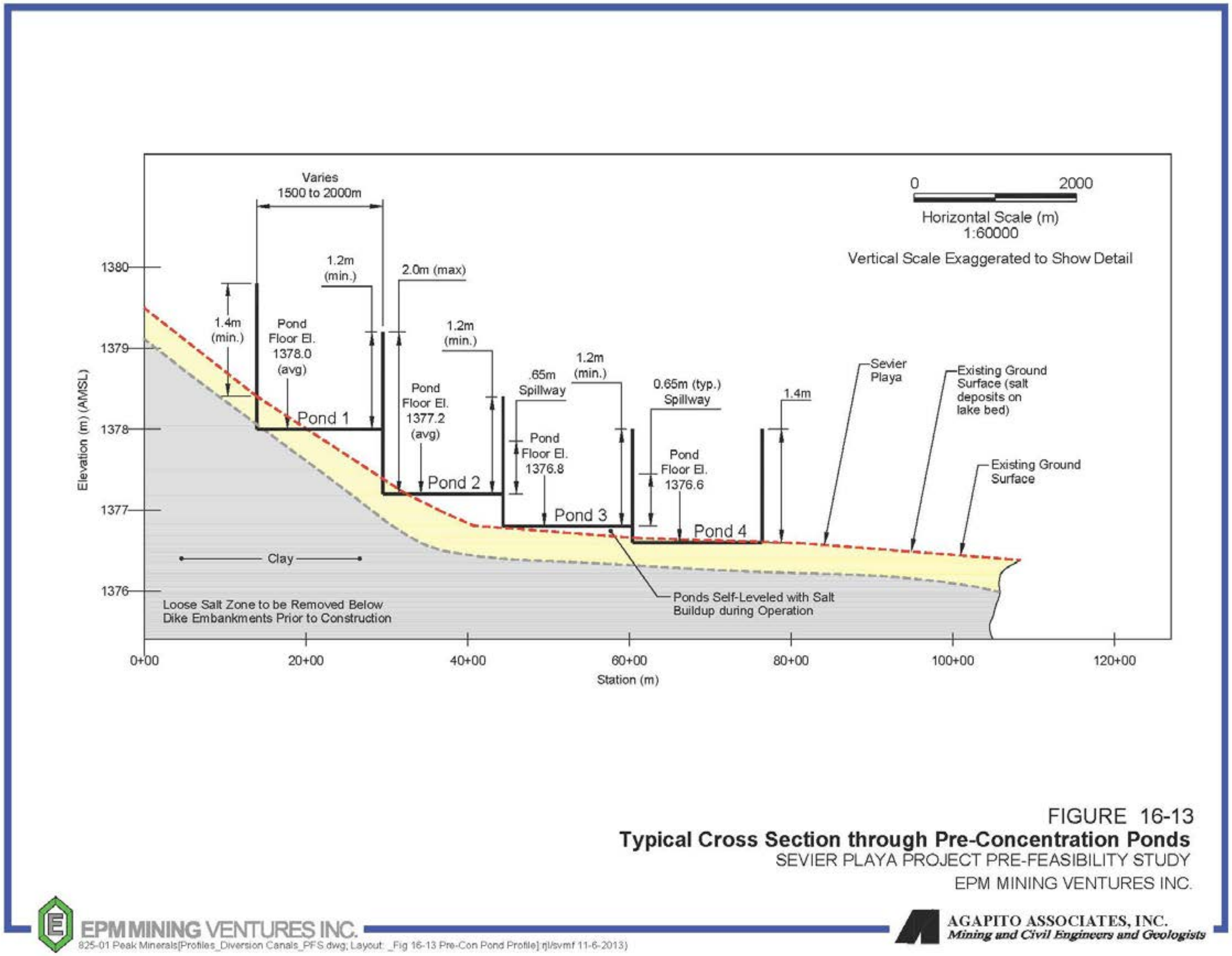
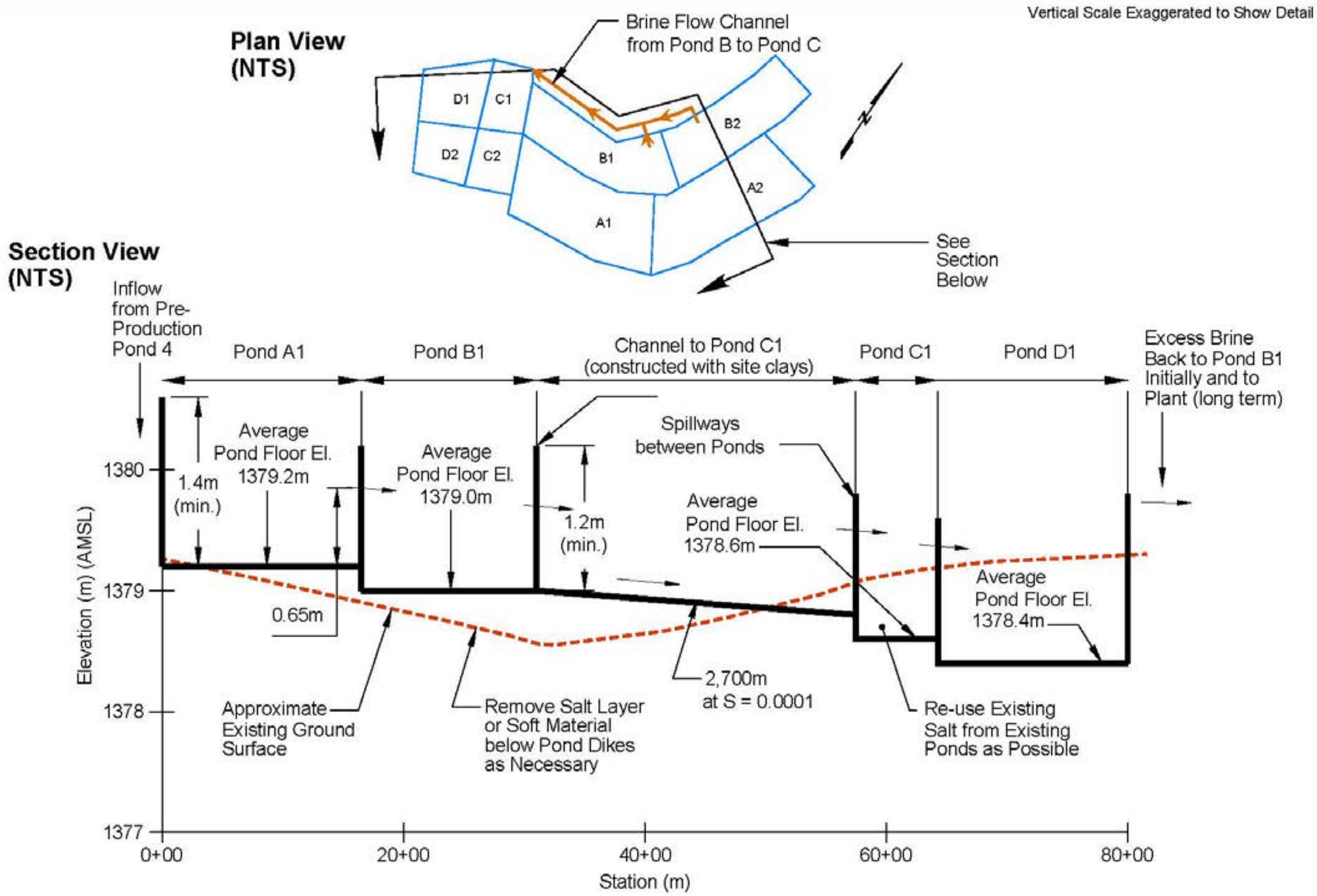


FIGURE 16-14
Typical Cross Section through Production Ponds



Note:
1. Section shown is approximate and is based on current topography mapping. More accurate topography and ground surveys will be required for final design.

FIGURE 16-17
Typical Cross Section through Production Ponds
SEVIER PLAYA PROJECT PRE-FEASIBILITY STUDY
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EPM MINING VENTURES INC.
825-01 Peak Minerals[Profiles_Diversion Canals_PFS.dwg; Layout: _16-14 Prod Pond Profile] rjl/svmf (11-6-2013)

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Flows from each up-gradient preconcentration pond are to discharge by gravity over trapezoidal spillways at each internal embankment to the downgradient pond. The flow velocity over the crest of the spillways would be relatively low; therefore, a gravel base should provide sufficient erosion control. It is anticipated that a typical spillway should be constructed with concrete cut-off walls both upstream and downstream, with gravel base along the crest and riprap along the outflow portion of the structure. The overall bottom width along the crest should be approximately 10 m (33 ft) from the upstream edge of the concrete cut-off wall to the downstream limits of the riprap. The total length of the structure should be approximately 15 m (49 ft).

The southeast corner of preconcentration Pond 4 is expected to include a geomembrane-lined sump for collection of brine and pumping to the production ponds at the south end of the Sevier Playa. This is discussed later in Section 16.8.

As determined from the pond balance model, the size of each pond, the pond floor elevation, and the pond volume capacity (based on a 0.60 m (24 in) freeboard) are summarized in Table 16-2.

TABLE 16-2
Summary of Average Pond Floor Elevation and Area

Pond Designation	Average Floor Elevation*		Area	
	(m)	(ft)	(km^2)	(mi^2)
Preconcentration Pond 1	1,378.0	4,521.0	14.5	5.6
Preconcentration Pond 2	1,377.2	4,518.4	19.0	7.3
Preconcentration Pond 3	1,376.8	4,517.1	19.1	7.4
Preconcentration Pond 4	1,376.6	4,516.4	21.0	8.1
Production Pond A	1,379.2	4,523.8	8.9	3.4
Production Pond B	1,379.0	4,524.4	6.4	2.5
Production Pond C	1,378.6	4,521.8	2.3	0.9
Production Pond D	1,378.4	4,521.4	2.8	1.1

* Pond floor elevations may vary by 0.4 to 0.9 m (1.3 to 3.0 ft) and are based on current topographic data

To reduce erosion on the interior dike slopes during storm and wind events, the interior side slopes should be 3:1 (horizontal: vertical). The salt materials removed from beneath the pond dikes could be used in the construction of the dikes and placed on the exterior surface to reduce erosion in the long term.

16.4.3 Production Ponds

The production ponds are expected to be located at the south end of the Sevier Playa to facilitate a short haul distance of product to the plant. The design criteria for the production ponds are as discussed Section 16.4.2 above for the preconcentration ponds. The total area of the four production ponds is approximately 20.4 km^2 (7.9 mi^2).

16.4.4 Control Structures, Pipes, and Pumps

It is anticipated that a main north-south extraction canal would be fed with brine from east-west extraction trench laterals spaced every 1,000 m (3,280 ft). A brine lift station consisting of an excavated sump with barge-mounted pumps is expected to pump brine from the sumps into the preconcentration ponds. A sump and barge-mounted pump system that has been designed for this purpose is illustrated in Figures 16-15 and 16-16.

The pump station from preconcentration Pond 4 to the pipeline that is to convey brine to the production ponds would likely consist of a geomembrane-lined sump with barge-mounted vertical turbine pumps. The sump and barge-mounted pump system required to feed the production ponds is anticipated to be similar to that illustrated in Figures 16-15 and 16-16, although the pumps are expected to require less capacity. It is anticipated that four 56,781 L/min (15,000 gpm) vertical turbine pumps will be needed for the brine lift station to production Pond 4, although the four vertical turbine pumps required to convey the brine to the production ponds are expected to have a capacity in the range of 11,356 L/min (3,000 gpm).

A 36-km-long (22-mi-long) pipeline is expected to convey brine from preconcentration Pond 4 to the production ponds. The alignment of the pipeline would be governed by a portion of the eastern section of the perimeter access road, which encircles the entire Sevier Playa as shown in Figure 16-2. The perimeter road will most likely be constructed of materials adjacent to the road alignment with a typical width of 4 m (13.1 ft) with 2:1 (horizontal: vertical) side slopes on each shoulder. The height of the road is expected to be approximately 30 cm (1 ft) above the adjacent ground. A 15 cm (0.5 ft) layer of salt should be placed on the road crest to provide a more durable wearing surface.

16.5 Construction Phasing

To facilitate the development of the mine plan, construction is anticipated to be conducted in a phased approach over several years. Not all of the components would be needed initially and therefore construction by phases would defer capital expenses and would bring the components on-line right as they are needed for production. Phase 1 of construction would be completed within the first 3 years (PP-3 to PP-1), while the entire Phase 1 operational period would extend through Production Year 9.

16.5.1 Pond Development Phasing

Preconcentration Pond 4.1 and production Ponds A1, B1, and C1 are planned to be constructed the first year of Phase 1 (PP-3). Ponds 1.1 through 3.1 are anticipated to be constructed during the second year of Phase 1 (PP-2), and the remainder of the preconcentration and production ponds would be constructed during the third year of Phase 1 (PP-1).

FIGURE 16-15
Plan—Brine Lift Station to Pond 1 (NTS)

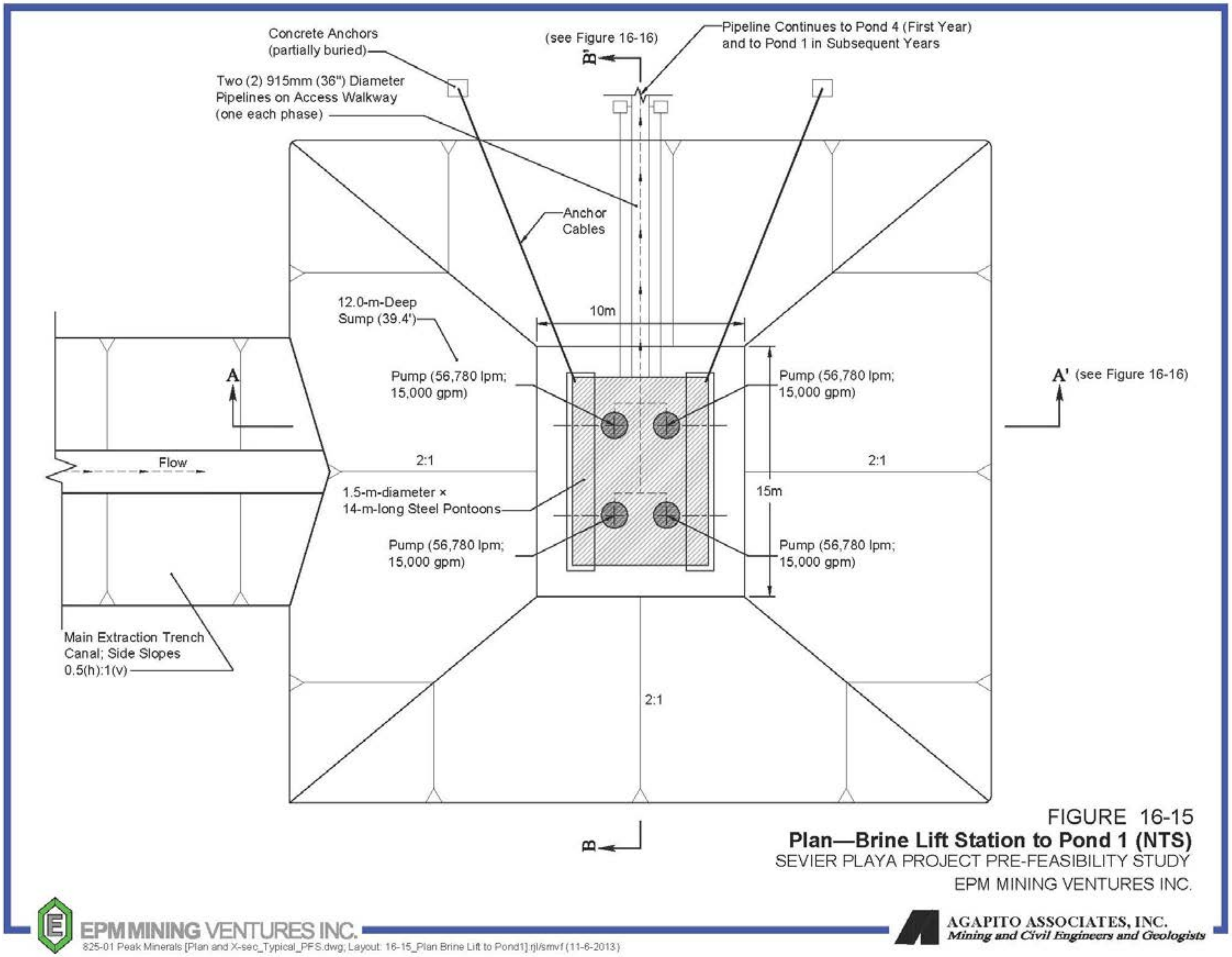

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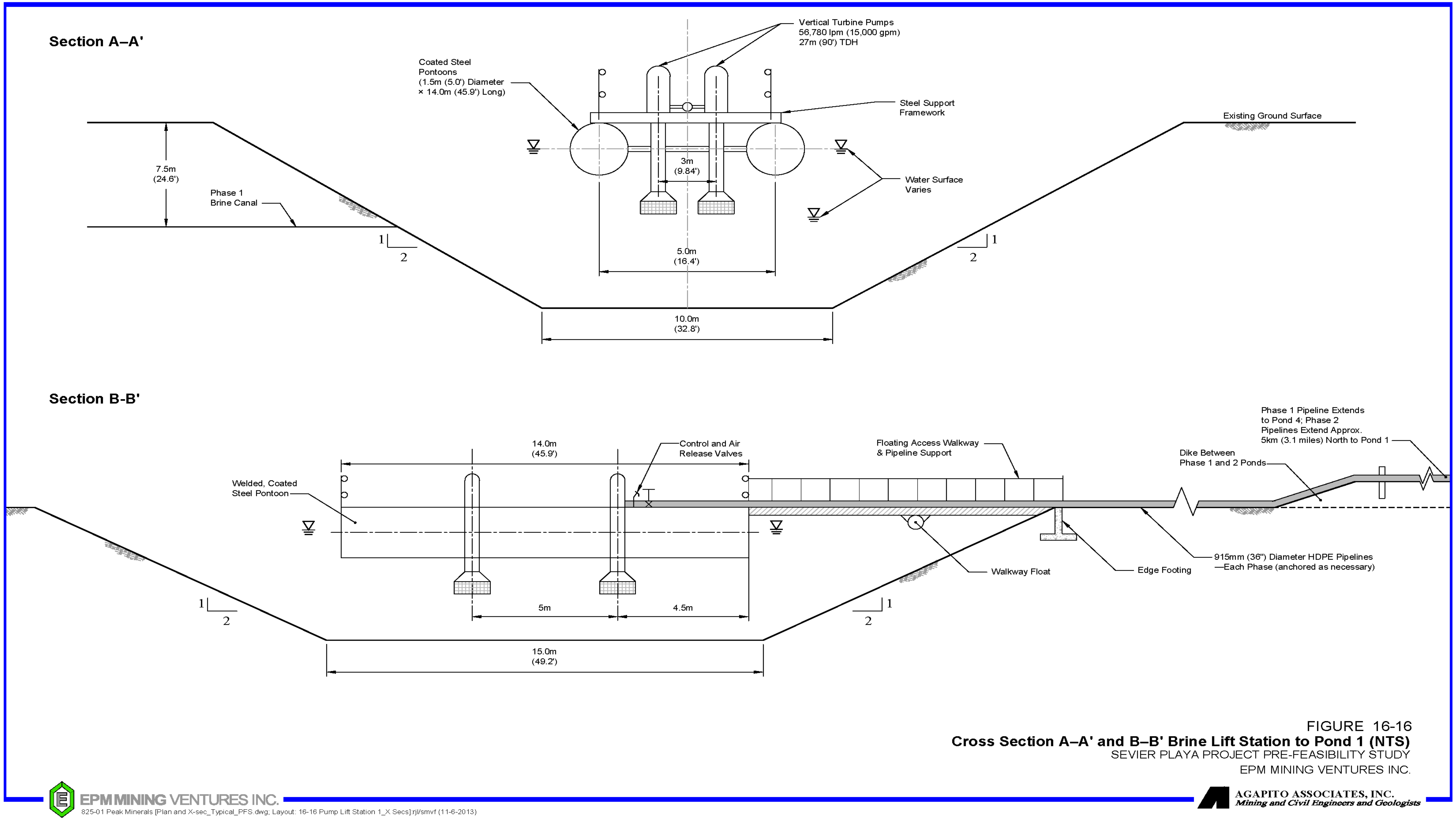
FIGURE 16-16
Cross Section A-A' and B-B' Brine Lift Station to Pond 1 (NTS)



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16.5.2 Extraction Trench Phasing

The full complement of extraction trenches needed to support the Project would be constructed in two phases, each phase consisting of trenches with an average depth of approximately 6 m (20 ft). It is anticipated that the first phase of trench construction would include approximately 125 km (78 mi) and would likely be completed within the first 2 years (PP-3 to PP-2). All preconcentration and production ponds are anticipated to be completed during the first 3 years of Phase 1 (PP-3 to PP-1). Brine concentration flow rates over time determined by groundwater modeling indicate that the primary productive life of each extraction trench phase is anticipated to be approximately 9.5 to 10 years. Therefore, Phase 1 of the extraction trenches should operate through Years 9.5 to 10. Phase 2 of the extraction trench construction should begin in Production Year 7 and would likely be completed in Production Year 9. Figure 16-17 highlights the areas where the first and second phases of trenching would be located. The construction activities in Phases 1 and 2 are provided as follows:

Phase 1

- Northern extraction trenches averaging 6 m (20 ft) deep completed in the first 2 years
- Northern brine conveyance canal system completed in the first 3 years
- Brine lift station into preconcentration ponds completed in the first year
- Brine pumps and pipeline for conveyance of preconcentration pond discharge to the production ponds completed in the first year

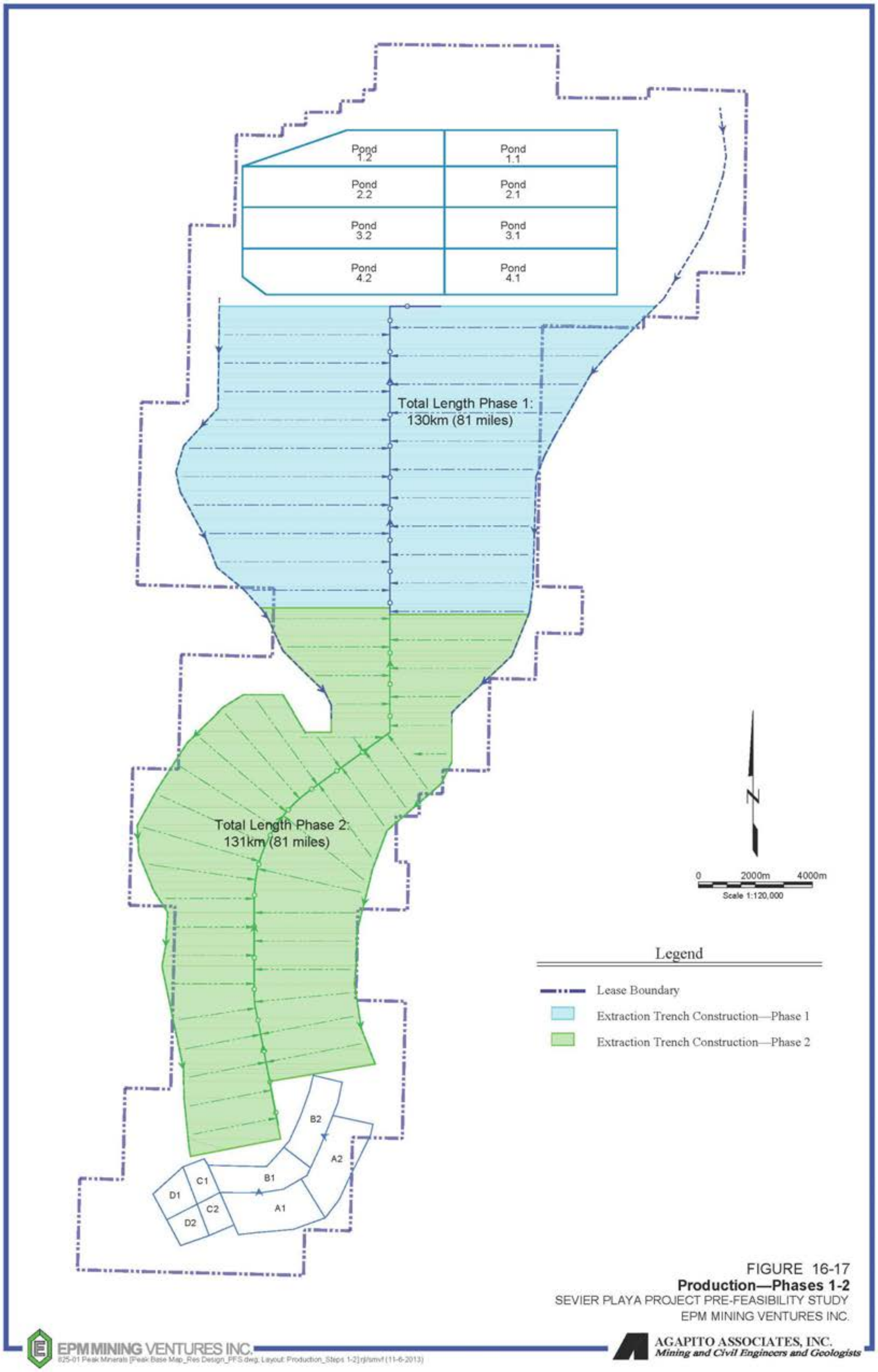
Phase 2

- Southern extraction trenches averaging 6 m (20 ft) deep completed in Production Years 7 and 8
- Southern brine conveyance canal system completed in Production Years 7 through 9

Phase 3

- All extraction wells started and completed in Production Years 15 and 16

FIGURE 16-17
Production—Phases 1-2



16.5.3 Recharge Canal/Trench System Phasing

The following summarizes the Sevier River recharge system construction, by phase:

Phase 1

- Diversion structure at Sevier River completed in the first year (PP-3)
- Northern recharge canal (approximately 31 km [19 mi] east and 18 km [11 mi] west completed in the first 3 years (PP-3 to PP-1)
- Northern portion of recharge canal turnouts and recharge trenches completed in the first 3 years (PP-3 to PP-1)
- Northern east-west pipeline pump station to the west side of the recharge system; completion of Phase 1 of the recharge system within the first 3 years (PP-3 to PP-1)

Phase 2

- Central recharge pump station and east-west pipeline to southwest recharge system completed in Production Years 7 and 8
- Southeastern portion of recharge canal turnouts and recharge trenches from east-west pump station to southeast lift station (4 km [2.5 mi]) completed in Production Years 7 and 8
- Southwest recharge canal (21 km [13 mi]) completed in Production Years 8 and 9
- Southeast pump lift station and southeast extension of east recharge canal and trenches (9.5 km [5.9 mi]) completed in Production Year 9
- Completion of the recharge system in Production Year 9

16.5.4 Extraction Well Phasing for Recovery of Lower Resource Zone

The extraction wells are expected to be constructed as part of Phase 3 following the completion of Phase 2. A timeline with the construction phasing of the various mine components is presented in Figure 16-18A and Figure 16-18B.

FIGURE 16-18A

Project Phase 1 Construction Phasing Timeline

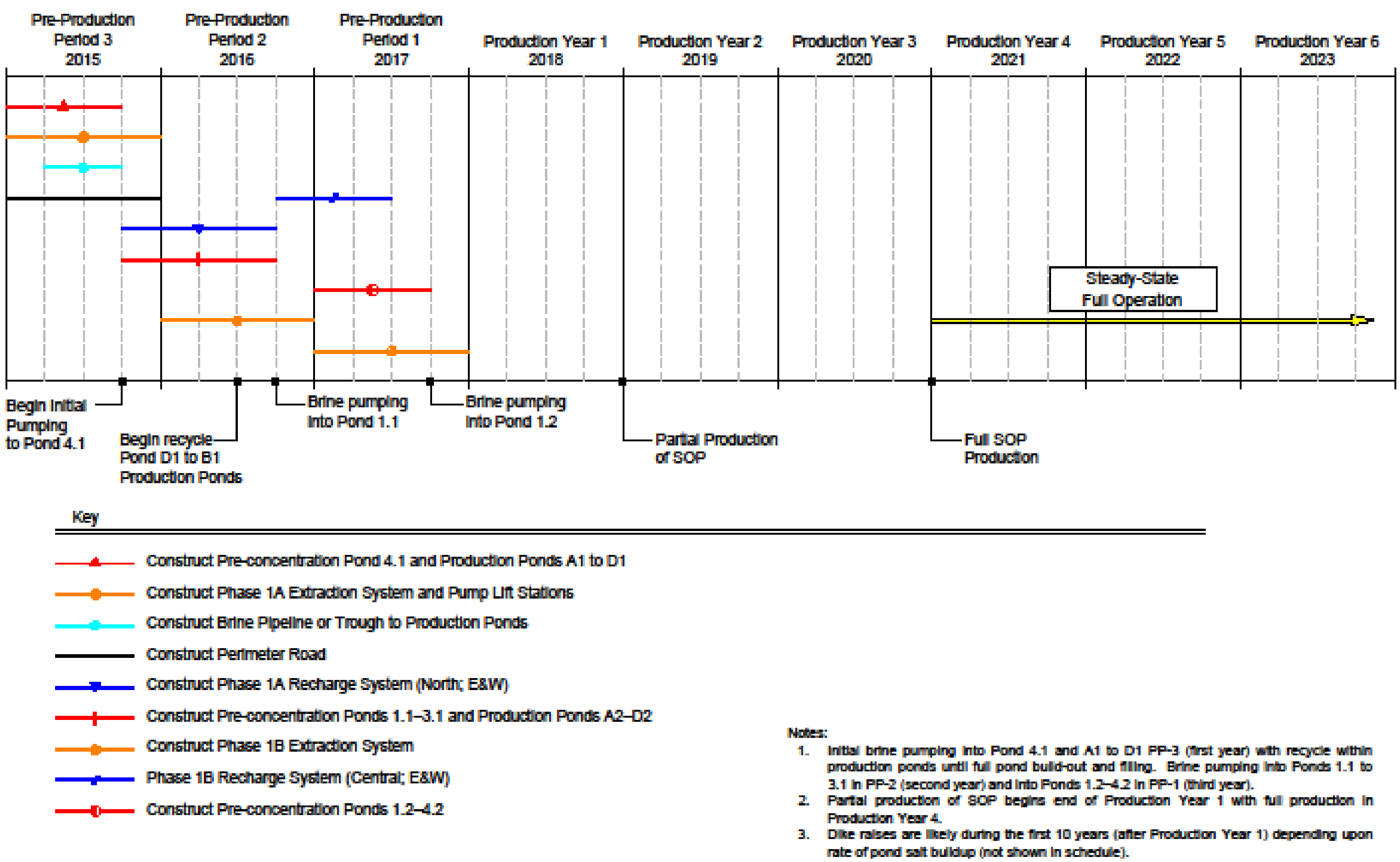


FIGURE 16-18a

Project Phase 1 Construction Phasing Timeline

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825-01 Peak [Project Phasing Timeline_PFS.dwg]:cjfiamvf (11-6-2013)

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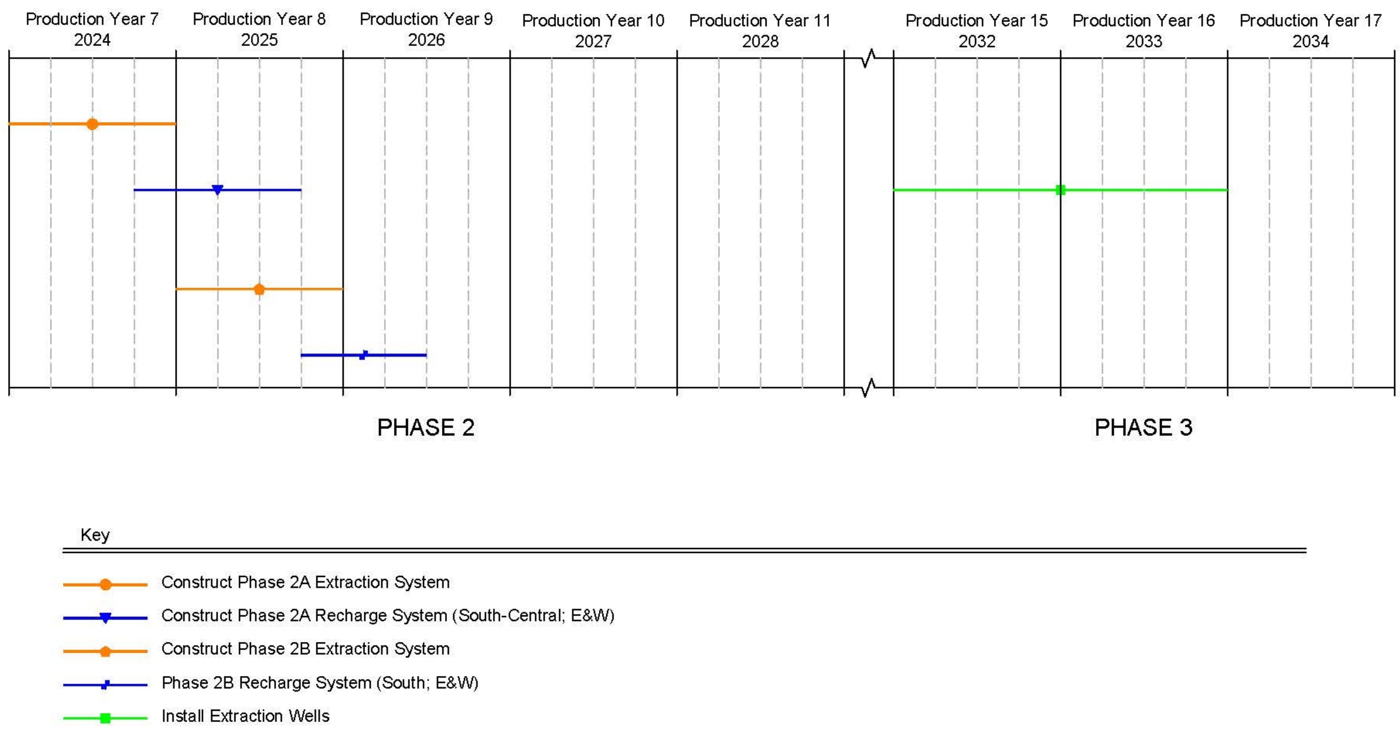
FIGURE 16-18B
Project Phase 2 and 3 Construction Phasing Timeline



Notes:
1. Phase 1 extraction trench laterals will be plugged for 5m length during during Production Year 7after Phase 2A extraction trench construction. Phase 1 North Extraction Canal to remain open for all of Phase 2.
2. Pond dike raises required every three to four years throughout mine life (not shown).

FIGURE 16-18b
Project Phase 2 and 3 Construction Phasing Timeline
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825-01 Peak [Project Phasing Timeline_PFS.dwg]:rjl/smvf (11-6-2013)

16.6 Mining Equipment

Mining equipment required during the start-up and development phases of the mine operations include tracked excavators, road graders, and scrappers. All of the equipment operated on the Sevier Playa surface would need to be equipped with low-ground-pressure tracks, or tires that can be deflated, to reduce surface pressures as needed.

It has been demonstrated that for the excavation of extraction and recharge trenches, excavators equipped with tracked pontoons with ground contact pressures of 13.8 to 20.7 kilopascals (2.0 to 3.0 pounds per square inch [lb/in^2]) perform adequately and can also maneuver and operate while afloat. A Caterpillar Model 320 LR equipped with tracked pontoons has been used successfully to excavate test trenches, though it may be slightly underpowered for excavating at depths greater than 7.5 m (25 ft).

A road grader would be used for several applications including road surfacing, maintenance, and salt/potash harvesting. In the case of harvesting SOP, the grader (Caterpillar Model 140H) would be used to windrow the crystallized salts into manageable configurations that can be picked up by a Caterpillar Model 615.

Large-capacity pumps would be required for brine extraction and conveyance. Two brine pump lift stations would be installed; one at the south end of the preconcentration ponds and one in Pond 4. Each brine pump station would have a total of four 57,000-L/min (15,000-gpm) pumps. These pumps would have stainless-steel bowls, impellers, and shafts with bronze and carbon steel parts for corrosion resistance.

Other pumps would be required to remove excess brine (bitterns) from the production ponds at the beginning of the potash harvest season. The removal of excess bitterns from the production ponds would only occur once a year and therefore a dedicated pump may not be warranted. For the purpose of back-mixing the bitterns to the plant, a portable pump of suitable size could be used. The capacity of such a pump is indeterminate at this stage of design. Water management during construction is discussed as follows.

A list of equipment for the mine start-up and operations is summarized in Table 16-3.

TABLE 16-3
Summary of Mine Equipment Needed for Start-up and Operations

Equipment Type	Use	Quantity
Long-reach (6 m [20 ft] minimum) excavator with tracked pontoons	Excavating brine extraction trenches, recharge canals, and trenches.	2
Self-loading scraper	Remove salt from preconcentration ponds and harvest potash from production ponds.	1
Motor grader	Access road surfacing and windrowing salt in preconcentration ponds and potash in production ponds.	1
57,000-L/min (15,000-gpm) pumps	Pump brine from extraction conveyance system into preconcentration Pond 1 (30 meters total dynamic head) and to pump brine from preconcentration Pond 4 to production Pond A (146 meters total dynamic head).	4 total
11,400-L/min (3,000-gpm) pumps	Pump brine from preconcentration Pond 4 to production Pond A (950 kW).	4 total
28,400-L/min (7,500-gpm) pumps	Recharge diversion to west side (North-Phase 1) (500 kW ea).	2
14,200-L/min (5,000-gpm) pumps	Recharge diversion to west side (South-Phase 2) (100 kW ea).	2
7,100-L/min (2,500-gpm) pumps	SE Recharge canal lift station (Phase 2) (10 kW ea).	2
75-L/min (20-gpm) submersible pumps	Pump brine from lower resource zone into extraction trenches (1.1 kW).	1,800

16.7 Water Management during Construction and Operations

Depending on when construction starts, the amount of water pooled on the surface of the Sevier Playa could vary. A dewatering or surface water management system may need to be employed to allow construction of the various mine components during periods when excess water can accumulate on the Sevier Playa. Unless construction occurs following several years of drought, it is anticipated that the pooled surface water can be managed by relocating and containing the volume in adjacent areas allowing the construction area to remain relatively dry. Temporary holding areas would need to be designed based on the location of the construction activity and the surface water; however, construction of low-height berms would be required to contain the pond edge.

Alternatively, surface water could be diverted to previously constructed recharge channels and trenches, provided there is adequate capacity to take the volume of displaced water. If construction occurs following significant drought so pooled water is not present, minimal water management would be required.

It is anticipated that early phases would include construction of the diversion structure and a portion of the east recharge canal. This would allow diversion of normal river inflow to the south end of the Sevier Playa meaning that initial work in the north end of the Playa could occur without concern for river inflow.

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Recovery Methods

The proposed process for the conversion of Sevier Playa brine into SOP would use operations commonly used in industries such as potash and soda ash, and is summarized in Section 1.12 of this Technical Report and detailed in the following sections. The basic process would consist of the following steps:

1. Solar evaporation and precipitation
2. Product stockpiling
3. Conditioning
4. Flotation
5. Conversion to leonite (multiple-effect crystallization)
6. Conversion to SOP (SOP crystallization)
7. Drying and storage

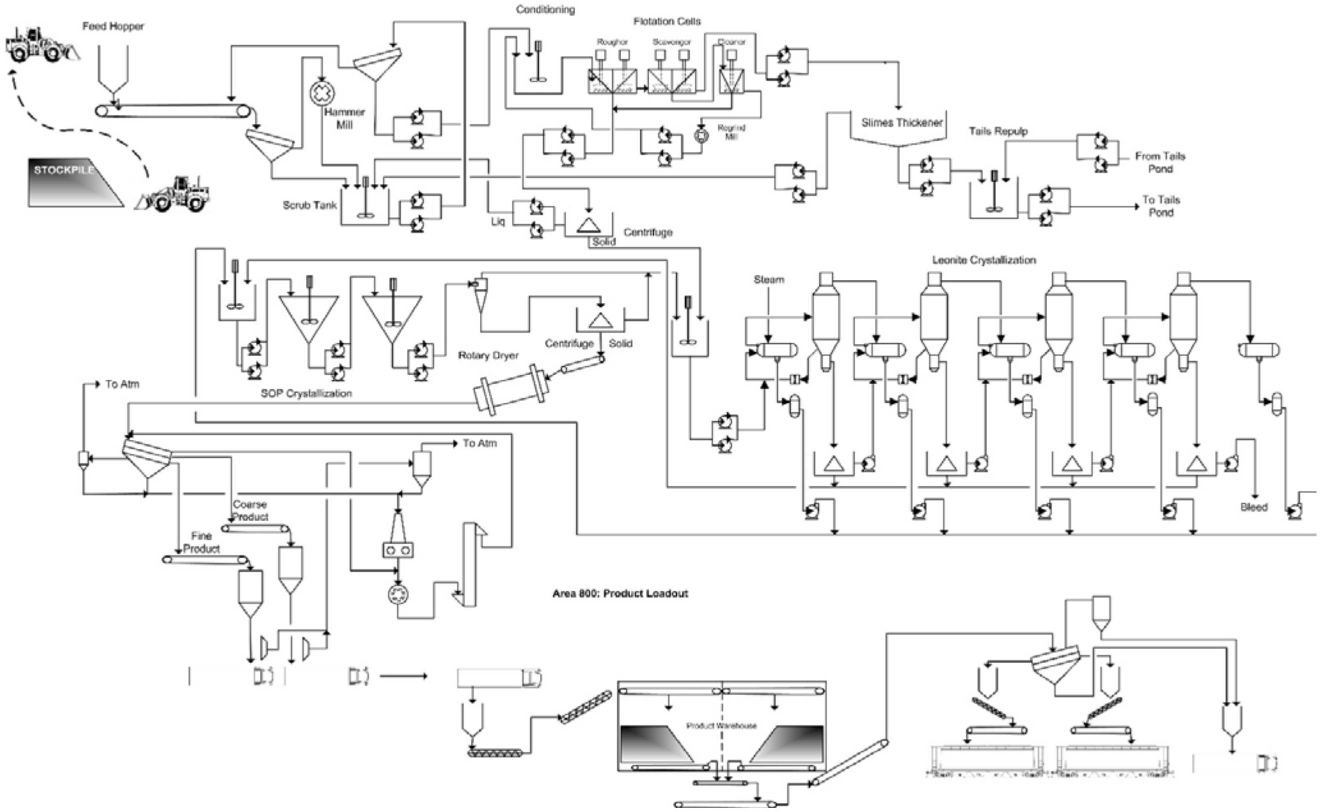
Playa brine would be collected in a trench or from extraction wells and pumped into a series of solar evaporation ponds. Water would be evaporated from the brine and salts would be selectively precipitated onto pond floors as described in Section 16.4 of this Technical Report. The potash-rich salts would be harvested and stockpiled. Flotation would separate the bulk of the potassium salt from halite, epsomite, and minor materials.

The flotation concentrate solids would be sent to leonite multiple-effect crystallizers. The leonite crystals would be sent to the SOP crystallizers where water would be added to dissolve the magnesium sulphate to produce SOP. The dried SOP crystals would be screened and sized to meet desired size specifications. Oversize material would be combined with undersize product, load-out fines, and drier dust to be processed in a compaction circuit. Process steps are illustrated in Figure 17-1.

17.1 Solar Evaporation Ponds

The playa brine would be concentrated to facilitate the precipitation of complex potash salts for harvesting as feed material and subsequent processing into SOP. The concentration would be accomplished by solar evaporation within a series of preconcentration and production ponds. The series of preconcentration ponds would allow for the precipitation of the majority of the halite minimizing the coprecipitation of halite with potash salts in subsequent production ponds. Additional information related to the evaporation ponds is included in Section 16.4.

FIGURE 17-1
Process Flow Diagram



Brine concentration in each pond has a specific purpose and would result in the crystallization of specific minerals to produce the desired ion ratios in the brine leaving each pond. Over time, solar evaporation would precipitate several dissolved salts that are likely to include the following:

1. Halite
2. Epsomite
3. Hexahydrite
4. Schoenite
5. Leonite
6. Kainite
7. Carnallite
8. Thenardite

17.1.1 Preconcentration ponds

Solar evaporation begins with the collection of unsaturated brine from trenches and wells. A series of preconcentration ponds would be used to concentrate the brine up to the sulphate saturation point. Each pond would act as an evaporator with selective precipitation, which by gradual removal of water and impurities such as sodium chloride, would concentrate the potassium-bearing salts.

17.1.2 Production ponds

The purpose of the production ponds would be to bring the brine to saturation with respect to potassium salts and to deposit those salts for harvesting as process feed material. The brine from the preconcentration ponds would be transferred to the first production pond at near saturation with respect to sulphate salts. Evaporation would continue within the first production pond, crystallizing halite and thenardite, until the brine is completely saturated with respect to potassium salts. The complex potash salts would be precipitated within the second production pond and deposited on the pond floors. Typically, schoenite and/or leonite would be deposited along with epsomite and more halite. In the third pond, more halite and potassium salts would be precipitated, which may include lesser amounts of kainite and carnallite when pond brine reaches higher than normal temperatures during above-average temperature years. The ponds would be configured as follows:

1. In the preconcentration ponds, the brine would be concentrated up to the sulphate saturation point. Halite would be precipitated during the concentration process.
2. Solution at the outlet point of the preconcentration ponds would be pumped into the production ponds where additional evaporation of the brine would take place.
3. The first production ponds would be the mixed salts ponds where a mixture of salts, principally halite and thenardite, would be precipitated by further evaporation of the brine. The mixed salts pond would be used to bring the brine to the saturation point of the potassium.
4. The outlet solution of the mixed salt ponds would be pumped into the potassium ponds (Ponds B and C) where leonite, kainite, and halite would be precipitated until the carnallite saturation point is reached. It is possible that other potassium salts and epsomite could be precipitated in the ponds.
5. The outlet of the potassium ponds would be pumped into the carnallite pond (Pond D) for carnallite precipitation. Additional halite and hexahydrate would be crystallized in this pond. Residual brine would then be pumped to the bittern’s ponds for disposal or further refining.

17.2 Process Feed Stockpile

A process feed stockpile would be required to enable year-round production of SOP. The potash salts would be harvested primarily during the cooler months when solar evaporation is minimal. The production ponds would be drained and GPS-guided road graders would be brought in to windrow the deposited salts for pickup and delivery onto the process feed stockpile. The stockpiles would be sited such that entrained brine would be captured and returned to the start of the production ponds. Material would be reclaimed from the stockpile during the year using scrapers that bottom-dump over a grizzly screen directly into a feed hopper.

17.3 Crushing and Sizing

Raw potash salts from the stockpile would be conveyed from the feed hopper to a scrubber circuit in preparation for flotation. Oversize stockpile material would be scalped out and fed to a primary crusher. Besides reducing particle size, crushing would help separate mechanical agglomerates of individual salts.

Scalping screen undersize and slurry would report to the scrubber tank. The primary crusher would discharge crushed material into the scrubber tank slurry formed by the addition of recycled flotation brine. Scrubbing (high-energy agitation of the slurry) would liberate contained insolubles, such as gypsum, clays, and silicates originating from lake mud and wind-blown desert dust. The slurry would be pumped over the wash screen with the undersized material proceeding to flotation. The oversize would fall to the primary crusher, a hammer mill, which would discharge to the slurry tank.

17.4 Conditioning and Flotation

Conditioning may occur in two stages; mineral aging and flotation conditioning. Mineral aging is the process of mixing feed material with recycled brine to convert a variety of potassium minerals to leonite and could require up to 2 hours of retention time. In the flotation conditioning stage, flotation conditioners, including amine and flotation oil, would be metered into the conditioning tank to prepare the leonite for flotation. After an approximate 20- to 30-minute retention time with mixing, the slurry would be pumped to the two parallel rougher flotation cell banks.

The flotation circuit has been designed to separate the potassium rich salts from other salts and slimes. Flotation reagents, including depressants, aliphatic amines, foamers, and extender oils would be added to the potash salt slurry in the conditioning tank prior to entering the first of several banks of flotation cells. Intermediate flotation bank tailing material containing significant amounts of unliberated potash-containing agglomerates would be reground and returned to the conditioning circuit. The scavenger flotation bank tailing slurry, being substantially potassium-free salt, would be pumped to the tailings thickener for separation from flotation brine. The thickener underflow stream would be returned to the lake while the clarified overflow brine would be recycled to the scrubbing circuit. The flotation banks concentrate slurry would be collected and fed to centrifuges to be separated into a substantially brine-free cake, which would be conveyed to the crystallization circuits.

Each of the rougher flotation banks would consist of six cells to provide the necessary residence time. Frother would typically be metered as required into the rougher feed box to enhance bubble growth and stability. The rougher concentrate would flow to a pump box to be sent to dewatering. The tailings from the rougher would gravitate directly into its respective six-cell scavenger bank. The scavenger concentrate would be sent to the cleaner flotation cells. The cleaner concentrate would be added to the rougher flotation concentrate pump box. The cleaner tailings would be sent to a hammer mill and then would be returned to flotation conditioning.

The combined rougher and cleaner concentrates would be pumped to a distribution box where the flow would be directed to three centrifuges. The centrate would flow to the slurry repulp/scrubber tank for reuse in the process. The centrifuge cake would be collected and conveyed to the leonite repulp tank by a screw conveyor.

17.5 Multiple Effect Leonite Crystallization

As part of this study, an analysis of several crystallization processes resulted in the selection of the leonite-to-SOP process for producing potash from the Sevier Playa brine. The results of the analysis indicate that the leonite-to-SOP process would yield higher potassium recoveries at lower energy costs and with lower estimated water losses than the other processes considered, including the mechanical vapor recompression (MVR) process that used MVR to evaporate water; and the water leach process that evaporated water with multiple-effect crystallizers at a lower temperature than the leonite-to-SOP process. Table 17-1 presents a summary of the theoretical yields based on computer modeling of the processes evaluated.

TABLE 17-1
Summary of Results

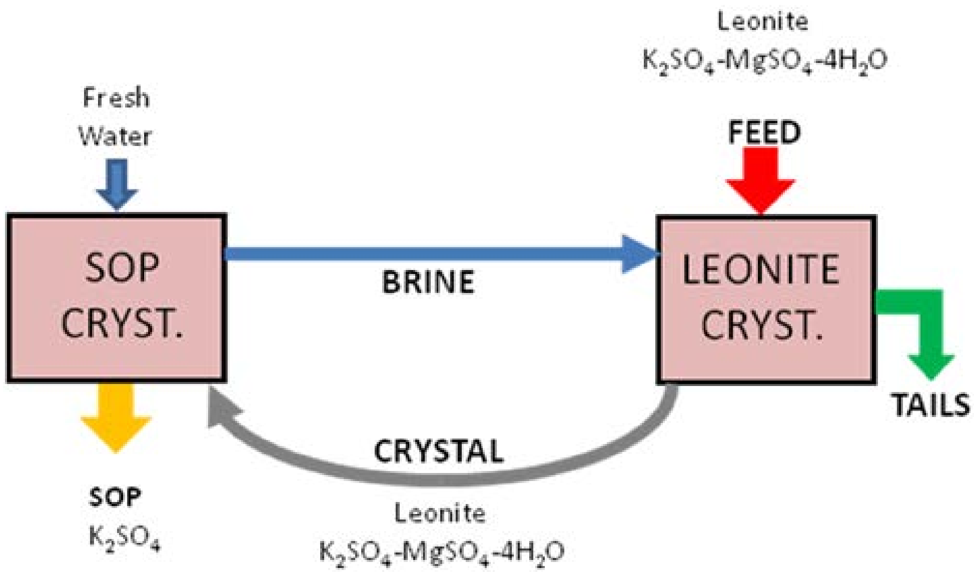
Process	Potassium Recovery (%)	Water Loss (ton H_2O/ton SOP)	Steam (MMBtu/ton SOP)	Electricity Use (kW-hr/ton SOP)	Power Cost ($/ton SOP)
Modified MVR	70.1	3.62	6.69	1,155	72.96
Water leach	78.9	5.56	9.50	0	35.62
Leonite to SOP	83.4	1.35	6.92	0	25.95

The leonite-to-SOP process would include the following steps:

1. Conversion of flotation concentrate to leonite
2. Conversion of leonite to SOP

The leonite-to-SOP process is shown in Figure 17-2.

FIGURE 17-2
Leonite to SOP Process



Flotation concentrate would drop from the screw conveyor into an agitated tank where it would be slurried with potassium-rich brine recycled from the later SOP crystallization step. The slurry would be heated to about 90°C (194°F) in a preheater to dissolve the solids. This solution would feed into a multiple-effect crystallization system consisting of four crystallizers operating at sequentially lower temperatures. Progressively, more potassium would be crystallized as leonite in each crystallizer.

The brine left over from leonite crystallization would be discarded to prevent impurity build-up. The leonite crystals would be sent to the SOP crystallizers where water would be added to dissolve the magnesium sulphate and produce SOP. Because a significant amount of SOP dissolves with the magnesium sulphate, the brine from SOP would be recycled to the leonite crystallizers for recovery of additional potassium.

Slurry from the crystallizers containing leonite and brine would be centrifuged and the centrate would be pumped to the next crystallizer stage. The centrate from the final crystallizer would be purged. The condensate from the crystallizers would be recovered for reuse in the process. The leonite in the centrifuge cake from the crystallizers would be conveyed to the SOP crystallization system.

17.6 Sulphate of Potash Crystallization

The leonite would be mixed with fresh water in the SOP feed tank and agitated in the SOP crystallizers for 90 to 120 minutes at 47°C (117°F). During this time, the leonite would be converted to SOP. The SOP crystals would be recovered from the brine by a combination of cyclones and centrifuges to concentrate the solids and recover them from the thickened slurry. The cyclone overflow and centrate would be recycled to the leonite slurry tank. The solid cake from the SOP centrifuge would be collected in a screw conveyor and conveyed to the SOP dryer.

17.7 Product Drying, Handling, and Shipping

The product exiting the SOP crystallizer circuit would be dried and screened to produce the desired fertilizer products to specification. The fertilizer-grade SOP products would be produced as standard and granular grades.

The damp centrifuge cake would be conveyed to a natural gas-fired, fluid-bed dryer and subsequently sized into coarse and fine products. A compressed air blower and burner system would heat the cake sufficiently to dry the crystals of SOP to over 99.9 percent solids. The dryer off-gas would be processed through a dust cyclone and scrubber unit. Some of the fines would be collected as dry solids and added to the product. Some of the solids would be collected in the scrubber solution and pumped to the leonite slurry tank. The dried product would be cooled and sent to product sizing, storage, and load-out through a series of conveyors.

The sizing area would separate the SOP into oversize, coarse product, fine product, and fines using a three-deck vibrating screen. The oversize product would be sent to the cage mill. The fines would be conveyed to a compactor to be converted into larger particles. Compacted fines and the oversize material would pass through a cage mill to reduce it to an acceptable product size before being returned to the three-deck vibrating screen. The coarse and fine products would be sent to product storage silos by a combination of bucket elevators and screw conveyors. The solids in the silos would be loaded into trucks for direct delivery or for transport to the rail load-out facility.

17.8 Ancillary Products

Several potential by-products, coproducts, or opportunities for improved recovery have been identified during the process development work, including the following:

1. Halite would be generated during the early stages of evaporation in the preconcentration ponds. The amount of halite is estimated to be about 14 percent of the starting weight of the brine. The material might be sold for ice melting or as road salt without reprocessing. For other applications, a processing facility would be needed to clean the halite prior to sale.

2. Sodium sulphate would be precipitated in the mixed salts pond. Additional ponds and pond control might allow recovery of the salt with limited impurities. Potential recovery could be up to 300,000 tpy (330,693 tons/yr) but would require crushing, flotation, and drying to separate the sodium sulphate from the other salts. Chilling of brine in the preconcentration ponds in the winter could also cause sodium sulphate crystallization.

3. Leonite could be produced in an impure form from the flotation concentrate or could be recovered as a purified product from the leonite crystallizer.

4. Magnesium sulphate could potentially be recovered from three areas. Thermodynamic modeling of the solar ponds suggests that it may crystallize in the second or third production pond. The salt is also dissolved in the bitterns that is removed from the final production pond. According to the process model, the process purge stream from leonite crystallization contains 34 percent magnesium sulphate and 4.5 percent SOP. Recovery of SOP from any of these streams would require process development testing to evaluate the technical and economic feasibility.

5. Magnesium chloride is present with magnesium sulphate in the bitterns. Recovery of lithium, discussed below, will require removal of those salts. This may present an opportunity to recover the magnesium chloride. Test work will need to be performed to determine if a process is economically feasible.

6. Lithium does not appear to be crystallized in any of the solar evaporation ponds. In pond simulation work at Hazen lithium was concentrated to 0.136 percent (about 2 grams/L [0.27 oz/gal]) in the final pond. There are a number of processing options that have the potential of recovering the lithium. These are recommended for further study during the next stage of design.

SECTION 18

Project Infrastructure

18.1 Site Infrastructure Layout

Figure 18-1 shows the area map of the Project. The site would be accessed via state highways on the north and east sides. Power would be brought in from beyond the north end of the lake. UPRR has a main line approximately 24 km (15 miles) due east of the plant site. The water supply would be from a well due south of the plant site while the natural gas supply line would be brought in from the Kern River Pipeline east of the plant site.

The main electrical substation for the facility would be located on the northeast corner near the main production building. Additional buildings would include a single-level adminstration building, truck shop, and covered area for on-site product storage near the product load-out area. All buildings would be pre-engineered structures with the exception of the main production building.

18.1.1 Communications Infrastructure

EPM expects to use telecommunications and portable two-way radio systems. EPM would need to construct dedicated facilities to provide all local and long distance communication.

Internet and telephone service would originate in Delta, Utah, and would connect to the Administration Building at Sevier Playa by means of a microwave system. Communication between the Administration Building and the rail load-out facility would be handled by a fiber-optic communication system running over cables strung on the power poles connecting the two facilities. Portable two-way radio units would be used for on-site communication.

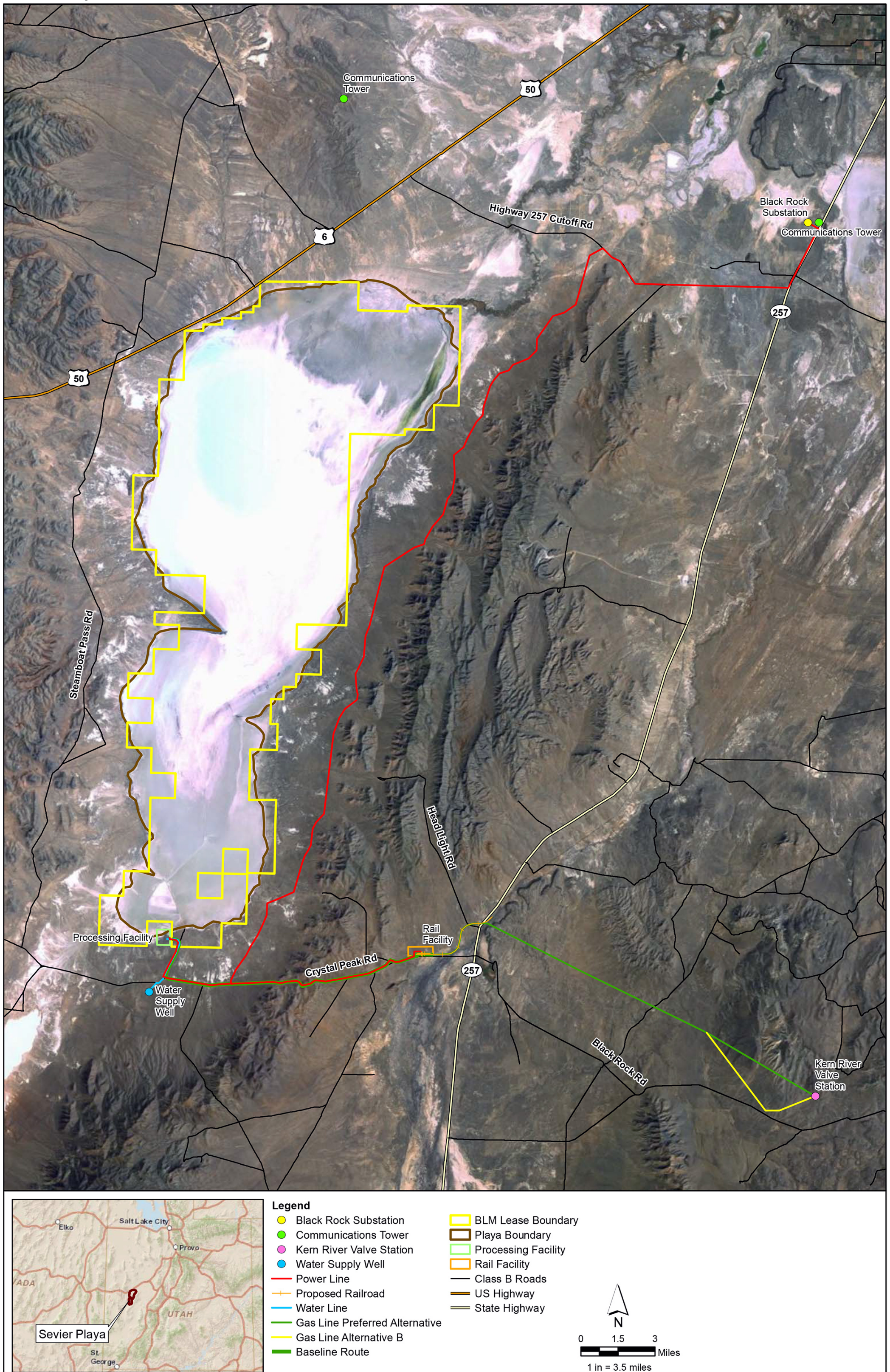
18.1.2 Site Access Roads

The Sevier Lake is located approximately 64 km (40 miles) southwest of Delta, Utah. Delta is located approximately 160 km (100 miles) southwest of Salt Lake City, Utah. Delta can be accessed from Salt Lake City via Interstate 15 and the state highway system.

The main plant site would be accessed by traveling south from Delta on State Highway 257 for approximately 84 km (52 miles) then traveling east for 24 km (15 miles) on an improved county road to the plant site located on the south end of Sevier Lake. The east and west shores of Sevier Lake can be accessed from Delta by traveling west on State Highway 6 for 68 km (42 miles).

FIGURE 18-1

Area Map



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18.1.3 Rail Load-out

Product from the processing plant would be transported by haul truck along the Crystal Peak Road from storage silos to the rail load-out facility. There, bottom-discharge trucks would unload into a hopper. Products would be unloaded from the bottom of the hopper onto a conveyor that would feed another conveyor carrying material to the top of the storage building. The coarse and fine products would be piled in separate ends of the building. Material would be reclaimed from storage with belt conveyors that would carry the selected product out of the storage building and up to a two-deck screen. The screen would recover coarse and fine products for shipment and would recycle undersized materials to the processing plant. The separate products would be stored in load-out bins to facilitate rail car loading.

UPRR operates a main-line rail service approximately 24 km (15 miles) by road east of the plant site. A new rail line would be built from the rail load-out facility, intersecting with the main line rail service as shown in Figure 18-2. The yard tracks would consist of an arrival or loading track, a run-around track, and a departure track.

No major crossings or restrictions are anticipated. Graymont Lime, one of the ten largest lime plants in the U.S., operates a similar rail arrangement 29 km (18 miles) to the north along the same track.

18.2 Utilities

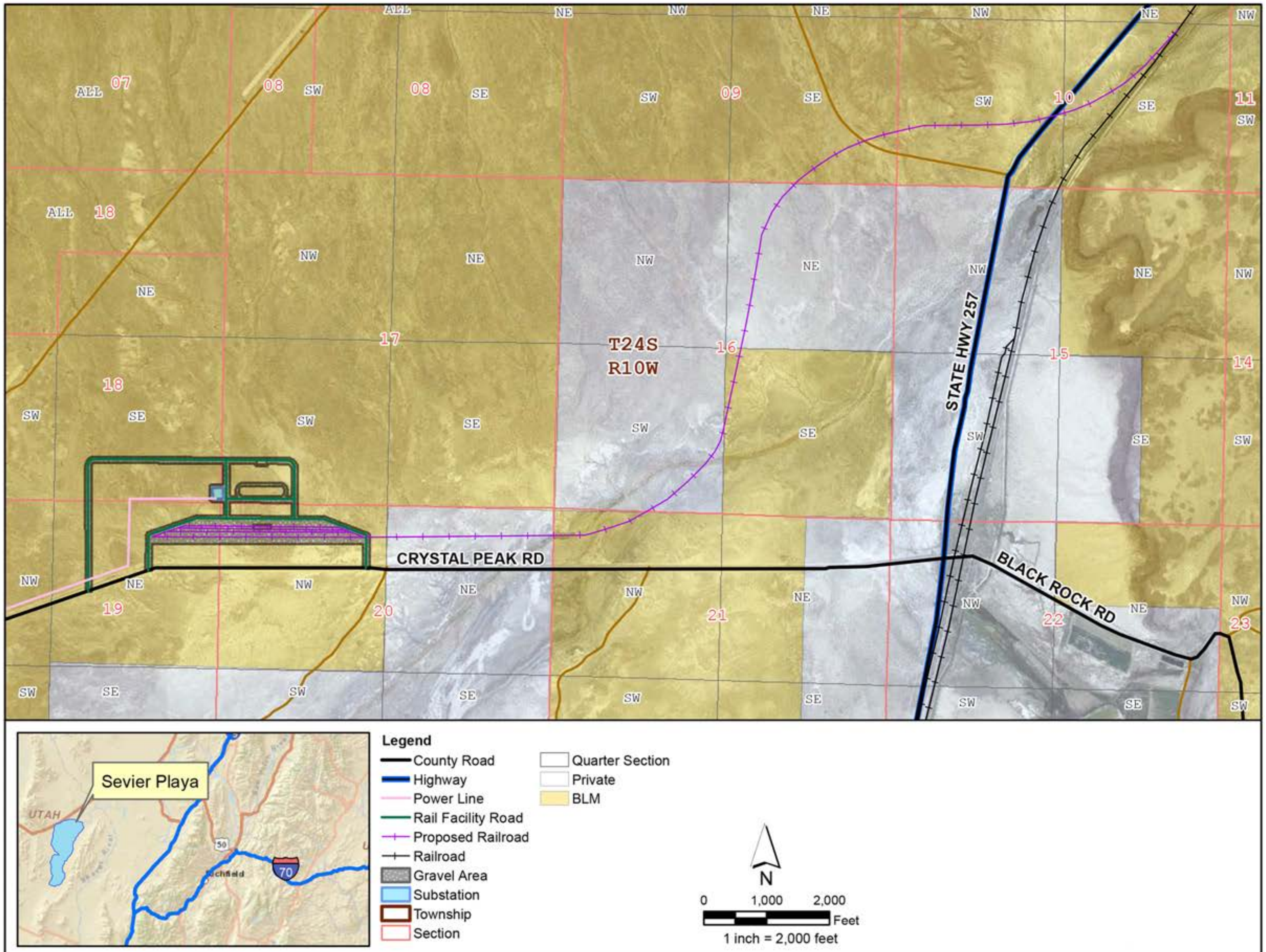
18.2.1 Water

The operation would require approximately 1,100 L/min (290 gpm) of fresh water for processing and other uses, including fire suppression. A fire-fighting system was included in the basis of estimate and will be further detailed during the next design phase.

The closest public water supply is in the town of Milford, Utah approximately 40 km (25 miles) southeast of the proposed plant site. Therefore, local groundwater is the most viable water supply for the plant. EPM completed an assessment of three possible locations to explore for groundwater resources around the south end of Sevier Lake. An exploratory test hole was drilled to a depth of 228 m (750 ft) at the most promising of the three locations, about 4 km (2.5 miles) south of the lake along the foot of the San Francisco Mountains. The test hole intersected acceptable quality groundwater at a depth of approximately 140 m (460 ft) in fractured quartzite bedrock.

FIGURE 18-2

New Rail Line



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Air-lift testing within this exploratory hole, and aquifer testing of a 13 cm (5 in) monitoring hole completed in the same formation about 21 km (13 mi) northeast of the test hole location, indicated that a production well completed to a depth of approximately 457 m (1,500 ft) in this fractured quartzite zone could continuously supply between about 757 to 1,514 L/min (200 to 400 gpm) of fresh water. Two wells may be necessary to provide an adequate and redundant water supply for the plant. A storage tank may need to be constructed nearby to allow for fluctuations in flow rates. Water from these locations was collected and submitted to an analytical labouratory and the results indicate that the groundwater from the fractured quartzite is high quality.

18.2.2 Natural Gas

Natural gas consumption was estimated at 0.231 million m^3/d (8.2 million ft^3/d). Natural gas may be supplied by the Kern River Gas Transmission line via a new, 20-cm (8-in), below-grade pipeline to the plant site. The tap location would be approximately 56 km (35 miles) from the project site tapping into a 0.9 m (36 in) supply line that has a capacity of 4.26 million m^3/d (145 million ft^3/d). Kern River Gas Transmission is located in Salt Lake City, Utah, and operates an interstate natural gas pipeline extending from the oil and gas fields in southwestern Wyoming to California.

18.2.3 Electricity

The connected load for the project was estimated at approximately 19 megawatts (MW) connected, 12.2 MW diversified. The new 69-kilovolt (kV) transmission line would connect to PacifiCorp's Black Rock Substation and 83.7 km (52 miles) of transmission line would be constructed along the east side of the lake. A switchyard would be constructed at the plant site. Power lines to three different pump stations on the playa would be constructed from this main transmission line as it traverses north to south along the eastern edge of the lake. Power from the switchyard would follow the Crystal Peak Road to the rail yard.

PacifiCorp owns and operates approximately 25,400 km (15,800 miles) of transmission lines ranging from 46 to 500 kV across multiple western states. PacifiCorp is interconnected with more than 80 generation plants and 15 adjacent control areas at approximately 124 points of interconnection.

18.2.4 Fuel Storage

On-site fuel storage would be limited to that required for haul trucks and site vehicles and would be located in aboveground storage tanks near the truck shop. Fuel supply would likely be contracted with a local fuel supplier.

18.2.5 Waste Management

Solid wastes that may be generated include various chemicals or wastes from the processing plant or from maintenance activities. Additionally, solid waste will be generated from the site workers and administrative operations. All solid waste would be collected, stored, and properly disposed of in a permitted Resource Conservation and Recovery Act (RCRA) landfill. The amount of hazardous waste, such as spent solvents, that would be generated is expected to be minimal and would be properly stored while onsite, then would be documented, transported, and disposed of in accordance with RCRA and the Utah Department of Transportation standards.

Tailings disposal and salt waste streams are described in Section 20 of this Technical Report.

Stormwater and Sanitary Sewage Facilities

Stormwater runoff from the plant and wash-down water will be segregated as appropriate in lined holding ponds for subsequent treatment or discharge in accordance with environmental regulations. Sewage will be managed using a permitted leach field.

18.3 Preliminary Construction Schedule

The project would include three construction phases with the majority of construction scheduled to be completed in the first phase. The initial construction would include the following:

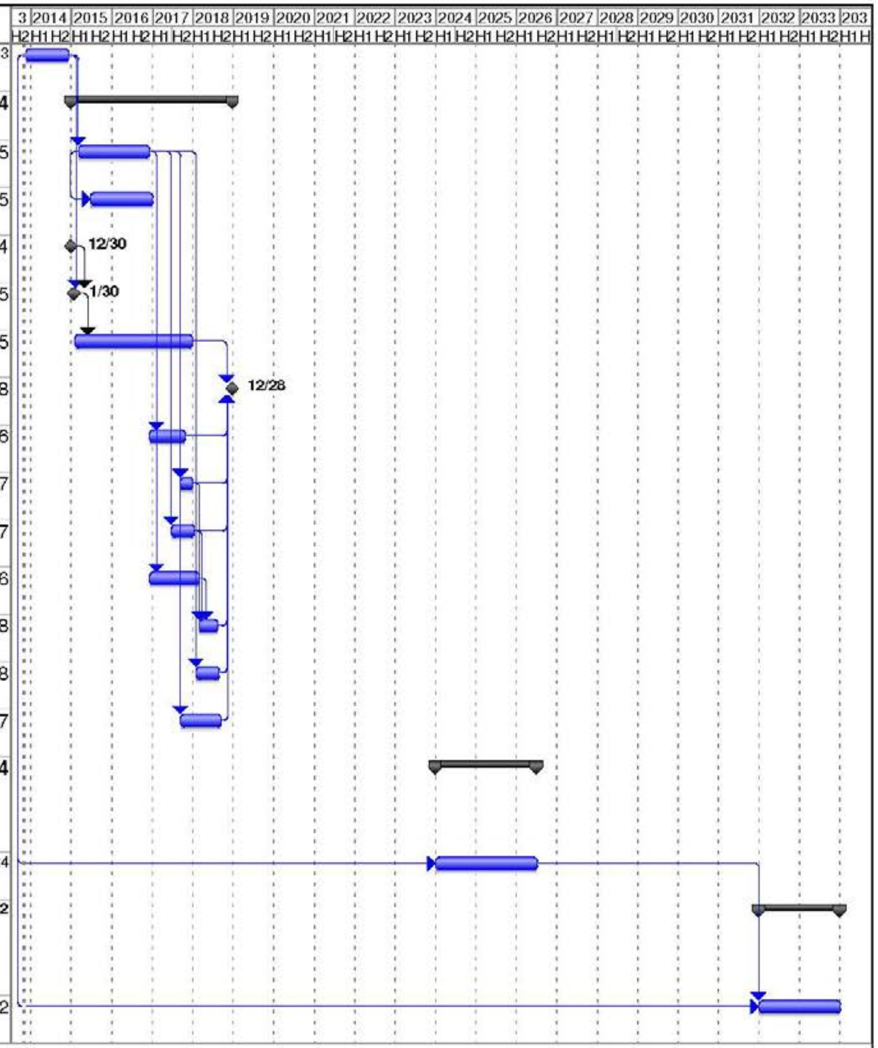
- Solar ponds
- Processing plant
- 52 miles of 69-kV transmission line
- 35 miles of natural gas supply pipeline
- Fresh water line
- Extraction and recharge trenches
- Pond dikes
- Brine lift stations
- Rail load-out facility

Local housing would be used during construction. Since sufficient accommodations are expected to be available in the immediate area, no camp would be required.

Phase 2 activities would include construction of recharge and extraction systems and Phase 3 would include construction of additional extraction wells intended to access lower resource zones. A construction schedule is included as Figure 18-3.

FIGURE 18-3
Construction Schedule

ID	Task Name	Duration	Start
1	Definitive Feasibility Study	280 days	Mon 11/11/13
2	**PHASE 1**	**1043 days**	**Tue 12/30/14**
3	Detail Design	460 days	Mon 3/2/15
4	Procurement Long Lead Equipment	400 days	Mon 6/22/15
5	BLM Approval EIS	0 days	Tue 12/30/14
6	Regulatory Project Plans Approved	0 days	Fri 1/30/15
7	Construction of Ponds & Canals	760 days	Fri 1/30/15
8	First Salt Harvest for Partial SOP Production	0 days	Fri 12/28/18
9	69kV Transmission Line Construct	230 days	Mon 12/5/16
10	6" HDPE Fresh Water Pipeline Construct	80 days	Mon 9/11/17
11	8" HDPE Gas Pipeline Construct	150 days	Mon 6/19/17
12	Plant Construction	320 days	Mon 12/5/16
13	Plant Startup	120 days	Mon 2/26/18
14	Construct Rail Spur	150 days	Mon 1/29/18
15	Construct Rail Loadout Site	260 days	Mon 9/11/17
16	**PHASE 2**	**652 days**	**Mon 1/1/24**
17	Construct Extraction and Recharge System	652 days	Mon 1/1/24
18	**PHASE 3**	**522 days**	**Thu 1/1/32**
19	Construct Extraction Wells	522 days	Thu 1/1/32



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Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Progress | Deadline

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Market Studies and Contracts

The information in this section was compiled from public and private materials including industry studies, reports, forecasts, and estimates, as well as a market assessment and distribution strategy study commissioned by the EPM and prepared by The Parthenon Group (Parthenon). This study, titled “SOP Market Assessment, Summary of Findings” (Market Study) included both primary and secondary research and focused on market analysis, supply and demand capacity and pricing trends, economic forecasting and modeling, and developed a framework for domestic and international distribution of potassium sulphate and magnesium-based minerals. Parthenon conducted interviews with agronomists, wholesalers, distributors, and retailers, both domestically and abroad; and also completed a comprehensive survey of U.S. farmers that grow chloride-sensitive crops (Farmer Survey). Responses to the Farmer Survey provided further definition for domestic potassium sulphate usage by region and crop, decision dynamics, as well as barriers and opportunities for increased usage. The QP for this section has reviewed the studies and analyses and has determined that the results support the assumptions presented herein.

19.1 Fertilizer Introduction

19.1.1 Nutrient Overview

Chemical fertilizers have played a major role in the dramatic increase in agricultural production over the past 40 years. While mechanization, better yielding seed varieties, more-effective use of soil and water resources, and the development of disease resistant crop varieties are frequently cited as the main forces underlying the “Green Revolution,” fertilizers have and continue to play an important role.

Higher crop yields take up large amounts of nutrients from the soil in quantities that cannot be replaced effectively by so-called “natural” or “organic” fertilizers. Mineral nutrients can be classified into three macronutrients, which are required in greater quantities; and ten micronutrients, which are required in lesser or trace amounts. The three primary macronutrients are nitrogen, phosphorous, and potassium, while micronutrients include but are not limited to sulphur, magnesium, calcium, boron, iron, zinc, manganese, chloride, and copper.

Nitrogen is essential in the production of protein and is a part of chlorophyll, the biomolecule responsible for photosynthesis. Nitrates help plants grow, improve leaf quality, and increase fruit and seed production. Phosphorous encourages strong root development, improves plant maturation and growth, and is essential in photosynthesis as well as in the formation of sugars, starches, and oils. Like the other two macronutrients, potassium assists in protein production and photosynthesis. It also enhances nutrient uptake, increases disease resistance and drought tolerance, and improves crop yield, quality, and shelf life.

All three macronutrients are available in manures and crop residues; however, their concentrations are usually low or in a form that cannot be easily absorbed by plants. Certain organic fertilizers, especially animal manures, if applied in the quantities required to support profitable crop yields, can cause environmental problems. Due to such limitations, chemical fertilizers are considered a more-efficient and cost-effective source of essential nutrients in modern agricultural production.

Of the three macronutrients, nitrogen-based fertilizers are most commonly used. Today, commercial scale production of nitrogen-based fertilizers is primarily based on chemical processes that use natural gas or other low-cost sources of hydrocarbons to convert atmospheric nitrogen into anhydrous ammonia with a follow up conversion into various fertilizer forms. Since reserves of natural gas are relatively common throughout the world, ammonia production facilities are widespread and many countries have some domestic nitrogen fertilizer production. On the other hand, phosphorous and potassium fertilizers are obtained from phosphate-bearing, potash-bearing, or brine deposits. Thus, commercially viable sources of phosphate and potassium are limited.

19.1.2 Fertilizer Demand Fundamentals

A number of micro and macro drivers underpin current and future demand for potassium-based fertilizers, including the following four main macro drivers:

1. **Increasing World Population –** According to the United Nations Food and Agricultural Organization (UN FAO), food production would need to increase approximately 70 percent by 2050 to feed a population expected to increase by approximately 33 percent over the same period. This will require significant increases in annual meat, cereals, fruit, vegetable, and dairy production to meet demand.
2. **Declines in Per Capita Arable Land –** According to the UN FAO, per capita arable land has been declining since the 1960s.
3. **Disposable Income and Dietary Changes –** Globalization of commerce has resulted in rising incomes and demographic changes in developing countries. As disposable incomes rise, caloric intake also rises as demand for more meat, fruits, vegetables, and dairy products increases.
4. **Under-application of Potassium Fertilizers in Developing Countries –** Historically, fertilizer application rates in developing countries have been below scientifically-recommended levels. Some of the major developing economies, like India for example, have been severely unbalanced in their fertilizer use, being skewed toward nitrogen and phosphorous.

While a portion of the required increase in food production can be met through the expansion of arable land in developing countries, increasing production yields via fertilizer usage coupled with advanced agricultural techniques, mechanization, seeding applications, and other techniques has become the primary objective.

19.2 Potassium Fertilizers

The potassium fertilizer market comprises four primary products—potassium chloride (KCl or MOP), potassium sulphate (K_2SO_4 or SOP), potassium magnesium sulphate ($K_2Mg_2[SO_4]_3$ or sulphate of potassium magnesium [SOPM]) and potassium nitrate (KNO_3 or nitrate of potassium [NOP]). Total estimated global demand of potassium-based fertilizers is approximately 63 to 64 Mt (69 to 70 Mtons) per annum. MOP represents the largest component of global demand at approximately 88 percent with SOP, SOPM, and NOP composing approximately 8, 2, and 2 percent of global demand, respectively.

Because the potassium content varies between fertilizer products, the ionic compound K_2O is used as a standard to indicate the potassium oxide equivalent contained in each product. Refer to Table 19-1 for comparative information for each potassium product.

TABLE 19-1
Potassium-Based Fertilizers

Product	K_2O Equivalent %	Description
Potassium Chloride	60	Most common form of potassium fertilizer Includes 46% Cl content Chloride can be harmful to certain crops and detrimental in acidic soils
Potassium Sulphate	50	Used principally for high-value crops with chloride sensitivities, such as fruits, tree nuts, tobacco and vegetables Includes 17.5% sulphur content, a necessary nutrient for many plants SOP does not contain Cl
Potassium Magnesium Sulphate	28	In addition to providing potassium and sulphate, it is used to correct magnesium deficiencies in the soil Includes 16% sulphur content Includes 5% to 18% MgO content depending on the potash mineral
Potassium Nitrate	45	Used in water soluble forms on crops that are sensitive to chloride and require nitrogen Includes 13% nitrogen

Source: Parthenon, UN FAO, BMO Capital Markets, CRU

The prime drivers for potassium-based fertilizer selection are the total required amount of K_2O by a plant, solubility, chloride sensitivity, and nutrient composition. For example, row crops such as cereals, typically require smaller amount of K_2O per plant and have a high tolerance for chloride. Consequently, potassium chloride is the preferred and most economical source of potassium for them. However, high-value crops such as fruits, tree nuts, tobacco, and vegetables are chloride-sensitive, or in some cases chloride intolerant, and require larger amounts of K_2O, thus necessitating potassium sulphate usage instead of potassium chloride. Since chloride sensitivity varies by plant, they can be grouped based on their propensity to use potassium sulphate (examples listed in Table 19-2 below – not an exhaustive list).

TABLE 19-2
Chloride Tolerance by Crop

Crop Classification	Chloride Tolerance	Crop Examples*
Tier 1	Highly Chloride Sensitive	Tobacco, tea, almonds, grapes
Tier 2	Chloride Sensitive	Potatoes, oranges, pistachios, cashews, tomatoes, mango
Tier 3	Partly Chloride Tolerant	Sunflower, coffee, peas, spinach, carrots, cucumber
Tier 4	Chloride Tolerant	Cereals, maize, rice, soybean, sugar cane, cotton

Notes:
*Examples not meant to be an exhaustive list
Source: Parthenon, K+S Kali, SOPIB

Sulphur is another driving factor for SOP consumption since sulphur helps support plant functions that can affect yield, quality, and marketability; it is often referred as the fourth macro nutrient. Sulphate levels in the soil have declined in the United States over the past 10 years increasing the need to deliver additional sulphur through fertilization.

Potassium sulphate also provides additional flexibility for potassium applications in environments with highly saline soils or poor irrigation water quality. With a salt index per unit of K of approximately 0.88 versus potassium chlorides' 1.94, SOP has the lowest salt index of all major potassium sources and as such ensures safety to plant tissue relative to other potassium forms.

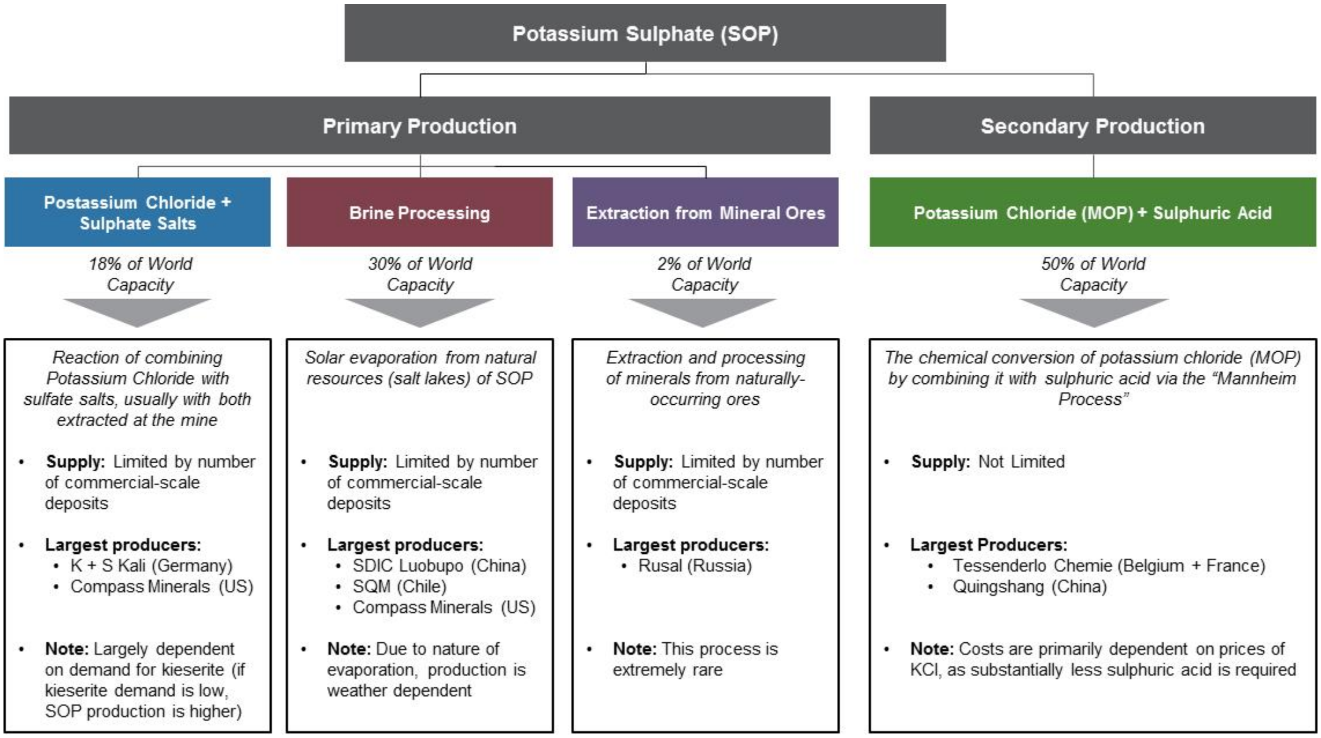
19.3 Potassium Sulphate

19.3.1 Production Methods

Global potassium sulphate production capacity was estimated at 7.2 Mt (7.9Mtons) in 2012. China accounts for approximately 52 percent of the world's production capacity, followed by Germany (16 percent), Belgium (9 percent), the U.S. (4 percent), and Chile (4 percent). The balance of world capacity is highly fragmented and is distributed over more than a dozen other countries. Outside of China, most countries have only one domestic potassium sulphate producer.

As shown in Figure 19-1, SOP production can be classified as either a) Primary – based on the processing of natural sulphate-rich brines or ores; or b) Secondary – based on the chemical conversion of potassium chloride and sulphuric acid using the "Mannheim Process".

FIGURE 19-1
Production Methods



Source: Parthenon, CRU

Primary production from natural brine is the most cost-effective method for producing potassium sulphate. However, due to the scarcity of this brine, it represents less than one-third of the world's SOP production. Brine producers use solar evaporation ponds to precipitate potash salts contained in the brines. The largest producer in the world is SDIC Luobupo in the Xinjiang province of western China. SDIC's capacity of 1.3 Mt (1.4 Mtons) per annum is four times greater than the next largest brine producer. Compass Minerals, through its Utah subsidiary GSL, and Sociedad Quimica y Minera also produce potassium sulphate from natural brine with annual production of approximately 300,000 t (330,690 tons) each.

K+S Kali is the only company in the world to produce potassium sulphate using ore mined at its own sites in a process that requires a reaction of potassium chloride with magnesium sulphate in the form of kieserite or epsomite). Since K+S produces ores that contain both minerals, and is therefore not required to purchase potassium chloride to make SOP, industry participants usually refer to it as a primary producer.

Lastly, production of potassium sulphate from mined ores such as sodium potassium alumonosilicate is done on a very small scale in Russia and only represents about 2 percent of global capacity.

The secondary production method known as the Mannheim Process represents approximately 50 percent of the 7.2 Mt (7.9 Mtons) of worldwide potassium sulphate production capacity. The Mannheim Process is the highest-cost method of SOP production given the raw materials, labour, and energy costs consumed in the chemical conversion. Mannheim producers require raw material inputs including potassium chloride and sulphuric acid, as well as significant amounts of energy. These typically compose over 80 percent of their cash costs. It takes approximately 0.85 Mt (0.94 Mtons) of potassium chloride and 0.60 Mt (0.66 Mtons) of sulphuric acid to produce 1.0 Mt (1.1 Mtons) of potassium sulphate. Moreover, due to the high cash costs, receiving a credit for the output of the hydrochloric acid byproduct is necessary for a Mannheim producers' profitability. This cost structure is a significant point of differentiation between primary and secondary producers.

Potassium sulphate production is done on a different scale than that of potassium chloride. While it is not unusual for a company to produce millions of tonnes per annum of MOP, potassium sulphate producers operate in thousands of tonnes of production per year. Only four companies in the world produce more than 500,000 t (551,156 tons) of potassium sulphate per annum. Moreover, three of the four companies are high cost, secondary producers that manufacture between 590,000 t (650,364 tons) and 1.2 Mt (1.3 Mtons) per annum.

For brine producers, production scalability is a function of the availability of brine as well as area for evaporation ponds. For Mannheim producers, production scalability is based on the number of furnaces in operation, access to potassium chloride and sulphuric acid, and demand for hydrochloric acid.

Refer to Table 19-3 for a ranking of the world's largest potassium sulphate producers. The balance of worldwide production capacity is highly fragmented.

TABLE 19-3
Largest Potassium Sulphate Producers

Company	Country	Production Method	Annual Production Capacity (t per annum)
SDIC	China	Brine	1,300,000
K+S	Germany	Mannheim/Reacted Salts	1,200,000
Tessenderlo Chemie	France/Belgium	Mannheim	750,000
Qingshang	China	Mannheim	590,000
Compass	USA/Canada	Brine/Reacted Salts	333,000
Migao	China	Mannheim	320,000
SQM	Chile	Brine	300,000
Yara	Finland	Mannheim	200,000
Rusal	Russia	Mineral Ores	180,000
Kemira Kemi	Sweden	Mannheim	100,000
Gansu Xinchuan Fertilizer Corp.	China	Mannheim	100,000
Shijiazhuang Hehe	China	Mannheim	100,000

Note: Source: CRU, Compass Minerals

Due to the scarcity of brine and ore deposits rich in potassium sulphate, announced greenfield and brownfield capacity is relatively limited. With the exception of SDIC's announced brownfield expansion of 600,000 t (661,387 tons) per annum, additional international capacity is nominal. In the U.S., excluding EPM's Sevier Playa Project, there are only two additional potassium sulphate greenfield projects under evaluation; IC Potash in New Mexico and Potash Ridge in Utah. Accordingly, announced U.S. greenfield capacity is approximately 1.5 Mt (1.6 Mtons). Brownfield expansion at Compass' Great Salt Lake facility, which is currently being evaluated, could add approximately 200,000 t (220,462 tons) if completed.

19.3.2 Product Grades

The three commonly produced grades of potassium sulphate are standard, granular, and soluble. High-purity industrial-grade material is produced only in small amounts. There are no published data related to the production or consumption of each grade so estimates were developed based on production estimates from installed capacities, interviews, and farmer preferences.

CRU International Ltd. estimates that approximately 50 percent of global SOP demand is for standard product, 40 percent for granular product, and 10 percent for soluble product. It is believed that demand is growing fastest for soluble and granular grades with the share of standard-grade material decreasing. In response to growing demand, nearly all major potassium sulphate producers have added the capacity to granulate a portion of their output. Demand is highest in regions where bulk-blended NPK products are favored over compound fertilizers (e.g., the Americas, Europe, Middle East). Nearly half of all granular potassium sulphate is consumed by North America and parts of Latin America.

Soluble potassium sulphate is a relatively new product since it was developed in the late 1980s. The consumption of soluble SOP is reflected by the spread of fertigation techniques where it competes for market share with potassium nitrate and, to a lesser extent, potassium chloride and potassium phosphate. Hence, the demand is expected to be concentrated around the Mediterranean Rim; particularly in Spain, Italy, Egypt, and Turkey. The Unites States is also a significant consumer as are Chile, Peru, and Australia.

In the United States, most growers use granular grade but soluble forms are useful in areas of little rainfall. Granular grades are also commonly used on sandy soils whereas soluble fertilizers work well on heavier soils and are typically used in dry areas where drip fertigation systems are already in place.

19.4 Potassium Sulphate Market Overview

19.4.1 Domestic Market

Since 1995, U.S. potassium sulphate demand has grown at an average annual rate of 10 percent. In 2012, potassium sulphate demand was 320,000 t (352,736 tons), approximately 60 percent of which was consumed along the west coast with the balance consumed in the Midwest and Southeast. Imports account for approximately one-third of U.S. supply with the majority of the supply imported into the southeast.

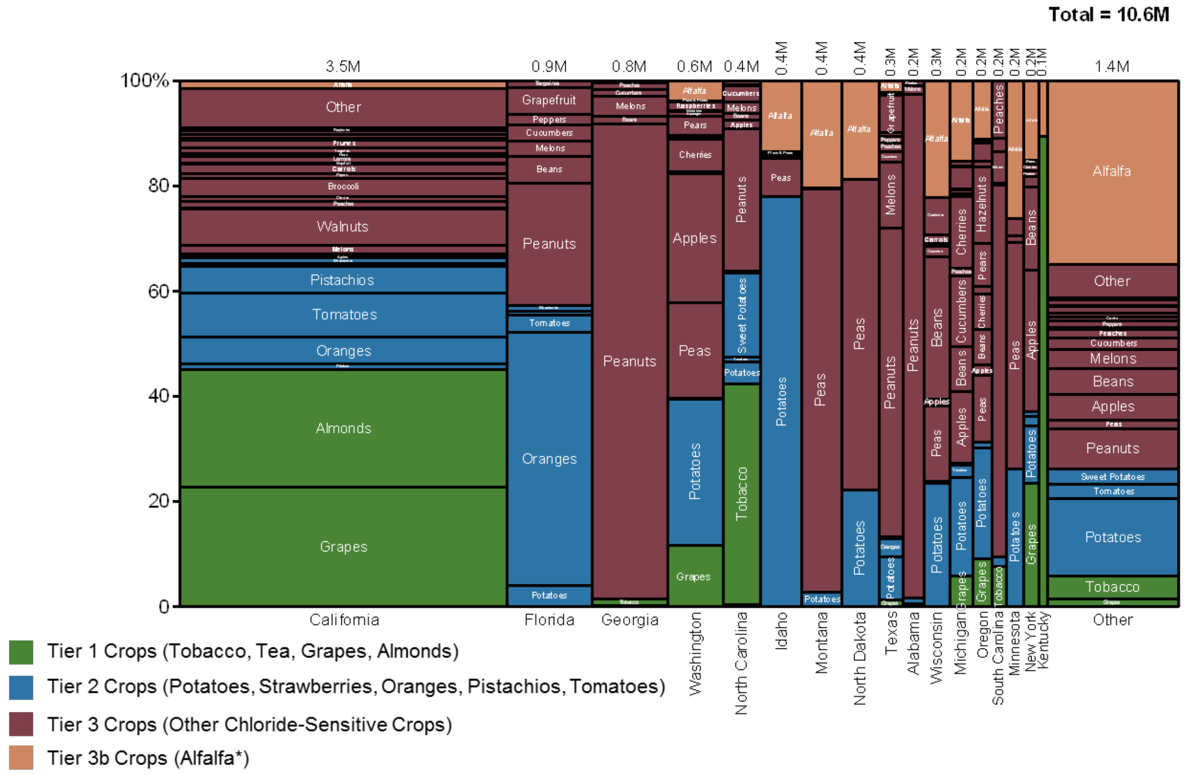
Between 1991 and 2012, California accounted for approximately 47 percent of all potassium sulphate consumption in the U.S. This is due to the types of crops grown in California. As shown in Figure 19-2, one-third of all chloride-sensitive crops is grown in California, followed by Florida, Georgia, Washington, North Carolina, and Idaho.

According to the U.S. Department of Agriculture's National Agricultural Statistics Service, California Field Office, in the 2011 crop year, California produced 50 percent of U.S.-grown fruits, nuts, and vegetables and accounted for 15 percent of the total national crop receipts. California accounts for 58 percent of U.S. non-citrus fruit and nut production and 68 percent of the national value; for Tier 1 crops, such as almonds and grapes, California production accounts for 100 and 90 percent, respectively. California also leads U.S. vegetable production with about 50 percent of national production and 52 percent of national value.

The Market Study projects that, under a base-case scenario, U.S. demand for potassium sulphate will grow at 4 percent per annum, of which 1 percent is directly attributable to production acreage growth and 3 percent is attributable to penetration/usage growth in crops. Based on 2012 consumption of 320,000 t (352,736 tons), demand is expected to reach approximately 510,000 t (562,173 tons) by 2020. The Market Study further estimates that approximately 540,000 t (595,242 tons) of additional SOP consumption opportunity exists in the U.S. among chloride-sensitive crops at full penetration rates resulting in total potential demand of 1.05 Mt (1.16 Mtons) by 2020.

FIGURE 19-2

U.S. Farm Acreage by Chloride-Sensitive Crop and State, 2012



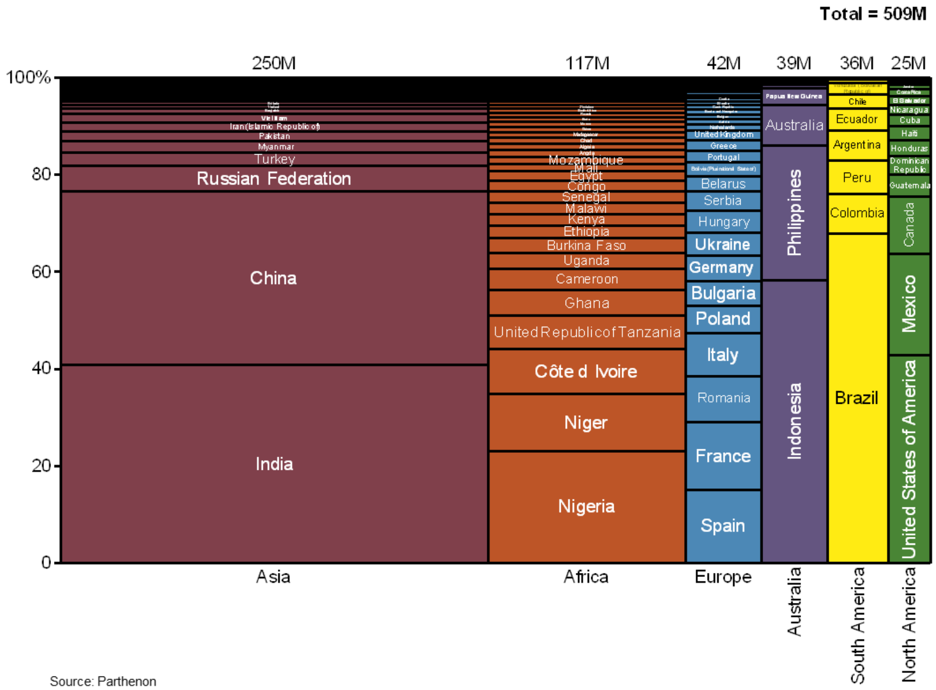
Note: Acreage is acreage planted; excludes sunflowers as a chloride-sensitive crop **Approximately 1M acres of 17M acres of alfalfa in the U.S. is considered "high-yield" and addressable by SOP
Source: Parthenon

19.4.2 International Market

The international market represents a significant opportunity for both existing and greenfield potassium sulphate producers. The UN FAO estimates that there are 509 million acres of chloride-sensitive crops, the significant majority of which are located in Asia (Figure 19-3). India has the world's largest area of chloride-sensitive crops under cultivation. Second only to India, China grows a significant amount of chloride-sensitive crops and is the world's largest consumer of potassium sulphate. Brazil and a number of Southeast Asian countries also represent significant opportunities based on their chloride-sensitive crop production (Figure 19-4)

FIGURE 19-3

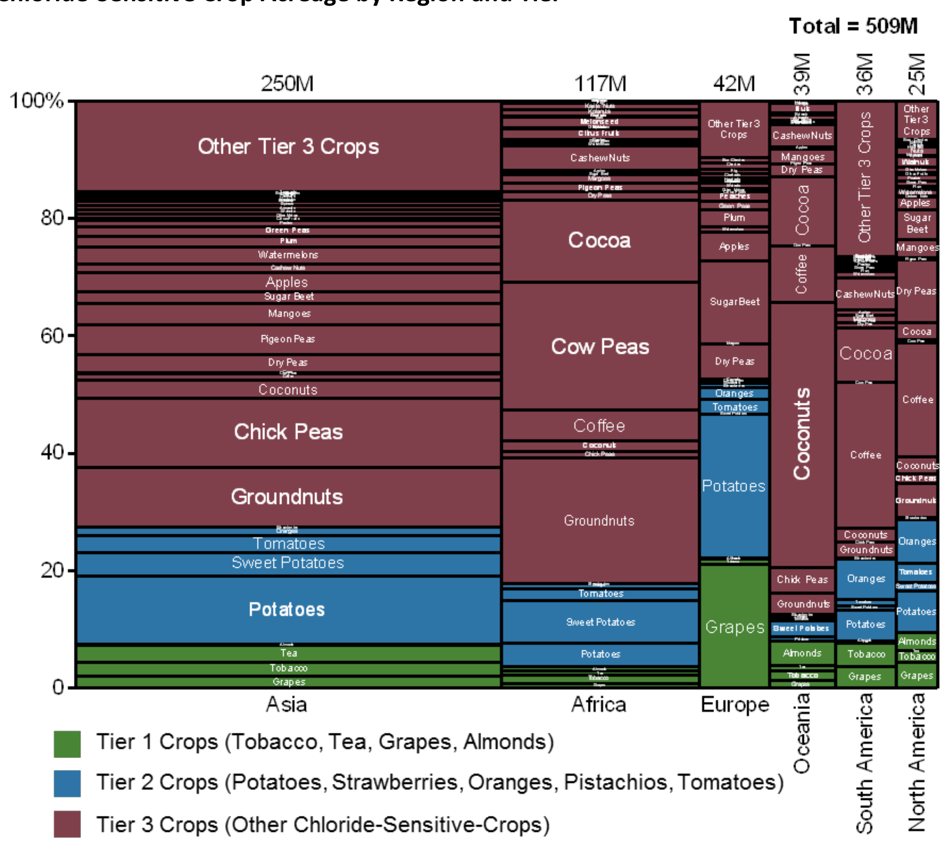
Chloride-Sensitive Crop Acreage by Region and Country



Source: Parthenon

FIGURE 19-4

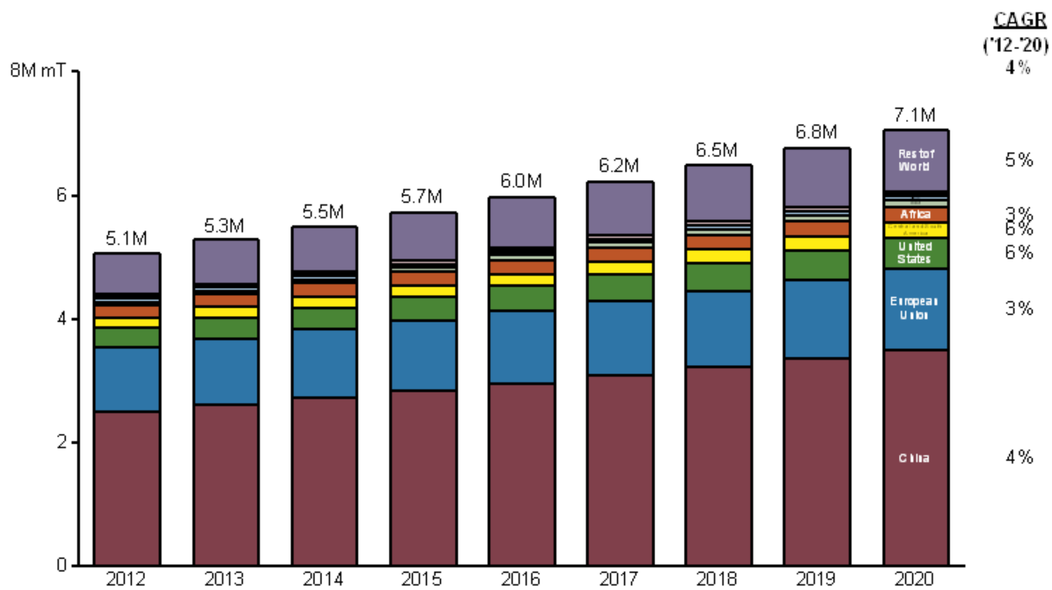
Chloride-Sensitive Crop Acreage by Region and Tier



Source: Parthenon

Global potassium sulphate demand in 2012 was estimated at 5.1 Mt (5.6 Mtons) (4.8 Mt [5.3 Mtons] excluding the U.S.). China represents approximately 50 percent of demand, followed by the European Union, and the U.S. (Figure 19-5). Demand is projected to increase across all regions, reaching worldwide demand of 7.1 Mt (7.8 Mtons) by 2020 (Figure 19-5).

FIGURE 19-5
Parthenon Global Potassium Sulphate Demand Estimate, Mt, 2012–2020



Source: Parthenon Analysis

19.4.2.1 China

China is the world's largest producer and consumer of potassium sulphate. The country produces nearly half of the world's fruits and vegetables and approximately one-third of the world's tobacco and tea. About 20 percent of potassium sulphate demand in China is used in tobacco cultivation. The recent growth in supply and demand of SOP in China is due in large part to SDIC's brine deposit in the Xinjiang province. Prior to SDIC, China relied almost exclusively on Mannheim production as its main source of supply. Since SDIC's commissioning, the capacity utilization rates of Mannheim producers have declined from the mid-90 percents in 2005 to less than 50 percent in 2012. Negative operating margins have resulted in the reduction of many secondary producers.

Imports have accounted for 10 percent or less of their total supply over the last 5 to 7 years, and potassium sulphate exports are non-existent due to a prohibitive potash export tariff. The foreign producers (primarily K+S and Rusal) generally serve niche markets such as granular and high purity/solubility potassium sulphate.

Approximately 80 percent of potassium sulphate sold in China is in standard (powder) form and is used in the production of NPK compound fertilizers by blenders. Granular potassium sulphate sells at a premium to standard grade and is typically used directly by farmers. Soluble grades represent a very small component of the Chinese market but demand is expected to grow due to government policies that promote fertigation and drip irrigation. Imported potassium sulphate brands, which have higher potassium purity and solubility, compete better than domestic products in the soluble-grade space.

Current domestic potassium sulphate capacity is estimated to be approximately 3.8 Mt (4.2 Mtons) per annum, half of which is primary production capacity and half of which is secondary production capacity. Total capacity is expected to increase about 33 percent by 2020 with the 600,000 t (661387 tons) expansion of SDIC plus Mannheim additions. It is anticipated that additional primary production capacity will further displace existing secondary capacity as well as provide for the expected growth in demand.

According to the China Inorganic Salts Industry Association, potassium sulphate demand is estimated at approximately 2.5 Mt (2.7 Mtons) per annum and is estimated to increase to more than 3.5 Mt (3.8 Mtons) by 2020, an increase of 4.3 percent per annum. According to Parthenon, based on the total chloride-sensitive crop acreage under cultivation, and using suggested application rates, the full potential SOP market is 7.9 Mt (8.7 Mtons) per annum.

19.4.2.2 India

Agriculture plays a significant socio-economic role in India, employing more than half of its workforce. According to India's Central Statistical Office, the agriculture and allied sectors represent approximately 14 percent of the country's gross domestic product. India has approximately 180 million ha (445 million acres) of land under agricultural production with major commercial row crops accounting for 25 percent of the area. On average, Indian farm-holdings are small with approximately 80 percent of the farm-holdings less than 5 acres in size.

Potassium sulphate is most useful in the arid and semi-arid regions in India, particularly in the states of Maharashtra, Kranataka, and Andhra Pradesh. SOP is also useful in the black soil regions of Madhya Pradesh, Maharashtra, and Andhra Pradesh due to the clay and high-water-retention nature of the soil. In these regions, salinity can build up in the soil over the years; therefore the use of MOP can exacerbate this issue.

Like China, India has a vast amounts of chloride-sensitive crops under cultivation. These crops account for approximately 16 percent of India's cultivated land, approximately one-quarter of which is considered chloride-intolerant. As is the case with China, fertilizer use in India is heavily skewed towards nitrogen and phosphorous. At present, India imports all of its potash with potassium sulphate representing approximately 1 percent of the potassium fertilizers imported into the country. The Archean Group, through its company Archean Chemical Industries Pvt. Ltd, located in the Rann of Kutch in Gujurat, India, is attempting to build India's first greenfield production facility estimated to be 100,000 t (110,230 tons) per annum.

Historically, the Indian market for potassium sulphate has been limited due in large part to nutrient-based subsidies and other controls. For non-subsidized fertilizers, such as potassium sulphate, the manufacturers set a retail price. Due to the potassium chloride subsidy, which reduces the price paid by the farmer, a significant price disparity between potassium chloride and potassium sulphate has developed in the current market. However, a depreciating currency has forced the government to begin reducing subsidies, thereby decreasing the price differential between the two fertilizers.

According to Parthenon estimates, and based on the total chloride-sensitive crop acreage under cultivation in India and suggested fertilizer application rates, the full potential potassium sulphate market size is 5.9 Mt (6.5 Mtons) per annum.

19.4.2.3 Brazil

Brazil is one of the largest consumers and importers of potassium fertilizers in the world, although SOP represents less than one percent of its overall potassium fertilizer consumption. According to the Brazilian national fertilizer association ANDA, in 2012 Brazil consumed approximately 8.1 Mt (8.9 Mtons) of potassium chloride, of which approximately 7.5 Mt (8.3 Mtons) was imported. However, with approximately 9.7 million ha (24 million acres) of chloride-sensitive crops under cultivation, approximately 10 percent of its total cultivated land, Brazil represents a significant market opportunity for potassium sulphate consumption. For example, Brazil is the largest grower of citrus fruits in the world and exports more than 90 percent of its production.

Unlike China and India, potassium-based fertilizers are the dominant fertilizer type used in Brazil and usage has grown substantially over the last few years. In 2011, potassium-based fertilizers accounted for 39 percent of all fertilizer consumption, nearly all of which was in the form of potassium chloride. The usage of SOP and potassium magnesium sulphate has been minimal due to lack of education and awareness of the economic benefits. Further lower chloride levels in the soil due to leaching caused by heavy precipitation have constrained useage.

Potassium sulphate demand has primarily been driven by its use in tobacco farming with grape and mango farms within the Sao Francisco Valley composing the remainder of consumption. Land cultivated for tobacco has remained constant at about 445,145 ha (1.1 million acres) and is primarily located in the southern states of Rio Grande do Sul and Parana. Tobacco production is also found in the states of Sao Paulo, Pernambuco , and Bahia. Potassium sulphate usage in tobacco farming is highly regulated and directed by the Big 4 tobacco companies since they are directly involved in the production value chain. The Big 4 run approximately 60 percent of the farms and buy the majority of the tobacco crop produced by independent farmers as well. The land under cultivation for tobacco in southern Brazil remained unchanged between

2009 and 2011. However, to be compliant with the World Health Organization's Framework Convention on Tobacco Control, the cultivated area will be reduced by approximately 7 percent and will remain capped thereafter.

The price of fertilizers in Brazil closely follows international pricing. Although there is currently no government subsidy for fertilizers, to make them more affordable to farmers, the Brazilian government imposes no import duty or value-added taxes on imported fertilizers. Potassium sulphate has historically sold at a 30 percent premium to potassium chloride in Brazil.

Brazil currently has no domestic production of potassium sulphate. According to Parthenon, based on suggested application rates and the total chloride-sensitive crop acreage under cultivation in Brazil, the full potential potassium sulphate market size is 1.5 Mt (1.6 Mtons) per annum.

19.5 Pricing

There is no benchmark pricing for potassium sulphate since it is a specialty fertilizer produced in smaller volumes relative to MOP. Due of the relative scarcity of primary producers, and to Mannheim production that requires MOP as an input, SOP exhibits a historical premium of 30 to 60 percent over MOP. The SOP price forecast generated by CRU is based on the combination of the export price of potassium chloride from Vancouver/Portland and the forecasted premium for SOP over the average MOP export price. Historical SOP and MOP prices are depicted in Figure 19-6.

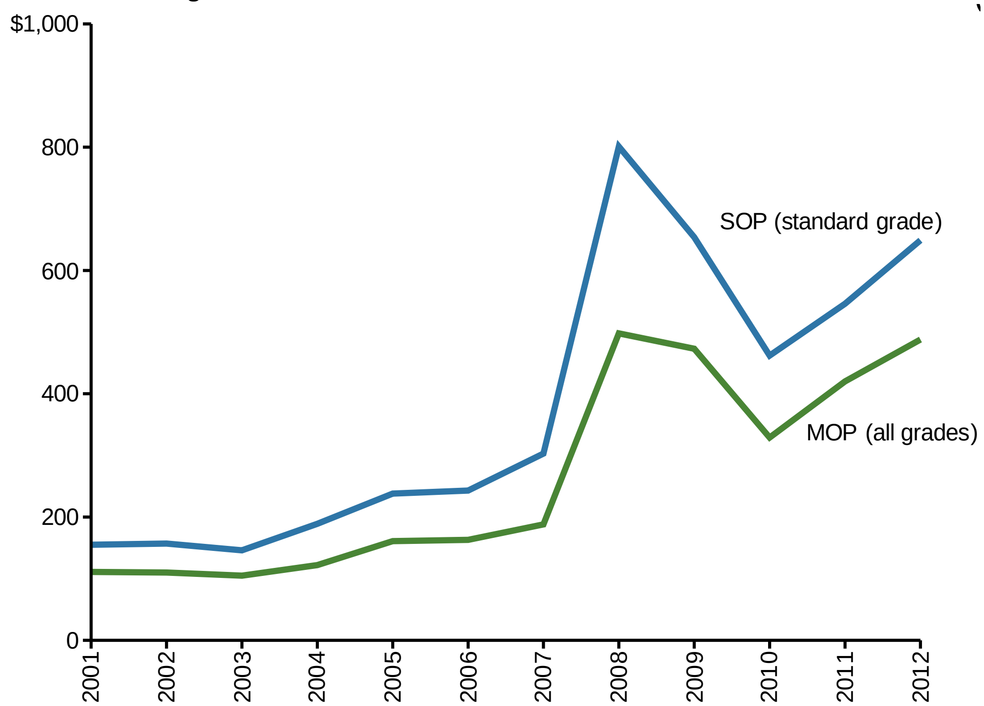
According to Parthenon's analysis, many suppliers and retailers view the U.S. market as being in equilibrium at the current SOP price, though supply-demand dynamics and/or other factors can affect price.

It is estimated that the premium for SOP over MOP is likely to follow historical pricing trends and CRU estimates a go-forward premium of 35 percent.

Three factors, in order of importance, that influence the price premium of potassium sulphate over potassium chloride are:

1. The marginal cost production (secondary production) required to satisfy global SOP demand
2. The nature of the market for high-value crops to which potassium sulphate is typically applied
3. Sulphur prices

FIGURE 19-6
Historical Potash Pricing



SOP Price Premium	40%	43%	39%	55%	48%	49%	61%	61%	38%	40%	30%	33%

Note: Prices are a product basis rather than a K_2O basis; SOP is standard grade CIF NW Europe; MOP is all grades, FOB Vancouver/Portland
Source: CRU

The SOP prices projected by CRU for the 2013 to 2020 forecast period are for standard grade product, FOB Vancouver/Portland. Based on (1) the premium for granular and soluble product over standard grade product in the marketplace; (2) the EPM's proposed mix of granular, soluble, and standard grade product; (3) the EPM's estimated mix of domestic and international sales; and (4) the estimated transportation costs between the mine gate and Vancouver/Portland (including port fees), the price forecast used in the economic model represents FOB mine gate (ex-works) pricing, and is estimated to be equal to the prices projected by CRU (Table 19-4).

TABLE 19-4
Potassium Sulphate Price Forecast, $/t

Economic Model Year (Calendar Year)	**PP-3** (2015)	**PP-2** (2016)	**PP-1** (2017)	**1** (2018)	**2** (2019)	**3** (2020)
Potassium sulphate	566	566	578	597	663	721

Source: CRU, 2012

On July 30, 2013, the potash sector was thrown into turmoil when the Chief Executive Officer of Uralkali, the world's largest potash producer, announced that it would exit its Belarusian Potash Company partnership and predicted that MOP prices would fall. The announcement adversely impacted the market capitalizations of both producers and development-stage companies around the globe and created uncertainty and speculation about the pricing of potash fertilizers. Although the announcement triggered widespread speculation, it is too early to tell what impact this development will have on the price of potash, particularly potassium sulphate, or how long these impacts may last. Pursuant to discussions with CRU, it plans to issue an update to its Potassium Sulphates and Potassium Nitrates Market Outlook Report in November 2013. It is anticipated that this report will include updates to its potassium sulphate price forecast.

As of the date hereof, EPM does not have any forward sales contracts or off-take agreements in place for the sale of its SOP.

Environmental Studies, Permitting, and Social or Community Impact

20.1 Permits

Moving the Project from the exploration phase through construction and into production will require many authorizations and permits. This section provides an overview of eight significant permits and approvals that are required or are likely to be required. The list of permits and approvals will be expanded as the Project becomes better defined.

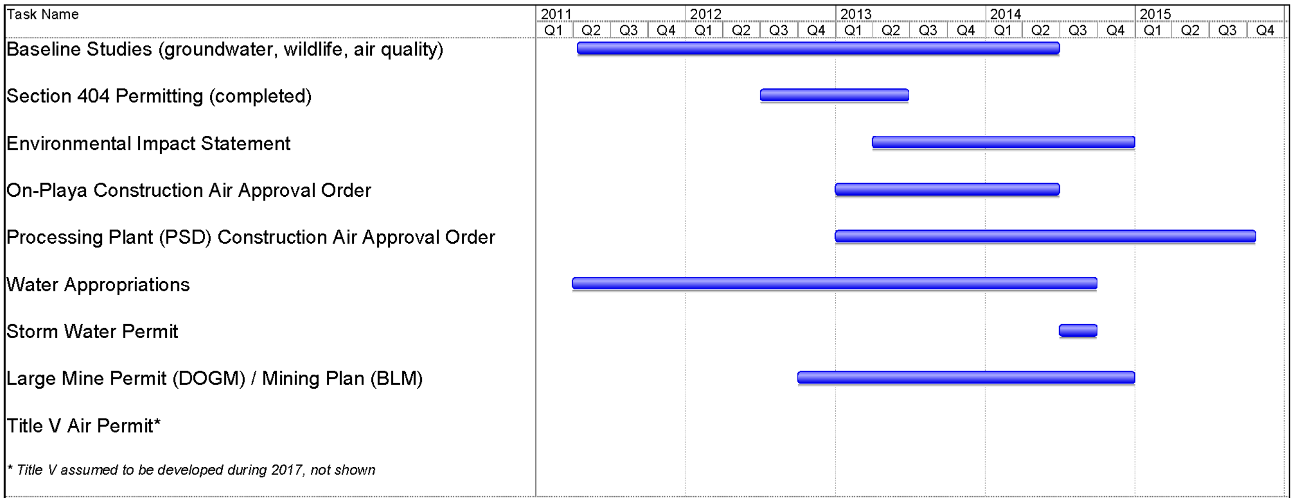
The eight significant permits and approvals required for construction are identified in Table 20-1. Of these, the Clean Water Act (CWA) compliance authorization has been completed. The BLM-led EIS process has been initiated, and once completed, a ROD will be issued to authorize construction on BLM-administered lands. Preparation for the construction Air Approval Orders has begun and meetings with the State of Utah for the water appropriations for the project have occurred and will continue. Stormwater and large mine permitting preparation has been initiated and are expected to be completed in late 2014. The Title V air permit will be initiated within 1 year after operation of the project starts in 2017.

TABLE 20-1
Permits and Approvals

Permit	Agency
CWA compliance	USACE
BLM ROD	BLM, Fillmore Field Office
On-Playa elements – Construction Air Approval Order	UDAQ
PSD (processing plant) – Construction Air Approval Order	UDAQ
Water appropriations	Utah State Engineer
Stormwater Permit	Utah Division of Water Quality (UDWQ)
Large Mine Permit	DOGM
Title V Air Permit	UDAQ

Application development, submittal, review, and approval for most permits will require from 3 to 22 months. Discussions have already been initiated with BLM, UDAQ, DOGM, SITLA, and other regulatory agencies on all significant permits. To meet the proposed schedule, additional communications with the regulatory agencies will be required. The permitting and approval processes are underway and are expected to be completed in late 2014, excluding the PSD Approval Order and Title V permit. Some studies are required to support authorization by all of the agencies. These are referred to as the baseline studies.

FIGURE 20-1
Preliminary Permitting Schedule



At this time, the scheduled start for evaporation pond construction is by the first quarter 2015 after BLM has issued a ROD for the EIS and EPM has received the On-playa Air Approval Order from UDAQ.

20.1.1 Environmental Impact Statement

Proposed mining projects on federal lands are evaluated for a range of potential social, economic, cultural, and environmental impacts under NEPA. NEPA requires that an EA or an EIS be prepared in compliance with the Council on Environmental Quality regulations. For projects expected to have significant impacts, or which are of significant size or have notable public interest, an EIS is required for the assessment of impacts. BLM has determined that an EIS will be required for the proposed project.

Development of the EIS has been initiated and a third-party contractor has been selected to support BLM's preparation of the project EIS. CH2M HILL will provide technical reports including field studies and data collection of the resources under consideration by BLM and will provide ongoing support as questions arise during the analysis of the project.

The EIS will assess the environmental impacts of implementing the proposed action (construction and operation of mine facilities as described in the Mining Plan), a No-Action Alternative (required under NEPA to assess what would happen if the project were not constructed), and a range of reasonable alternatives. BLM will use the EIS to make an informed decision on whether and how to approve the proposed project through a ROD.

The NEPA process generally includes the following components (not necessarily in chronological order): baseline data collection, development of a proposed action, scoping, development of alternatives, description of the affected environment, impact evaluation, identification of mitigation measures, preparation of a Draft Environmental Impact Statement (DEIS) and a Final Environmental Impact Statement (FEIS), as well as public participation and review.

Baseline Studies

Typically, baseline studies of at least 1 year are required for NEPA processes. However, data collection for some resources is seasonally dependent so survey protocols are designed to focus on critical periods. To expedite the EIS schedule, and in close consultation with BLM, baseline data collection for wildlife commenced in the spring of 2011. Class I and Class III cultural surveys have been conducted on and around the Sevier Playa from 2011 to 2013. Class I and Class III cultural surveys for all proposed facilities were initiated in July 2013.

The collection of groundwater levels in the bedrock and alluvial aquifers in the basin, and associated water quality data, commenced in summer of 2011. Surface water monitoring of the Sevier River was initiated during the spring of 2012.

Per discussion with UDAQ, baseline air quality and meteorological data will be required for permitting. A meteorological station was installed on site near the proposed processing plant location and became operational in January 2012 with the collection of baseline air quality data commencing in July 2013. See the Construction Air Approval Order section of this document for more details.

EPM has been conducting ongoing biological surveys in the project vicinity since the spring of 2011. Baseline data collection includes the following:

- Vegetation field survey—one survey, within a year of EIS preparation
- Wildlife field survey:
  - Migratory birds, 2011 through 2013
  - Raptor nests, Summer 2013
  - Bats, Summer-Fall 2013 and Spring 2014
  - Kit fox:
    - Incidental, 2011 through 2013
    - Intensive, Summer–Fall 2013, Spring 2014
  - General wildlife, 2011 through 2013

The extreme physical and chemical characteristics of the Sevier Playa area are, in general, not conducive to the establishment and growth of vegetation. Area surveys conducted in 2011 identified the following five vegetation zones (in order of greater elevation and distance from Sevier Playa): salt flats, salt desert scrub, sagebrush-grassland, desert woodland, and montane forest. Only salt flats and salt desert scrub occur in the immediate vicinity of the project site. Sagebrush-grasslands could also be traversed by project access roads.

Wildlife habitat for large mammals is poor on the Sevier Playa. However, the Utah Division of Wildlife Resources heritage database identifies substantial to critical habitat value for pronghorn around the perimeter of the playa and in the surrounding area.

The Sevier Playa is located within the Great Basin Bird Conservation Region 9, which lists 28 species of birds, some of which are listed as BLM-sensitive species. However, no direct impacts to migratory birds on the playa are anticipated because suitable habitat is lacking and surveys indicate the playa experiences low use by birds. Direct impacts to migratory birds or raptors could occur as a result of offsite vehicle collisions.

EIS Sections

The Project's purpose and need provides the justification for a proposed action on federal lands and will be developed from the Mining Plan. The Mining Plan is substantially complete as of October 2013 and is expected to be deemed complete by BLM by the second quarter of 2014. BLM and DOGM have agreed that the Mining Plan will be a joint document that will meet the requirements of both agencies.

Scoping meetings will be held to obtain public input on the NEPA process. At these meetings, the Proposed Action is presented and the public is invited to comment on the scope of the Proposed Action. The results of these public scoping meetings will be described in the EIS and a scoping document will become an appendix to the EIS.

The Proposed Action will be developed from the Mining Plan. BLM also will evaluate a No-Action Alternative, and will develop reasonable alternatives to the proposed action that meet the project needs while avoiding or minimizing impacts to resources. These additional alternatives could include mitigation actions or changes to the project footprint. The alternatives will become the basis for the impact evaluation.

The affected environment section of the EIS describes the existing environment, including physical, natural, and human-made resources, and is intended to provide adequate detail to assess potential project impacts. Resources that are described in the affected environment section of the EIS include those that could be adversely or positively impacted, either directly or indirectly, by the proposed action or alternatives. Both existing data and those data collected specifically for the project (e.g., baseline surveys) will be used to characterize existing environmental conditions. Existing data include published literature, existing surveys, modeling, data analyses, and agency databases.

The environmental consequences section describes the impacts of the proposed action and alternatives on the resources described in the affected environment section. This section provides the basis on which BLM will make its decision with respect to the project's effects on the natural and social environment.

The impact analysis will include a description of the types and magnitudes of impacts. For example, an impact could be long- or short-term, adverse or beneficial. Applicant-committed measures and mitigation measures are part of the analysis and additional commitments may be proposed as part of the impact analysis.

Cumulative impacts are determined by evaluating the effect of the impacts of the proposed project in light of any other "past, existing, or reasonably foreseeable" activities in the area. For example, a proposed project may have a minimal impact on air quality but when considered with the air emissions from other existing or proposed projects, the sum of project air emissions may adversely affect air quality.

DEIS, Public Comment, and FEIS

The DEIS will be prepared and released for public review following an announcement of its availability. Subsequent public meetings will be held following release of the DEIS to facilitate public response. These meetings are typically presentations of the project and identified impacts with opportunities for verbal or written public responses. The public comments and BLM responses are summarized in the FEIS and included as an appendix. BLM takes into account the public comments received and develops an FEIS that may include additional information or clarifications.

Record of Decision

BLM will prepare the ROD, which is the final statement of approval or denial of the NEPA process. It will contain the stipulations to which the project must adhere if it is to go forward, usually by referral to the EIS. Typically, the other permitting agencies will set standards equal to or exceeding those in the ROD. Following issuance of the ROD and a subsequent appeal period, and if all other state and local construction permits have been obtained, construction can begin at the site.

It is important to realize that NEPA is a public environmental review process. The EIS is not a permit document or a design report. This is a significant difference from the permitting processes in that the DEIS and FEIS are intended to document the impacts and the review process, not to provide a starting point for negotiations or present ultimate designs. As part of the NEPA process, BLM will define a "preferred alternative" that can be the proposed action or a combination of alternatives.

Potential Impacts

The following potential socioeconomic, cultural, and environmental impacts could result from the Sevier Playa Project:

- Surface and groundwater impacts related to incidental oil and gas release from equipment associated with a mining operation
- Surface and groundwater impacts from seepage of process solutions from processing operations
- Air quality impacts due to dust from ground-disturbing activities
- Air quality impacts due to emissions from the operation of the processing plant and transportation equipment
- Visual impact on recreational users in the House and Cricket Ranges for playa surface disturbance
- Impacts on livestock grazing from project development and operation activities
- Impacts on wildlife habitat and species from project development and operation activities
- Impacts on state-listed sensitive animal species due to ground-disturbing activities
- Archaeological and cultural impacts due to ground-disturbing activities

It is anticipated that the majority of these impacts either would be minor or would be eliminated through relatively easy and/or required mitigation measures. Although potential impacts to groundwater, defined as groundwater that has less than 10,000 mg/L (1.34 oz/gal) TDS, are considered to be minor, additional monitoring is required for this particular item as discussed as follows.

Per the Decision Record of the Leasing EA, baseline groundwater data have been collected to document the alluvial and bedrock aquifers that potentially could be affected by brine extraction from the playa aquifer. Potential impacts to existing water rights holders were evaluated and this is discussed in more detail in the Water Appropriations section. A groundwater monitoring plan is required to monitor impacts to groundwater resources that may occur due to extraction of brine from the playa aquifer.

20.1.2 Construction Air Approval Orders

The State of Utah has been granted the authority to implement and enforce the permitting requirements specified by the federal Clean Air Act. The general requirements for permits and permit revisions are codified under the state environmental protection regulations, Utah Administrative Code (UAC) R307-401.

UDAQ has the review and approval authority for the construction of new sources or modifications to existing sources of air pollution. Facilities proposing to construct a new source or modify an existing source must submit an NOI application to UDAQ.

EPM will be required by UAC R307-401-5 to submit a NOI application to the UDAQ and to obtain an Approval Order issued by UDAQ prior to commencing construction of this project. UAC R307-401-5 requires the NOI to include the following:

- A description of the project
- Description and characteristics of emissions
- An analysis of the Best Available Control Technology or the proposed source or modification
- Location map
- Emissions impact analysis
- Preconstruction monitoring data

Work is progressing on obtaining a minor source Approval Order for the construction of on-playa elements, including extraction trenches, recharge trenches, preconcentration ponds , and production ponds with an Approval Order expected by April 2014. It is presumed that a PSD Approval Order for the construction of the processing plant would be submitted to UDAQ after 12 months of preconstruction air quality monitoring has been collected at the project site and that the Approval Order will be granted prior to construction of the processing plant. Preconstruction air quality monitoring commenced in July 2013 and monitoring of air quality at the project site will continue until at least July 2014.

20.1.3 Title V Air Permit

The federal operating permits program (Title V) is implemented by regulations codified at 40 CFR Parts 70 and 71. Title V of the Clean Air Act does not impose new substantive requirements. Title V does require that sources subject to UAC R307-415 pay a fee and obtain a renewable operating permit that clarifies in a single document which requirements apply to a source and that ensures the source’s compliance with those requirements. The State of Utah has been granted authority to implement and enforce the federal Title V program through state regulations outlined under UAC R307 415. The Project is a major source emitter and is therefore subject to the requirements of UAC R307-415. EPM will apply for a Title V permit within 12 months of commencing operation of the plant.

20.1.4 Section 404 Permitting

Section 404 of the CWA falls under the oversight of USACE that is charged with regulating activities for dredging or filling into any waters of the U.S. In deciding whether it has jurisdiction over a proposed activity, USACE must determine whether waters of the United States occur in the project area. To make this assessment, the applicant must provide USACE with information about water bodies in the project area that meet the definition of Waters of the United States. EPM submitted a report to USACE that documented the absence of any jurisdictional criteria that would lead to regulation of the Sevier Playa under the CWA (Section 404).

USACE responded in a letter dated June 28, 2013 stating that it had determined that the Sevier Playa is not a regulated feature under Section 404 of the CWA and is exempt from USACE permitting requirements under the CWA. USACE determined that the playa is an “intrastate isolated feature with no apparent interstate or foreign commerce connection” in support of its decision. With this determination, EPM would be able to conduct the work of developing trenches and evaporation ponds on the playa without the need for USACE permitting and associated mitigation that otherwise would have been required were the playa to have been determined to be jurisdictional under the CWA.

20.1.5 Stormwater Permits

The National Pollutant Discharge Elimination System (NPDES) Stormwater Program regulates stormwater discharges from construction and industrial activities. Most stormwater discharges are considered point sources, and operators of these sources may be required to receive an NPDES permit before they can discharge. These permits are designed to prevent stormwater runoff from washing harmful pollutants into local surface waters. “Pollutants” are defined as any material added to water that changes the physical, chemical, and/or biological nature of the receiving water; as well as intermittent streams and arroyos associated with tributary systems.

The State of Utah has been authorized to implement the NPDES Stormwater Program, which administered by UDWQ. Therefore, the stormwater permits are referred to as Utah Pollutant Discharge Elimination System (UPDES) permits.

Two UPDES permits likely would be required for the project; a General Construction Permit and a General Multi-Sector Industrial Stormwater Permit. The General Construction Permit is required for projects that disturb more than 0.405 ha (1 acre) of land. As part of the General Construction Permit, a Stormwater Pollution Prevention Plan (SWPPP) must be developed. The SWPPP includes best management practices and controls to minimize impacts to surface waters, primarily due to sedimentation from the disturbed surface area. The General Multi-Sector Industrial Stormwater Permit also requires a SWPPP that addresses minimization of impacts to surface waters from operations. This permit must be approved before operations commence. It is assumed that the mine is covered under Sector J (Mineral Mining and Processing Facilities) of the general permit.

20.1.6 Large Mine Permit

An NOI to Commence Large Mining Operations (the Large Mine Permit) is required to be submitted and approved by DOGM prior to the start of operations. Additionally, the BLM Mining Plan must be approved prior to the start of operations. BLM and DOGM have agreed that the Mining Plan will be a joint document that will meet the requirements of both agencies (the combined BLM/DOGM Mining Plan).

20.1.7 Water Appropriations

The Utah Division of Water Rights Office of the State Engineer is responsible for issuing water rights to appropriate waters of the State of Utah for beneficial uses. EPM has filed water rights applications for extracting up to 33.3 million m^3/yr (27,000 ac-ft/yr) of brine to produce potash on the SITLA and BLM leases it controls. Further, EPM has filed two applications to use 1.8 million m^3/yr (1,500 ac-ft/yr) of groundwater from underground wells for plant operations. EPM has also filed water rights applications to use 2.5 million m^3/yr (2,000 ac-ft/yr) of surface water if and when it reaches Sevier Playa via the Sevier River. All of the applications are for a fixed time. EPM may alter its application filings based on the findings of this PFS.

20.2 Mine Closure and Reclamation

Mine closure and reclamation is described in the Reclamation Plan of the combined BLM/DOGM Mining Plan. Reclamation of the playa would consist of grading the pond areas to remove the embankments, backfilling extraction and recharge trenches, and abandoning extraction wells. The processing plant would be demolished and the utilities properly capped or removed.

It is anticipated that because the playa is not currently suitable for supporting native or non-native vegetation due to the chemical composition of the playa substrates, and that it will remain so after mining operations cease, final re-vegetation efforts likely would be limited to offsite facilities. The combined BLM/DOGM Mining Plan will contain a detailed Reclamation Plan that will be used as the basis for a third-party reclamation cost estimate.

20.2.1 Community Relations

Community relations are important during all phases of the Project. EPM has met several times with state, county, and local government leaders to discuss the Project. Generally, it is viewed favorably and has received broad support from these government agencies. For example, during the public comment period for the Leasing EA, the surrounding communities did not object to the proposed work and continue to offer support and remain in an active dialogue with EPM.

Several public information meetings have been held in the two closest cities, Delta and Milford in Utah. These meetings have been well attended and feedback from residents has been positive with a high degree of interest in the jobs the Project would create. If the Project proceeds forward to construction and operation it would be one of the largest employers in the area and would provide jobs to the surrounding communities.

The Project site is located over 40 km (25 miles) from any community and there is little current use of the Project area, with the exception of occasional nearby recreational uses and seasonal grazing on the upland areas around the lakebed.

Early in the Project's leasing and exploration process, the Southern Utah Wilderness Alliance filed two Notices of Appeal (Appeals) and two Petitions for Immediate Stay (Petitions) against the Project with the U.S. Department of the Interior, Office of Hearings and Appeals, Interior Board of Land Appeals (IBLA). These actions were regarding findings made by BLM to lease lands and allow exploration activities on the Sevier Playa. The IBLA ruled against the Appeals and Petitions, thereby upholding BLM's decisions to lease the Sevier Playa and to allow exploration activities to begin. There are no outstanding environmental appeals or petitions as of the effective date of this Technical Report.

Capital and Operating Costs

21.1 Capital Cost Estimate

21.1.1 Introduction

The capital cost estimate includes costs associated with the development of the lake extraction infrastructure, processing plant, administrative and maintenance infrastructure, the natural gas and water pipelines, the 69-kv electrical transmission line, and the rail load-out facility. The QPs for this section have reviewed this data and determined it is adequate for the purposes of this Technical Report.

21.1.2 Basis of Estimate

The main components of the Basis of Estimate are listed in Table 21-1. The estimate has an accuracy of +25/-20 percent. All costs presented in Q3 2013 U.S. dollars.

TABLE 21-1
Basis of Estimate

Item	Basis of Estimate
Process Definitions	
Process selection	Provided by CH2M HILL using Swenson Hybrid Process
Design criteria	Provided by CH2M HILL
Flowsheets/plant capacity	Provided by CH2M HILL
Mass balance	Provided by CH2M HILL
Mill equipment list	Provided by CH2M HILL
Infrastructure definition	Provided by CH2M HILL
Capital cost estimating methodology	Provided by CH2M HILL
Direct costs	
Main site and rail car site grading	Scope based on plot plans; site plan Includes clear and grubbing, area grading, fencing, and gravel roads Rail site includes provision for 5,639 m (18,500 ft) of rail spur and siding trackage with one road Crossing All foundations estimated based on building specifications and preliminary drawings
Potable Water	System based on two small bore wells 4.5 km (2.8 mi) south of main site
Natural Gas	Based on 20.3-cm (8-in) high-density polyethylene pipeline 56 km (35 mi) long and installation of metering facility

TABLE 21-1
Basis of Estimate

Item	Basis of Estimate
Playa Construction	Earthworks cost based on vendor quote Recharge Diversion Structure Design Recharge canal along northeast shoreline – approximately 24.7 km (15.3 miles) Recharge canal along northwest shoreline – approximately 17.4 km (10.8 miles) Recharge pump station and pipeline from east to west approximately 15.5 km (9.7 miles) based on pump vendor quote Recharge trenches for Phase 1 – approximately 135 km (84 miles) Perimeter access road approximately 128 km (80 miles) Brine Extraction Canal – approximately 17 km (10.6 miles) Brine extraction trench laterals for Phase 1 – approximately 130 km (81 miles) Solar evaporation pond system (includes preconcentration ponds 1 through 4 and production ponds A through D) Brine lift pump station (barge) from extraction canal to preconcentration ponds based on pump vendor quote Brine lift pumping station (barge) from preconcentration pond 4 to production pond pipeline based on pump vendor quote Cost for 20.1-km (12.5-mi) aboveground pipeline
Buildings/structural steel	Building envelopes defined from plot plan and 3D model Interior platforms, pipe racks, and stairs are included
Mechanical equipment	Equipment definition and sizing defined by the project equipment list Equipment pricing is based on budgetary or historical quotes 93% budget quotes
Piping	Specification sources include the equipment list and PFDs Piping scope and schedule has been based on equipment layout and piping and instrumentation diagrams (P&IDs) Utility piping has been estimated based on equipment and P&IDs
Electrical	Electrical equipment and sizes based on equipment specification Cathodic protection is not required on gas pipeline using high-performance polyethylene pipe Includes 84-km (52-mi) overhead transmission line to feed the main process site and two lake substations Includes 21.7-km (13.5-mi) overhead 15-kV distribution line from main process site to load-out site
Instrumentation and Controls	Instrument and control valve types and quantities have been estimated based on equipment Communication between sites is a 12-strand fiber optic cable installed along the 15-kV distribution line
Corrosion and protective coatings	All carbon steel would be primed and painted, stainless steel would be bare Piping insulation is included where the design temperature is above 65°C (150°F) Fireproofing is excluded
Spares and initial fills	Capital spares included at 4% of rotating equipment costs Startup spares included at 1% of equipment costs Operating spares and initial fills are excluded from the CapEx. Operating spares are included in the operating cost.

TABLE 21-1
Basis of Estimate

Item	Basis of Estimate
Process Definitions	
Process selection	Provided by CH2M HILL using Swenson Hybrid Process
Design criteria	Provided by CH2M HILL
Flowsheets/plant capacity	Provided by CH2M HILL
Mass balance	Provided by CH2M HILL
Mill equipment list	Provided by CH2M HILL
Infrastructure definition	Provided by CH2M HILL
Capital cost estimating methodology	Provided by CH2M HILL
Direct Costs	
Main site and rail car site grading	Scope based on plot plans; site plan Includes clear and grubbing, area grading, fencing, and gravel roads Rail site includes provision for 5,639 m (18,500 ft) of rail spur and siding trackage with one road Crossing All foundations estimated based on building specifications and preliminary drawings
Contingency	A 20% contingency has been included for all lake work and a 9.5% contingency has been included on all remaining work.
Escalation	Escalation has been excluded
Owner's costs	Supplied by EPM and include all remaining feasibility study, permitting, project personnel, and other capitalized operating costs required during the preproduction years (PP-3 to PP-1).

21.1.3 Direct Capital

The direct costs for the project are divided into categories based on physical areas of the project. The estimated costs for the direct costs are detailed in Table 21-2.

TABLE 21-2
Direct Capital Costs*

Area	Total
Utility/common infrastructure	$44,910,519
Playa infrastructure	$48,811,358
Stock pile	$6,334,608
Process building/truck load-out	$155,829,898
Truck shop	$2,534,524
Administration building	$2,214,671
Rail load-out site	$31,148,515
Total direct capital	**$291,784,093**

***The direct costs (excluding playa infrastructure) include allocated expenses for contractor general conditions ($20,206,320) and construction

TABLE 21-2

Direct Capital Costs*

Area	Total

management ($7,013,687). The playa infrastructure costs include contractor overhead, profit, insurance, and taxes due to the nature of the fixed price budgetary estimate that was received for this work.

21.1.4 Indirect Capital

The indirect costs were estimated from the total project costs with the exception of the owner's costs that were supplied by EPM, and the contingency that was evaluated from a Monte Carlo risk analysis. The indirect costs are summarized in Table 21-3.

TABLE 21-3

Indirect Capital Cost

Indirects	Total
Contractor OH&P/bonds and insurance/taxes	$16,069,202
Tax on Owner-purchased equipment	$2,783,489
Engineering	$13,900,000
Owner's costs	$17,543,235
Subtotal	**$50,295,926**
Contingency	$36,319,281
Total indirect capital	**$ 86,615,207**

21.1.5 Total Capital

Table 21-4 summarizes the estimated $378 million of capital cost.

TABLE 21-4

Total Capital Cost Summary

	Total
Utility/common infrastructure	$44,910,519
Playa infrastructure	$48,811,358
Stock pile	$6,334,608
Process building/truck load-out	$155,829,898
Truck shop	$2,534,524
Administration building	$2,214,671
Rail load-out site	$31,148,515
Indirect costs	$86,615,207
	$378,399,300

21.1.6 Sustaining Capital

The estimated $199 million in life of mine (LoM) sustaining capital includes (1) the Phase 2 extraction and recharge canals and trenches and associated direct and indirect costs, (2) the Phase 3 well extraction system and associated direct and indirect costs, (3) playa estimates for dike raising and extraction/recharge trench clean-out, (4) estimates for plant equipment replacement and enhancements, and (5) project decommissioning and reclamation.

Table 21-5 summarizes the approximate $199 million of sustaining cost.

TABLE 21-5
Sustaining Capital Cost Summary

	LoM Total
Phase 2 Playa improvements	$21,174,720
Phase 3 well extraction system	$69,110,980
Playa sustaining capital	$27,868,000
Plant sustaining capital	$42,954,660
Decommissioning and reclamation capital	$38,146,460
	$199,254,820

21.2 Operating Cost Estimate

21.2.1 Introduction

Operating costs were determined based on the production schedule, process equipment requirements, operating hours, hourly equipment operating costs, and project workforce requirements. For the purpose of the economic analysis the operating costs were separated into the following categories: labour; power; natural gas; reagents, consumables and maintenance; salt harvest and haul to rail; and G&A. The QPs for this section have reviewed this data and determined it is adequate for the purposes of this Technical Report.

21.2.2 Basis of Estimate

The operating costs were determined from a variety of sources that include budgetary estimates from vendors, CH2M HILL historical information, and regional labour rates supplied by EPM.

The operating costs summarized in Table 21-6 were determined based on the following parameters:

- Production schedule: Plant throughput of 2.5 Mt (2.7 Mton) per year with 300,000 tpy (330,693 tons/yr) SOP, 365 days per year at 90 percent utilization
- Equipment requirements: based on equipment specifications
- Operating hours: two 12-hour shifts per day

- Hourly equipment operating costs: based on equipment specifications
- Project workforce requirements

Costs for salt harvesting and haulage to plant, as well as SOP haulage to rail, are based on contractor quotes. Maintenance materials for the processing plant are estimated as 4 percent of rotating equipment capital cost. Miscellaneous operating supplies are estimated at US$0.05 per tonne salt harvested. Power, natural gas, and labour costs were tracked separately. G&A costs primarily include insurance and property taxes.

The total operating cost of US$180.91 per tonne of SOP in the PFS is a 16.7 percent increase from the PEA. Although there were savings in other sections, this increase can be attributed mainly to a 90 percent increase (180 to 339 MBtu/hr) in the natural gas consumption due to changing the process from the use of MVR technology to the leonite-to-SOP process. The natural gas price also increased from US$3.00 to US$4.13 per MBtu. The combination of the higher consumption and higher gas price resulted in an increase of US$23.38 per tonne of SOP from the PEA. The operating cost also increased due to higher salt harvest cost because of an increase in plant feed, as well as an increase in playa maintenance cost. The operating cost increases were partially offset by a decrease in power-related costs.

TABLE 21-6
Summary of Operating Costs

	Operating Costs $/t SOP	Percent
Labour	$34.76	19.2%
Power	$13.97	7.7%
Natural gas	$37.57	20.8%
Reagents, consumables, and maintenance	$40.34	22.3%
Salt harvest and haul to rail	$37.57	20.8%
G&A	$16.70	9.2%
Total	**$180.91**	**100%**

21.2.3 Project Work Force

The estimated maintenance and operating staff are detailed in Table 21-7. Personnel requirements and wage rates were provided by EPM. The authors reviewed these data and determined them to be adequate for the purpose of this Technical Report.

The processing plant is estimated to operate 24 hours per day with two 12-hour shifts. Hourly worker costs have a 10 percent overtime allowance based on base rate. Burden for salaried employees is estimated at

35 percent of base pay. Burden for hourly employees is 35 percent of the sum of hourly rate plus overtime allowance.

Details of the workforce are listed in Table 21-7.

TABLE 21-7
Average Yearly Workforce Costs

Workforce Summary	Total Employees	Annual Total Cost
Ponds and earthwork		
Hourly personnel	12	$667,181
Salary personnel	0	$ 0
Total – Ponds and earthwork	**12**	**$667,181**
Plant and processing		
Hourly personnel	36	$2,149,804
Salary personnel	0	$ 0
Total – Plant and processing	**36**	**$2,149,804**
Storage, load-out, and transportation		
Hourly personnel	8	$543,629
Salary personnel	0	$ 0
Total – Storage, load-out, and transportation	**8**	**$543,629**
Infrastructure		
Hourly personnel	75	$4,682,470
Salary personnel	0	$ 0
Total – Infrastructure	**75**	**$4,682,470**
G&A		
Hourly personnel	4	$333,590
Salary personnel	23	$2,050,650
Total – G&A	**27**	**$2,384,240**
Project Total	**158**	**$10,427,324**

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Economic Analysis

22.1 Basis of Analysis

The economic analysis was conducted using a discounted cash flow model (Economic Model). The capital and operating costs presented in Section 21 of this Technical Report, and used in this economic analysis, were based on the brine recovery methods and process flowsheet described in Sections 16 and 17 of this Technical Report. The Economic Model was based on the LoM extraction of 9 Mt (9.9 Mton) of potassium sulphate, which is equal to an estimated 30 years based on average annual production of 300,000 tpy (330,693 tons/yr). Due to production ramp-up values that are less than 300,000 tpy (330,693 tons/yr) in Years 1 and 2 of the Economic Model, the mine life in the Economic Model is extended by 2 years to account for all 9 Mt (9.9 Mton) of potassium sulphate production.

The IRR, NPV, and payback period, summarized in Table 22-2, were calculated based on 100 percent equity financing, although it is anticipated that EPM would pursue debt financing alternatives for the Project. Sensitivity analysis was also performed to assess the impact of variances in the Project's capital and operating costs, revenues, inflation, and discount rate to demonstrate the effects of these variances on the Project economics.

TABLE 22-1
Potassium Sulphate Price Forecast, $/t, Ex-works

Economic Model Year (Calendar Year)	**PP-3** (2015)	**PP-2** (2016)	**PP-1** (2017)	**1** (2018)	**2** (2019)	**3** (2020)
Potassium sulphate	566	566	578	597	663	721

Source: CRU, 2012

For the determination of the mine life, only measured and indicated resources were used. No inferred resources were accounted for in the economic analysis. Minerals resources that are not mineral reserves do not have demonstrated economic viability.

22.2 Economic Model Parameters

The parameters and assumptions used in the Economic Model were as follows:

- The economic analysis begins in preproduction Year 3 (PP-3), with the initiation of construction activities on playa infrastructure.
- Two-year production ramp-up, with full production achieved in Year 3.

- Discount rate – 8 percent.
- Revenue is based on potassium sulphate prices projected by CRU for the 2013 through 2020 forecast period (Table 22-1). The CRU price forecast is for standard grade product, FOB Vancouver/Portland. Based on (1) the estimated premium for granular and soluble product over standard grade product in the marketplace; (2) EPM's proposed mix of granular, soluble, and standard grade product; (3) EPM's estimated mix of domestic and international sales; and (4) the estimated transportation costs between EPM's rail load-out facility and Vancouver/Portland (including port fees); the price forecast used in the economic model represents an FOB rail load-out facility (ex-works) price, and is estimated to be equal to the prices projected by CRU. Beyond the CRU 2020 forecast period, revenue was inflated at 2 percent per annum for the remainder of the mine life.
- Initial capital costs estimated at US$378 million.
- Sustaining capital costs estimated at US$199 million LoM, including additional playa improvements, sustaining capital, and decommissioning and reclamation.
- Cash operating costs estimated at US$180.91 per tonne.
- All capital and operating expenses were inflated at 2 percent per annum beginning in PP-3.
- Annual production royalties estimated at 5.61 percent of gross revenue.
- Estimated effective tax rate of approximately 29 percent, based on assumptions described in Section 22.3.
- All Project-related expenses incurred prior to the effective date of this Report are considered as sunk costs and are not included in this economic analysis. Expenses projected after the effective date of this Report, but before the start of construction, are included in PP-3; however, it is expected that certain expenses would be incurred prior to this year.

Additional details of the variables used in the discounted cash flow model, including the annual cash flow and production schedule, can be found in Appendix B.

22.3 Taxation

The Project is subject to income taxation at the following two levels: (1) federal income tax and (2) state income tax, based on federal taxable income. Federal taxable income is calculated based on gross revenues less operating expenses, royalties, and depreciation. Other taxable income deductions and credits included in the economic analysis and allowed under the federal tax code include (1) the percentage depletion deduction (14 percent of gross revenues less royalties) and (2) the domestic production activity deduction (the lesser of 9 percent of qualified production activities income, 9 percent of taxable income, or 50 percent of allocable W-2 wages). The economic analysis also forecasts the benefit of a state economic development tax credit incentive estimated at approximately $17 million over 15 years.

Due to the fact that state income taxes are deductible for federal income tax purposes, a combined federal and state income tax rate of 38.3 percent was used in calculating the income tax expense. The projected effective tax rate for the Project is approximately 29 percent.

The Project is also assessed an annual property tax, which tax has been included in the general and administrative cash operating costs.

22.4 Summary

An economic analysis was conducted to determine the value of the Project using the NPV and IRR financial metrics. NPV is the summation of the present value of all future cash inflows and outflows of the Project. A positive NPV indicates that the Project provides a financial return in excess of the capital requirements. IRR is the annual rate of return that makes the NPV of all cash flows equal to zero. In other words, it is the discount rate at which the present value of all cash flows equal's zero. The payback period, which is based on the undiscounted free cash flow, is the number of years required to repay the initial capital outflows.

The results of the economic analysis were positive, and NPV, IRR, and payback period are summarized in Table 22-2. The NPV at an 8 percent discount rate was US$957 million on a pretax basis and US$629 million on an after-tax basis, with a pretax IRR of 24 percent and an after-tax IRR of 20 percent. Based on the free cash flow generated by the Project, the payback period is estimated to be approximately 5.5 years from first production of saleable product.

TABLE 22-2
Economic Analysis Results

Financial Metric	Pretax Values	After-Tax Values
NPV at 8%	$957 million	$629 million
IRR	24%	20%
Payback period, years (after commencement of operations)		5.5 years

Over the Project's LoM, the Economic Model is based on the extraction and sale of 9 Mt (9.9 Mton) of SOP (refer to Appendix B), and projects US$8,679 million in gross revenues with US$2,480 million in operating expenses and US$487 million in royalties thereby resulting in a gross margin (revenue less cash operating costs) of US$6,199 million (71 percent) and an operating margin of US$5,712 million (66 percent). The

Economic Model also projects US$5,005 million of pretax free cash flow and US$3,578 million of after-tax free cash flow.

22.5 Sensitivity Analysis

A sensitivity analysis was completed for the Project economics to determine which variable(s) had the greatest impact on the Project economics. The results, presented in Table 22-3, and well as in Figures 22-1 through 22-4, illustrate the relative sensitivities of the various parameters to the Project NPV and IRR, on a pretax and after-tax basis. The analysis demonstrated that of the variables analyzed, the IRR and NPV are most sensitive to variances in SOP price. For each 5 percent increase (decrease) in the SOP price, the after-tax NPV increased (decreased) approximately US$66 million, and the after-tax IRR increased (decreased) approximately 1 percent. With respect to capital and operating expenditures, for each 5 percent increase (decrease), the after-tax NPV increased (decreased) approximately US$16 million and US$17 million, respectively, and the after-tax IRR increased (decreased) less than 1 percent and 0.5 percent, respectively. The sensitivity analysis also demonstrates that pretax and after-tax NPV are also very sensitive to discount rate.

The sensitivity analysis also demonstrates that pretax and after-tax NPV are also very sensitive to the discount rate as is illustrated in Table 22-3.

TABLE 22-3
Discount Rate Sensitivity

Discount Rate	Pretax NPV	After-Tax NPV
6%	$1,407 million	$956 million
7%	$1,158 million	$775 million
8%	$957 million	$629 million
9%	$792 million	$510 million
10%	$657 million	$412 million

FIGURE 22-1
Pretax NPV Sensitivity

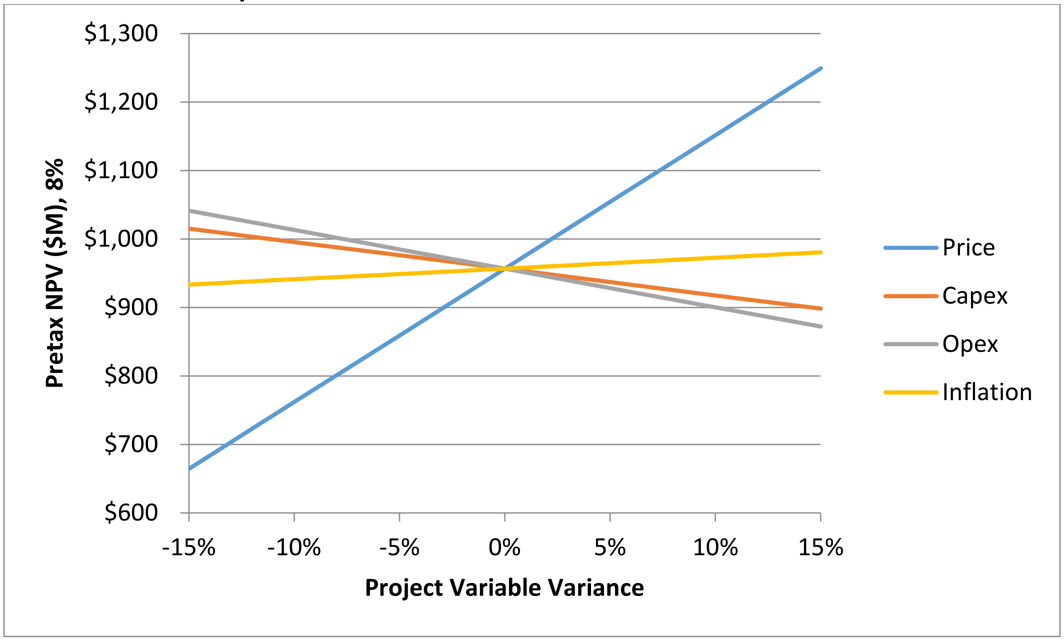


FIGURE 22-2
After-Tax NPV Sensitivity

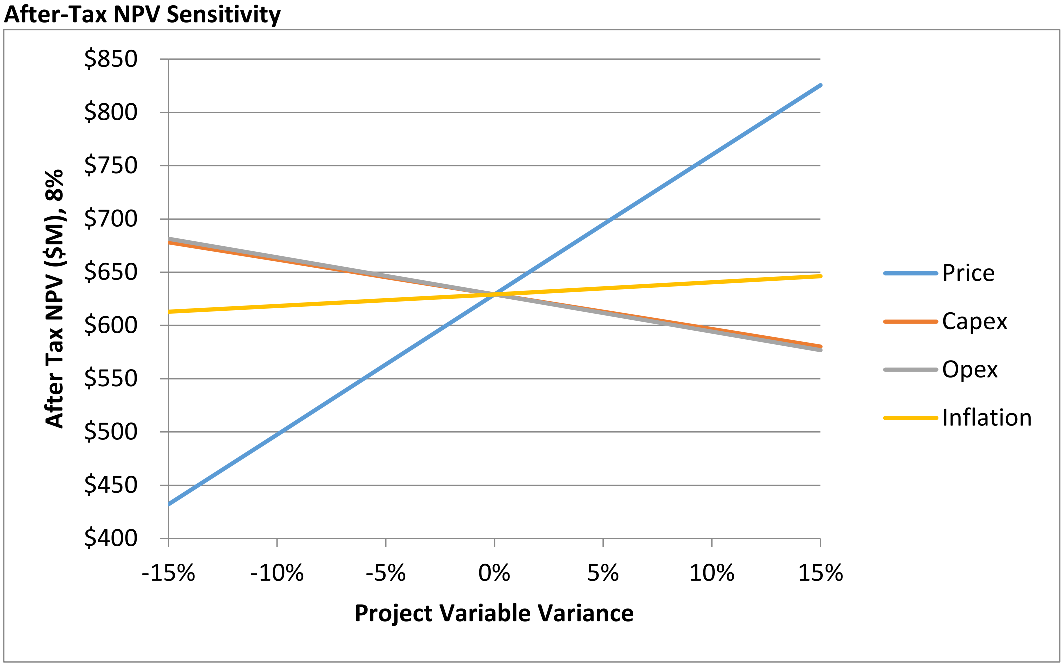


FIGURE 22-3
Pretax IRR Sensitivity

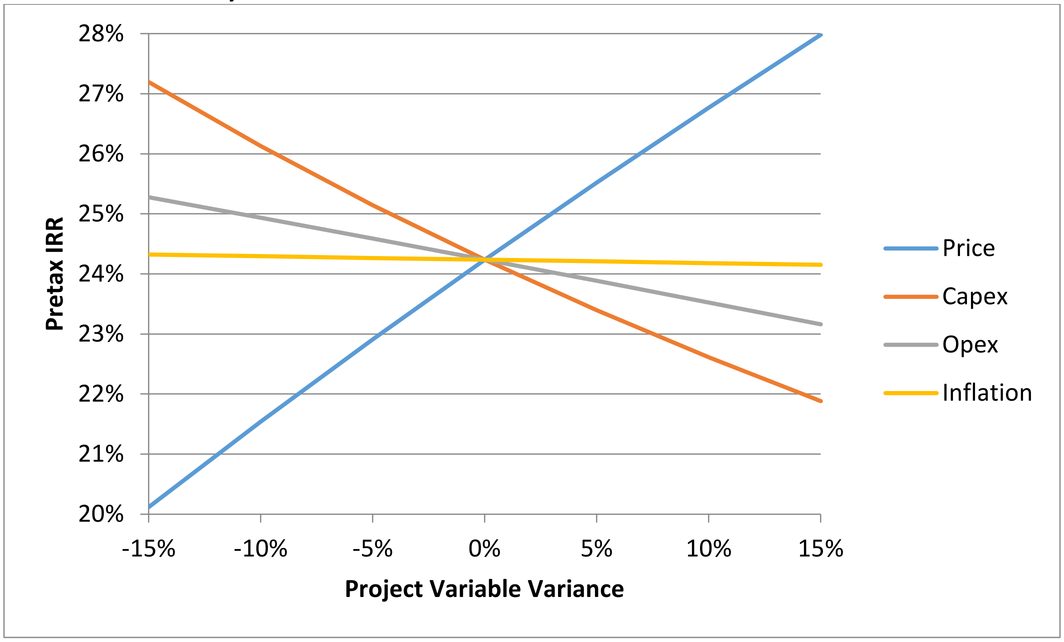
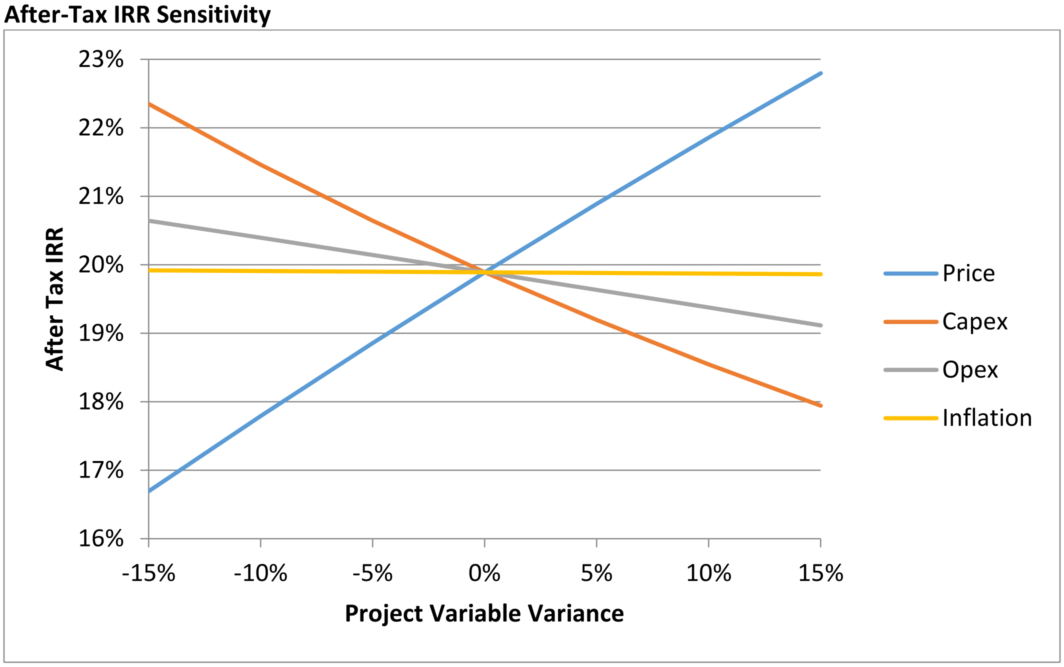


FIGURE 22-4
After-Tax IRR Sensitivity



Adjacent Properties

There are no adjacent properties relevant to this Technical Report.

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Other Relevant Data

24.1 Additional Lake Sediment Characterization

To better characterize the mineralogy of the sediments in Sevier Lake, additional analyses were performed on select samples specifically to determine whether sediments could yield brine and provide potential economic mineral value to the Project.

During the 2013 drilling program at the Sevier Playa, slices of the sonic core were saved in core boxes with the footage and drill hole number noted. Samples from several horizons in three different holes were collected from these cores and submitted for analysis by XRD. Three holes were sampled in their entirety for analysis by inductively coupled plasma-optical emission spectroscopy (ICP-OES). The sampling was limited to the borings from which the cores were obtained and was selected from the core slices available. This analysis provides an early indicator of the mineralogy and chemistry of the playa sediments. Additional work on brine-producing zones could further the understanding of the relationship between brine production and the mineralogy and petrology of the Sevier Playa sediments.

24.2 X-ray Diffraction Analysis

The XRD analyses (Table 24-1) were conducted by the Mesa State College Laboratoryin Grand Junction, Colorado. XRD analyses were performed on the clay-sized fraction obtained from small pieces of the core slices selected to represent the various layers within the lake sediments. The majority of that fraction was smectite clays with lesser amounts of illite and kaolinite. Minor to trace amounts of dolomite and calcite were present in the fine sediment fraction.

TABLE 24-1
XRD Results of Clay-Sized Fraction

Drill Hole ID	Sample Interval (ft)	Description	Smectite	Illite	Kaolinite	Dolomite	Calcite	Quartz
SN3-13-179A	18	URZ	8	1	1	ND	ND	ND
SN3-13-179A	32	Dry clay	7	1–2	1–2	ND	ND	ND
SN3-13-179A	51	LRZ	3	3	3	Minor	Trace	Trace
SN3-13-179A	71	LRZ	7	2	1	Trace	ND	ND
SN3-13-179A	98	LRZ	7	2	1	ND	ND	ND
SN3-13-PDH4A	4	Fat clay	6	3	1	ND	ND	ND
SN3-13-RR7-01	32	Clay	3	3	3	Minor	Minor	ND

TABLE 24-1
XRD Results of Clay-Sized Fraction

Drill Hole ID	Sample Interval (ft)	Description	Smectite	Illite	Kaolinite	Dolomite	Calcite	Quartz
SN3-13-RR7-01	38	Clay	6	3	1	Trace	ND	ND
SN3-13-RR7-01	49	Red brown and gray clay	5	4	1	Trace	ND	ND
SN3-13-RR7-01	61	Clay	9	1	<1	ND	ND	ND
SN3-13-RR7-01	75	LRZ	9	1	<1	Minor	ND	ND

24.3 Inductively Coupled Plasma Analysis

Fifty-seven samples from three of the 2013 drilling program drill holes were analyzed by SRC of Saskatoon, Saskatchewan, using ICP-OES (Table 24-2). All of the available core slices from SN3-13-RR7-01, SN3-13-303A, and SN3-13-179A were used in 1.2-m (4-ft) intervals except where preliminary HydroPhysical™ data indicated possible flow zones that were sampled at 2-foot intervals.

To determine if water or brine could leach out any additional mineral values, dried samples were jaw crushed and a sub-sample was split out using a riffler. The subsample was then pulverized using a ring and puck grinding mill. For the water soluble analysis, an aliquot of pulp was placed in a volumetric flask with deionized water. The sample was shaken and filtered and the soluble solution was then analyzed by ICP-OES. Forty-seven elements were analyzed using the water soluble method. Chloride and bromine were also analyzed by ICP mass spectrometry. Bromine and several other elements showed levels less than the detection limit and were not included in Table 24-2. Detection limits for the various analytes are listed in Table 24-2.

To help understand if any minerals might be recoverable from the lake sediments, a portion of the same samples were analyzed by total digestion. The total acid digestions were performed on an aliquot of sample pulp that was digested to dryness in a Teflon tube within a hot block digestion system using a mixture of concentrated hydrofluoric, nitric, and perchloric acid. The residue was dissolved in dilute nitric acid. Forty-six elements were analyzed using total digestion and ICP-OES; all that tested above the detection limits are listed in Table 24-2. The ICP analyses show concentrations of recoverable potash and other metals that are not economically recoverable at today's prices, with the possible exception of lithium. The levels of potassium and sulphate detected in the sediments may provide a source of recharge for circulating groundwater and potentially would have an influence on future brine geochemistry.

TABLE 24-2

ICP Analyses of Selected Drill Holes

			Soluble (Water)									Total Digestion (Acid)																																
Drill Hole No.	From	To	Cl MS	Ba	CaO	K_2O	Li	MgO	Na_2O	S	Sr	Al_2O_3	Ba	CaO	Ce	Co	Cr	Cu	Dy	Fe_2O_3	Ga	K_2O	La	Li	MgO	MnO	Mo	Na_2O	Nb	Nd	Ni	P_2O_5	Pb	Pr	S	Sc	Sm	Sr	TiO_2	U	V	Y	Zn	Zr
	(m)	(m)	(wt %)	(ppm)	(wt %)	(wt %)	(ppm)	(wt %)	(wt %)	(ppm)	(ppm)	(wt %)	(ppm)	(wt %)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(wt %)	(ppm)	(wt %)	(ppm)	(ppm)	(wt %)	(wt %)	(ppm)	(wt %)	(ppm)	(ppm)	(ppm)	(wt %)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(wt %)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
SN3-13-RR7-01	15.0	19.0	4.30	5	0.69	0.48	9	0.18	3.69	6,620	40	4.97	402	22.00	20	5	29	11	1.4	1.75	8	1.85	12	97	4.74	0.03	1	4.38	10	8	12	0.11	5	2	9,550	4	3	1,140	0.19	<2	47	10	29	38
SN3-13-RR7-01	19.0	23.0	4.80	8	0.36	0.26	10	0.22	4.07	4,270	40	4.17	485	23.90	17	3	32	10	1.1	1.35	7	1.59	11	65	2.98	0.03	<1	4.71	9	7	8	0.09	3	2	6,970	3	3	1,400	0.15	<2	36	8	21	31
SN3-13-RR7-01	23.0	27.0	4.41	5	0.50	0.40	9	0.22	3.70	5,100	46	3.92	664	26.50	15	3	34	9	1.1	1.19	6	1.56	10	53	2.24	0.03	6	4.41	8	6	10	0.10	4	1	8,700	3	3	1,810	0.14	<2	32	8	18	29
SN3-13-RR7-01	27.0	31.0	4.01	6	0.98	0.43	8	0.20	3.55	8,770	41	6.34	449	22.20	26	5	43	15	1.7	2.17	10	2.27	16	88	3.94	0.04	5	4.26	14	11	15	0.13	7	3	12,400	5	3	998	0.25	<2	54	12	38	51
SN3-13-RR7-01	31.0	35.0	3.57	8	0.83	0.28	7	0.18	3.23	7,860	148	6.98	329	15.50	33	6	40	15	2.0	2.45	11	2.12	18	109	5.11	0.04	7	3.88	16	13	16	0.13	7	4	9,870	5	3	709	0.28	4	63	13	48	60
SN3-13-RR7-01	35.0	39.0	3.42	8	0.98	0.48	7	0.18	3.03	8,880	174	7.43	394	15.50	32	6	37	16	2.1	2.46	12	2.57	19	103	5.36	0.04	8	3.73	16	13	15	0.14	8	4	13,400	6	3	703	0.31	2	62	14	49	66
SN3-13-RR7-01	39.0	42.0	3.78	15	0.13	0.36	8	0.12	3.20	2,490	86	7.02	372	14.80	32	5	53	16	2.0	2.35	11	2.29	17	94	5.12	0.04	7	3.87	15	13	16	0.13	8	4	8,850	5	3	692	0.29	3	59	13	51	57
SN3-13-RR7-01	42.0	44.0	3.69	19	0.14	0.30	8	0.13	3.31	3,120	119	7.40	362	15.10	33	6	37	17	2.1	2.48	11	2.23	19	94	5.44	0.04	7	4.00	16	14	15	0.14	8	4	7,410	6	3	827	0.31	3	62	14	49	60
SN3-13-RR7-01	44.0	46.0	1.97	7	0.11	0.20	3	0.05	1.66	1,360	20	5.69	450	8.66	35	4	63	11	1.8	1.85	9	1.74	19	53	2.38	0.03	2	2.16	12	14	11	0.10	7	5	6,490	4	3	349	0.25	2	43	11	32	53
SN3-13-RR7-01	46.0	48.0	2.30	6	0.13	0.18	4	0.08	1.89	1,400	25	4.10	364	7.14	23	3	44	9	1.4	1.35	7	1.28	13	38	1.83	0.02	1	2.70	9	10	7	0.08	5	3	3,540	3	2	283	0.20	<2	33	9	23	43
SN3-13-RR7-01	48.0	50.0	2.25	7	0.07	0.18	3	0.04	1.95	1,090	11	5.68	367	9.50	33	4	94	11	1.9	2.00	9	1.47	17	46	2.85	0.03	1	2.31	12	14	12	0.11	7	4	2,460	4	3	289	0.25	<2	45	12	37	57
SN3-13-RR7-01	50.0	52.0	2.03	6	0.15	0.20	2	0.06	1.68	1,580	12	4.05	379	6.93	24	3	95	6	1.4	1.43	7	1.24	13	29	1.71	0.02	<1	1.89	8	10	8	0.08	5	3	2,520	3	2	234	0.19	<2	31	9	24	42
SN3-13-RR7-01	52.0	54.0	2.72	12	0.07	0.22	4	0.05	2.44	1,620	6	8.40	363	11.50	40	7	46	13	2.4	2.88	14	2.30	22	64	4.38	0.04	<1	2.81	18	16	16	0.14	9	5	2,880	7	4	305	0.34	<2	67	15	59	69
SN3-13-RR7-01	54.0	58.0	2.41	6	0.04	0.20	3	0.03	2.09	1,000	4	9.70	388	14.20	46	7	61	17	2.7	3.26	15	2.71	25	74	5.57	0.05	<1	2.63	21	19	18	0.16	10	6	2,410	8	4	361	0.40	2	80	18	67	79
SN3-13-RR7-01	58.0	62.0	2.02	7	0.06	0.20	3	0.03	1.78	1,330	41	8.52	419	17.60	37	7	47	17	2.3	2.84	13	2.55	21	85	5.48	0.05	<1	2.33	18	15	17	0.15	9	5	3,180	6	4	803	0.34	<2	67	15	55	68
SN3-13-RR7-01	62.0	66.0	1.97	7	0.53	0.30	4	0.08	1.96	6,020	79	8.17	442	18.90	36	7	46	25	2.3	2.68	13	2.27	20	87	5.42	0.05	1	2.38	17	15	16	0.14	8	5	8,590	6	4	733	0.32	2	68	15	53	64
SN3-13-RR7-01	66.0	70.0	1.70	6	0.26	0.18	3	0.05	1.86	4,290	39	9.10	387	14.70	42	7	67	18	2.6	3.10	14	2.56	23	74	5.54	0.05	<1	2.18	20	17	18	0.16	9	6	5,950	7	4	479	0.36	2	75	17	64	73
SN3-13-RR7-01	70.0	74.0	1.71	5	0.60	0.21	3	0.07	1.91	6,930	73	9.33	387	16.10	42	8	51	18	2.6	3.20	15	2.52	23	74	5.83	0.05	1	2.32	20	17	19	0.16	9	5	9,300	7	4	543	0.37	<2	77	17	65	76
SN3-13-RR7-01	74.0	78.0	1.96	6	0.08	0.16	3	0.03	1.93	2,240	10	9.41	412	14.90	44	8	56	21	2.6	3.29	15	2.71	23	83	5.47	0.05	<1	2.40	20	18	18	0.16	10	6	3,890	7	4	413	0.38	2	76	17	65	77
SN3-13-RR7-01	78.0	82.0	1.90	5	0.14	0.24	3	0.05	1.80	2,830	16	8.40	395	16.90	37	7	44	20	2.4	2.81	13	2.81	20	86	5.61	0.05	<1	2.28	18	15	17	0.14	8	5	5,080	6	4	500	0.34	<2	65	16	56	68
SN3-13-RR7-01	82.0	86.0	1.47	6	0.04	0.16	2	0.02	1.37	1,250	4	8.45	420	18.00	37	7	42	19	2.3	2.72	13	2.52	22	88	5.85	0.05	<1	1.88	18	15	16	0.14	9	5	3,120	6	4	557	0.34	<2	68	15	53	65
SN3-13-RR7-01	86.0	90.0	1.71	7	0.12	0.13	3	0.04	1.77	2,800	30	9.09	366	16.80	40	8	46	20	2.5	3.04	14	2.49	22	89	6.16	0.05	<1	2.10	19	16	18	0.15	9	5	4,590	7	4	522	0.36	<2	71	16	62	72
SN3-13-RR7-01	90.0	94.0	1.25	6	0.64	0.14	2	0.06	1.57	7,150	198	9.14	438	16.50	42	7	48	18	2.6	3.10	14	2.55	23	85	6.30	0.05	<1	1.94	19	17	18	0.15	10	6	9,940	7	4	1,400	0.37	<2	77	17	63	75
SN3-13-303A	19.0	23.0	3.80	5	0.34	0.42	7	0.12	3.26	3,870	32	5.04	389	21.50	22	4	29	13	1.4	1.71	8	1.91	13	100	4.98	0.03	1	4.00	11	9	11	0.12	4	2	7,980	4	3	1,170	0.20	2	46	10	30	39
SN3-13-303A	23.0	27.0	4.46	5	0.33	0.32	8	0.20	3.75	3,940	38	3.66	580	26.80	14	3	29	9	1.0	1.10	6	1.64	10	53	2.38	0.03	1	4.71	7	5	8	0.10	2	<1	7,480	2	3	1,750	0.13	<2	31	8	16	27
SN3-13-303A	27.0	31.0	4.62	5	0.22	0.30	8	0.18	3.90	3,040	28	4.59	569	26.00	18	5	32	12	1.3	1.50	7	1.83	11	66	2.84	0.04	8	5.26	10	7	13	0.11	4	1	7,370	3	3	1,660	0.18	<2	42	9	24	36
SN3-13-303A	31.0	35.0	4.07	9	0.93	0.33	9	0.21	3.74	8,860	65	6.96	338	18.00	31	6	34	17	2.0	2.35	11	2.30	17	101	4.53	0.04	2	4.45	15	12	14	0.13	6	3	12,100	5	3	612	0.28	<2	58	13	44	56
SN3-13-303A	35.0	39.0	3.75	11	2.72	0.20	9	0.23	3.93	21,300	261	6.18	277	17.40	27	5	39	14	1.7	2.10	10	2.00	16	109	5.08	0.04	5	4.49	14	11	15	0.12	5	3	31,400	5	3	1,190	0.25	<2	56	12	42	50
SN3-13-303A	39.0	43.0	3.77	10	1.62	0.57	8	0.19	3.46	13,700	222	6.36	313	17.60	27	6	40	14	1.8	2.16	10	2.06	16	104	5.38	0.04	7	4.14	14	11	13	0.12	6	3	20,100	5	3	1,250	0.26	3	58	12	41	52
SN3-13-303A	43.0	47.0	3.30	7	1.82	0.30	8	0.18	3.31	14,800	125	6.62	326	18.50	29	6	40	14	1.8	2.23	10	2.14	16	99	5.10	0.04	5	4.11	14	12	13	0.13	6	3	22,100	5	3	990	0.27	3	60	12	42	54
SN3-13-303A	47.0	51.0	3.76	11	0.24	0.32	8	0.13	3.32	3,770	32	6.67	332	19.20	29	6	43	16	1.8	2.27	11	2.38	16	93	4.74	0.04	8	4.07	14	12	14	0.12	6	3	9,000	5	3	1,160	0.27	3	62	12	43	53
SN3-13-303A	51.0	55.0	3.75	9	0.83	0.33	8	0.17	3.42	7,930	58	6.88	340	18.50	30	6	53	16	1.9	2.37	11	2.12	17	102	4.91	0.04	10	4.06	15	12	15	0.13	6	3	13,900	5	3	1,050	0.28	4	64	13	45	55
SN3-13-303A	55.0	59.0	3.81	13	0.15	0.27	8	0.11	3.37	2,960	30	7.25	349	17.20	32	6	45	17	2.0	2.49	12	2.19	18	98	4.90	0.04	11	3.96	16	13	16	0.13	7	4	7,820	6	3	1,040	0.30	5	67	13	48	59
SN3-13-303A	59.0	63.0	3.42	16	0.16	0.33	7	0.11	3.04	3,330	36	7.54	355	16.30	33	6	39	18	2.1	2.60	12	2.35	19	96	5.00	0.04	13	3.73	16	13	16	0.14	7	4	8,540	6	3	857	0.30	6	72	14	52	63
SN3-13-303A	63.0	66.0	2.49	7	0.12	0.24	5	0.05	2.28	2,310	99	8.21	428	16.00	38	7	60	18	2.3	2.77	13	2.65	20	96	5.37	0.05	6	2.76	17	16	16	0.14	9	5	7,610	6	4	919	0.34	3	69	16	54	70
SN3-13-303A	66.0	69.0	2.51	14	0.06	0.24	5	0.04	2.28	1,870	31	8.22	447	17.50	36	7	43	24	2.2	2.67	13	2.43	20	100	6.20	0.05	2	2.65	17	15	16	0.14	7	4	5,140	6	4	681	0.33	2	73	15	53	68
SN3-13-179A	17.5	20.0	5.73	8	0.45	0.33	6	0.06	5.89	8,860	125	5.26	399	21.60	22	4	32	13	1.5	1.77	8	2.10	13	96	6.65	0.04	3	6.91	11	9	10	0.12	4	2	14,600	4	3	1,180	0.22	<2	44	11	30	44
SN3-13-179A	20.0	24.0	3.10	4	0.31	0.27	6	0.05	3.38	6,410	35	6.50	405	21.50	30	6	41	14	1.9	2.18	10	2.50	17	97	5.08	0.04	1	4.05	14	12	14	0.14	6	3	11,400	5	3	942	0.26	<2	54	13	39	53
SN3-13-179A	24.0	28.0	2.91	5	0.36	0.27	5	0.11	3.07	6,520	43	4.00	680	30.80	15	3	22	10	1.2	1.18	6	1.44	10	49	1.93	0.03	5	3.95	8	6	8	0.10	3	1	11,200	3	3	2,120	0.14	<2	32	9	15	29
SN3-13-179A	28.0	32.0	2.87	4	0.30	0.38	5	0.07	3.14	6,670	31	6.55	455	21.90	29	6	37	17	1.8	2.19	10	2.08	16	93	3.70	0.04	7	3.80	14	11	15	0.13	6	3	10,800	5	4	1,110	0.26	2	58	12	39	54
SN3-13-179A	32.0	36.0	2.42	7	2.56	0.46	7	0.12	3.49	23,800	213	7.36	273	15.60	35	7	38	15	2.1	2.51	12	2.14	19	135	5.77	0.05	3	3.72	16	14	14	0.14	7	4	27,400	6	3	949	0.30	3	62	14	48	62
SN3-13-179A	36.0	40.0	2.35	7	1.76	0.25	8	0.10	3.31	18,600	234	8.29	295	12.90	41	7	47	17	2.5	2.84	13	2.39	22	143	6.20	0.05	4	3.72	18	17	16	0.15	10	6	26,900	7	4	772	0.35	3	67	17	57	74
SN3-13-179A	40.0	44.0	2.15	6	2.50	0.24	8	0.09	3.18	23,100	189	8.39	281	14.90	41	7	46	17	2.5	2.84	13	2.53	22	140	5.96	0.06	3	3.65	19	17	16	0.15	9	5	33,300	7	4	647	0.34	2	67	16	56	71
SN3-13-179A	44.0	48.0	2.24	7	0.35	0.24	8	0.06	3.10	9,380	111	9.11	299	12.40	47	8	51	19	2.8	3.09	15	2.61	24	141	5.18	0.05	3	3.74	20	19	17	0.15	11	6	17,600	7	4	543	0.38	2	72	18	64	80
SN3-13-179A	48.0	52.0	2.11	7	1.31	0.41	9	0.09	3.28	17,200	191	8.56	305	14.20	41	8	44	19	2.5	2.90	14	2.79	23	142	5.66	0.05	4	3.80	18	17	16	0.15	9	5	25,300	7	4	715	0.35	3	69	17	58	73
SN3-13-179A	52.0	56.0	1.90	9	0.38	0.14	8	0.06	3.08	10,500	102	8.50	322	14.30	39	7	44	18	2.4	2.88	14	2.22	23	131	5.01	0.05	4	3.57	18	16	16	0.15	9	5	17,900	7	4	679	0.35	3	69	16	57	72
SN3-13-179A	56.0	60.0	1.90	6	0.70	0.36	9	0.06	3.04	12,800	107	9.27	311	13.60	44	9	46	20	2.7	3.12	15	2.64	24	134	4.87	0.05	2	3.41	20	18	17	0.16	10	6	19,800	7	4	524	0.38	2	73	18	62	80
SN3-13-179A	60.0	64.0	1.46	6	0.98	0.25	7	0.06	2.79	14,600	81	9.45	308	14.10	45	8	51	20	2.7	3.19	15	2.65	25	129	4.79	0.06	1	3.35	20	18	18	0.16	10	6	21,500	7	4	465	0.39	2	74	18	64	81
SN3-13-179A	64.0	68.0	1.49	6	1.90	0.36	8	0.08	3.15	22,100	136	8.94	310	14.80	43	8	44	20	2.6	3.14	15	2.58	23	132	5.77	0.06	3	3.64	19	17	18	0.16	10	5	31,800	7	4	560	0.36	3	75	17	61	77
SN3-13-179A	68.0	72.0	1.59	7	1.67	0.37	8	0.08	3.34	21,400	191	9.13	314	14.80	42	8	43	20	2.6	3.17	15	2.54	24	131	6.33	0.06	3	3.80	20	17	18	0.16	10	5	30,400	7	4	678	0.37	2	77	17	62	78
SN3-13-179A	72.0	76.0	1.26	6	2.99	0.42	7	0.08	3.19	29,900	187	7.92	290	15.90	36	7	39	17	2.2	2.61	13	2.10	19	110	5.82	0.05	3	3.37	17	15	15	0.14	8	5	37,800	6	4	684	0.32	2	67	15	52	65
SN3-13-179A	76.0	80.0	1.30	6	1.68	0.46	6	0.08	3.02	21,400	240	8.69	319	15.70	40	8	43	19	2.5	2.98	14	2.52	23	116	5.97	0.05	4	3.50	19	16	17	0.16	10	5	30,600	7	4	969	0.35	3	73	16	57	73
SN3-13-179A	80.0	84.0	1.26	5	2.17	0.40	6	0.07	3.00	24,500	151	9.16	305	15.90	42	8	43	20	2.6	3.13	15	2.59	24	117	5.26	0.06	3	3.46	20	17	18	0.16	9	5	35,000	7	4	631	0.37	2	76	17	61	77
SN3-13-179A	84.0	88.0	0.85	5	3.02	0.17	5	0.06	2.84	29,200	123	8.01	308	18.50	35	7	38	18	2.3	2.72	13	1.88	21	100	4.64	0.05	5	3.30	17	15	16	0.14	8	5	41,500	6	4	898	0.32	2	71	15	52	66
SN3-13-179A	88.0	92.0	1.40	5	0.50	0.36	5	0.05	2.85	12,800	41	9.09	366	16.60	41	8	44	20	2.5	3.10	14	2.61	23	110	5.20	0.05	8	3.48	20	17	18	0.16	10	5	20,900	7	4	716	0.37	4	80	17	60	77
SN3-13-179A	92.0	96.0	1.35	5	0.42	0.37	4	0.04	2.50	10,800	242	8.08	412	21.70	34	7	40	18	2.2	2.75	12	2.40	20	107	5.01	0.05	6	3.15	18	14	17	0.15	8	4	18,800	6	4	1,710	0.33	2	71	15	51	67
SN3-13-179A	96.0	100.0	1.12	6	0.05	0.15	3	0.02	1.99	6,180	97	8.52	503	18.10	38	7	40	20	2.4	2.70	13	2.59	20	86	5.58	0.05	2	2.68	18	16	16	0.15	9	5	10,900	6	4	2,570	0.36	2	73	16	52	74

Note: Analyses less than limits of detection are not shown.

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24.4 Carbonate Content

Carbonate content testing was performed in 2012 by IGES on 97 direct-push and trench samples. The average carbonate content (calcite equivalent) was 41 percent (Table 6 in Green and Seely, 2012). If these samples are representative of all of the Sevier Playa sediments, the results of the analyses would make them an argillaceous marlstone.

During hydrologic tracer testing by Whetstone in 2013, four samples were taken from each of the two direct-push holes (DP270P10 and DP270P12). Results for carbonate content testing (calcite equivalent) by IGES are shown in Table 24-3.

TABLE 24-3
IGES Tracer Test Carbonate Content

Sample #	DDTT1-13-010				DDTT1-13-012			
Depth (ft)	0–5	5–10	10–15	15–20	0–5	5–10	10–15	15–20
Carbonate content								
Calcite equivalent (%)	20	30	43	44	20	23	44	42

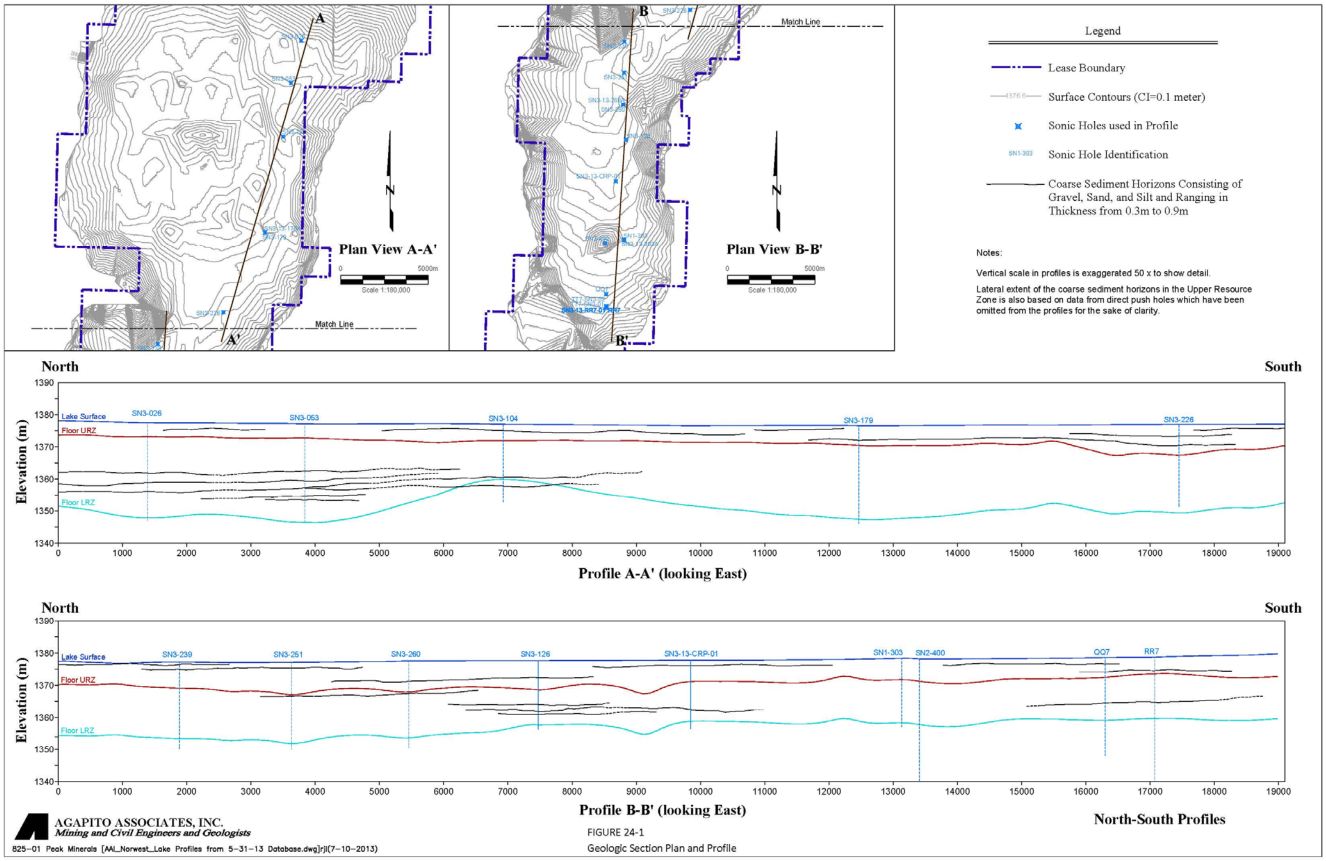
Like the 2012 samples, the upper "fat clay" was generally lower in carbonate and probably higher in clay content. The URZ is higher in carbonate and this presence of carbonate grains may add to the porosity with inter-granular pore space. Data for the LRZ are not available as no sonic holes were analyzed for carbonate content.

In D.A. Hampton's (1976) University of Utah Master's thesis titled "Geochemistry of the Saline and Carbonate Minerals of Sevier Lake Playa, Millard County, Utah," XRD analysis was used to determine that the sediments of the Sevier Playa contained a mixture of calcite, dolomite, and magnesite with clay minerals. Gypsum, halite, and thenardite, and its hydrated form mirabilite, were also common in the samples analyzed by Hampton. Sediments from the surrounding mountains have high carbonate content and the brine in the playa has relatively high magnesium content so the variety of carbonate sediments in the playa is easily explained. Hampton's samples were mainly from the margins of the lake and were less than 0.9 m (3 ft) deep; therefore, they do not represent the entire lakebed section.

24.5 Detailed Cross Sections

To better understand the geologic relationship of the various beds of gravel, sand, and silt within the stratigraphy of the Sevier Playa sediments, two profiles were constructed running north and south, using both sonic and direct-push drill hole log information (Figure 24-1). Correlation of the coarse-grained sections was attempted between adjacent drill holes. As illustrated in Figure 24-1, very few gravel, sand, or silt beds of varying thicknesses ranging from less than a foot to over 0.9 m (3 ft) thick can be correlated for more than a few km. These interbeds of coarse-grained sediments appear to be intermittent and discontinuous across the playa and more concentrated near the shoreline. The majority of the coarse-grained beds occur in the lower resource zone.

FIGURE 24-1
Geological Section Plan and Profile



Report, Peak Minerals, Sevier Dry Lake. October 18. 716 pp.

24.6 Quality Assurance/Quality Control

During the 2013 sonic drilling campaign, a visit was made to observe drilling/coring methods and core sampling, logging, and photographing techniques. During 2 days and on two different holes, observations of the drillers from Boart Longyear and the Norwest geologist found no problems with any aspect of, or the quality of, the work. While the drill hole advanced at a rapid pace, there was adequate attention to the detail of marking and communicating core intervals by the drillers and care was taken by the geologist logging and photographing the core. Samples of the core were placed into sample bags or whole core was placed in core boxes, that were clearly marked and transported to storage or to the lab for analysis. Sample preparation and security measures were found to be of high standards and followed protocols established by Norwest and CH2M HILL.

No visit was made by AAI personnel to the labouratories that performed the brine and solids analyses (AWAL and IGES, respectively). Examination of the sample analysis data and discussions of methods and QC; including the use of standards, duplicates, and blanks; gave a high level of confidence in the quality of the analytical results. It is believed by the applicable qualified persons that the recorded data have been properly acquired and that sufficient validation has been performed to make it acceptable for use.

24.7 Opportunities and Risks

24.7.1 Opportunities

The significant opportunities identified for the project include the production of ancillary minerals, the availability of recharge water, and the brine extraction plan.

24.7.2 Ancillary Minerals

Based on the current understanding of the Sevier Playa brine composition and the current process design, the potential may exist for the production of ancillary minerals that may include magnesium sulphate, magnesium chloride and sodium sulphate. Determination of the specific types and amounts of ancillary minerals would require the completion of additional process test work.

The playa brine contains lithium and the element was not precipitated or crystallized as lithium salts in the ponds. The lithium concentration of the final brine from Pond 4 is 0.139 percent. This is equivalent to 1.92 g/L of lithium. The amount of lithium deemed available was calculated as follows:

- Pond 4 filtrate (Hazen work) contained 0.139 percent lithium and 8.3 percent magnesium with brine SG of 1.380. This was adjusted by ratio to 8.0 percent magnesium and 0.134 percent lithium. SG was assumed to stay the same.
- The David Butts spreadsheet of August 2013 shows the bitterns recovered from Pond D would have a combined magnesium and calcium (Ca) of 8.00 percent. At that point, the Hazen work showed that calcium would be nil. David Butts' spreadsheet shows that the annual bitterns production would be 953,323 tonnes (1,050,758 tons)
- Therefore, the lithium available in the bitterns would be 953,323 tonnes (1,050,758 tons) x 0.134 percent lithium = 1,277 tonnes (1,408 tons) lithium.

24.7.3 Recharge Water

Based on the data collected to date, it appears that there is adequate recharge water to support the proposed potash production rate. If further work suggests that additional recharge water is available for the project, the annual potash production rates could potentially increase.

24.7.4 Brine Extraction Plan

The brine extraction plan was developed using the current data collected. If the extraction rates for trenches or wells are greater than current estimates, the length of the trenches and the number of wells could potentially be reduced. This would result in likely savings in capital costs.

24.8 Risks

CH2M HILL facilitated a risk workshop with project participants and developed the following risk matrix to identify the risks for the project. Various risk objectives were captured and their impact was rated within one of five categories from very low to very high. This was an iterative process with the results as follows:

RISKS FOR PROJECT

Client: EPM Mining Ventures, Inc.
Project: Sevier Playa Project PFS
Location: Sevier Lake, Utah

Project Risk Register

Quantitative Analysis

Project No: 464671
Currency: USD
0
Status Date: 06-Jun-13

Risk No.	Category: T/O	Category: RBS Level 1 (Internal)	Category: Project Objective	Cause, Threat/Opportunity, and Effect	Control Dates: Identified	Control Dates: Treatment Plan	Before Treatment – Most Likely: Impact	Before Treatment – Most Likely: Probability	Before Treatment: Overall Risk Ranking	Current Status: Status	Estimated Cost Impact: Cat.	Estimated Cost Impact: Best Case	Estimated Cost Impact: Most Likely	Estimated Cost Impact: Worst Case	Probability: Cat.	Probability: %	Overall Risk: Ranking	Overall Risk: Expected Value	Action: Treatment Type	Action: Treatment Plan	Action: Risk Owner
001	T	Technical	Quality	Brine chemistry can affect the salts crystallized in different ponds. Currently have imperfect understanding of the brine chemistry. The crystals produced in the potassium production pond can affect recovery in the pond, flotation, and the process.	1-Mar-13	15-Jul-13	Low	Low	Low	Active	Low	500,000	1,000,000	5,000,000	Medium	10%	Medium	100,000	Mitigate	Test work to improve definition of solution chemistry.	CH2M HILL
002	T	Technical	Cost	Solar pond evaporation and crystallization occurs under a wide variety of conditions throughout the year. Evaporation tests have been performed under "summer" conditions, but have not duplicated the entire cycle. May result in differences of mineral processed in the production ponds.	6-Jun-13	15-Jul-13	Very Low	Medium	Low	Active	Low	500,000	1,000,000	3,000,000	Low	1%	Low	10,000	Mitigate	Testing on low temp cyrstallization.	CH2M HILL
003	T	Technical	Cost	Flotation tests performed with synthetic leonite combined with commercial salt and epsom salts. Actual pond products may respond differently in flotation than the synthetic product.	6-Jun-13	15-Jul-13	Medium	Low	Medium	Active	Medium	100,000	300,000	500,000	Medium	20%	Medium	60,000	Mitigate	Continue testing. Verification testing with Hazen material.	CH2M HILL
004	T	Technical	Cost	Costs Related to Design Items to Meet Air Approval Order Requirements - Additional costs may be incurred due to things such as stockpile enclosures, paving roads, baghouses, etc.	6-Jun-13	30-Jan-14	High	Medium	Medium	Active	High	500,000	3,000,000	4,000,000	Medium	40%	Medium	1,200,000	Mitigate	Explore engineering design options.	CH2M HILL
005	T	External	Schedule	EIS delay due to BLM responsiveness, third-party responsiveness, and an NGO appeal.	6-Jun-13	30-Jan-14	Medium	Medium	Medium	Active	Medium	100,000	700,000	1,500,000	Medium	20%	Medium	140,000	Mitigate	Closer coordination with BLM Field Mgr; implementing weekly mtgs with BLM NEPA team; continue technical expertise and communications in rpt to BLM.	CH2M HILL
006	T	External	Reputation	Water Rights - Water rights are not granted for brine and/or groundwater and/or river water.	6-Jun-13	30-Jan-14	Very High	Low	Medium	Active	Low	100,000	500,000	1,000,000	Low	5%	Low	25,000	Mitigate	Submitting a accurate and persuasive application.	Peak Minerals
007	T	Technical	Cost	Brine extraction rate capable of hitting production target. Brine is not able to be extracted at the rates needed.	6-Jun-13	1-314	High	Medium	Medium	Active	Medium	100,000	500,000	1,000,000	Medium	20%	Medium	100,000	Mitigate	Complete modeling to define sustainable extraction rates.	Agapito
008	T	Technical	Cost	Extractable Resource - Amount of brine that can be readily extracted may not be sufficient for a 30-year mine life.	6-Jun-13	1-Sep-13	High	High	High	Active	High	100,000	500,000	1,000,000	High	30%	High	150,000	Mitigate	Additional testing in Feasibility Study to verify.	Agapito
009	O	Technical	Cost	Production Rate - Could happen if brine is able to be extracted at a rate greater than 40,000 gpm AND sufficient recharge is available AND there is enough extractable resource to achieve 30 years of life at this higher rate.	6-Jun-13	30-Jan-16	High	Medium	Medium	Active	Medium	500,000	1,000,000	2,000,000	Low	5%	Medium	50,000	Exploit	Expand the capacity of the plant.	Peak Minerals
010	O	Technical	Cost	Additional product streams may be developed, increasing revenue with marginal costs.	6-Jun-13	30-Jan-14	High	Medium	Medium	Active	High	500,000	2,000,000	4,000,000	Medium	60%	Medium	1,200,000	Exploit	Identify additional products.	CH2M HILL
011	T	External	Schedule	Delay in permit issuance due to longer review by DUAQ.	6-Jun-13	1-Mar-14	Very High	Medium	High	Active	Medium	50,000	100,000	200,000	Low	30%	Medium	30,000	Mitigate	Close coordination with DAUQ. Submit technically complete application.	CH2M HILL
012	T	External	Schedule	Delay in Air Permit issuance due to longer requirement for preconstruction monitoring. Delay in permit issuance, longer length of time for preconstruction monitoring.	6-Jun-13	1-Mar-14	Very High	Medium	High	Active	Medium	50,000	100,000	300,000	Medium	70%	Medium	70,000	Mitigate	Coordinate with DUAQ to minimize any delays.	CH2M HILL
013	T	External	Schedule	Delay permit issuance due to extensive NGO comments.	6-Jun-13	1-Jun-14	Very High	High	High	Active	High	200,000	500,000	1,000,000	Medium	60%	Medium	300,000	Mitigate	Submit a comprehensive plan.	CH2M HILL
014	T	External	Schedule	Air Permit overturned from appeals by NGO.	6-Jun-13	4-Apr-14	High	Very Low	Low	Active	Low	100,000	200,000	1,000,000	Low	20%	Low	40,000	Mitigate	Strong technical record.	CH2M HILL
015	T	Technical	Schedule	Delay in Project due to process design.	6-Jun-13	30-Jan-14	High	Low	Medium	Active	Low	300,000	1,000,000	2,000,000	Low	40%	Low	400,000	Mitigate	Close coordination process.	CH2M HILL
016	T	Technical	Schedule	Do we have enough data to support that recharge water is sufficient? Recharge water from river and precipitation needs to demonstrate it is adequate to support a sustainable project.	6-Jun-13	30-Jan-14	High	High	High	Active	High	1,000,000	5,000,000	10,000,000	Medium	10%	Medium	500,000	Mitigate	Additional analysis and additional fieldwork.	Agapito

RISKS FOR PROJECT

Client: EPM Mining Ventures, Inc.
Project: Sevier Playa Project PFS
Location: Sevier Lake, Utah

Project Risk Register

Quantitative Analysis

Project No: 464671
Currency: USD
0
Status Date: 06-Jun-13

Risk No.	T/O	Category: RBS Level 1 (Internal)	Category: Project Objective	Cause, Threat/Opportunity, and Effect	Control Dates: Identified	Control Dates: Treatment Plan	Before Treatment – Most Likely: Impact	Before Treatment – Most Likely: Proba-bility	Before Treatment: Overall Risk Ranking	Current Status: Status	Current Status – Estimated Cost Impact: Cat.	Estimated Cost Impact: Best Case	Estimated Cost Impact: Most Likely	Estimated Cost Impact: Worst Case	Probability: Cat.	Probability: %	Overall Risk: Ranking	Overall Risk: Expected Value	Action: Treatment Type	Action: Treatment Plan	Action: Risk Owner
017	T	External	Cost	Do we have enough recharge water?	6-Jun-13	30-Jan-14	Low	Low	Low	Active	Low	1,000,000	5,000,000	10,000,000	Medium	20%	Medium	1,000,000	Mitigate	Peak has budgeted US$100 per ac-ft and is willing to purchase 27,000 ac-ft per year. The cost will be carried in the operational costs.	Agapito
018	T	Technical		Leakage of brine through the floor of the ponds.	6-Jun-13	30-Jan-14	High	Low	Medium	Active	Medium	1,000,000	2,000,000	4,000,000	Medium	5%	Medium	100,000	Mitigate	Conduct several infiltrometer tests within limits of preconcentration and production ponds.	Agapito
019	T	External	Cost	Escalation of materials/equipment	6-Jun-13	1-Mar-16	Medium	High	Medium	Active	Medium	300,000	1,000,000	2,000,000	Medium	20%	Medium	200,000	Mitigate	Planning purchases. Including escalation in cost estimate.	CH2M HILL
020	T	External	Cost	Equipment delivery time related to availability of equipment.	6-Jun-13	30-Jan-15	Medium	Medium	Medium	Active	Medium	100,000	500,000	1,000,000	Low	20%	Medium	100,000	Mitigate	Develop critical path with materials/ equipment.	CH2M HILL
021	T	External	Cost	Availability of construction crews.	6-Jun-13	30-Jan-15	Low	Low	Low	Active	Low	200,000	500,000	1,000,000	Low	10%	Low	50,000	Mitigate	Began discussions with contractors early and know area.	Peak/CH2M HILL
022	T	External	Cost	Availability of concrete.	6-Jun-13	30-Jan-15	Very Low	Low	Low	Active	Medium	200,000	500,000	1,000,000	Low	20%	Medium	100,000	Mitigate	Batch plant on site.	CH2M HILL
023	T	Technical	Cost	Soils.	6-Jun-13	1-Aug-13	Very Low	Low	Low	Active	Low	10,000	20,000	40,000	Low	10%	Low	2,000	Mitigate	Design	CH2M HILL
024	T	External	Schedule	Power transformer lead times.	6-Jun-13	30-Jan-15	Very Low	High	Low	Active	Low	50,000	100,000	150,000	Low	20%	Low	20,000	Mitigate	Substation design yearly and select equipment.	CH2M HILL
025	T	Commercial	Cost	Signing of contracts with Rocky Mtn Power.	6-Jun-13	30-Jan-14	Medium	Very Low	Low	Active	Low	50,000	100,000	150,000	Low	10%	Low	10,000	Mitigate	Decision on contract with RMP	Peak Minerals
026	T	Technical	Cost	Resource - The continuity of brine-producing zones is uncertain in lower resource zone.	6-Jun-13	30-Jan-14	Medium	Low	Medium	Active	Low	1,000,000	5,000,000	10,000,000	Medium	20%	Medium	1,000,000	Mitigate	Improved characterization of LRZ is planned.	Agapito
027	T	Technical	Cost	Mining and Operations - Control of existing water from Sevier Lake to not inundate and dilute extraction trenches.	6-Jun-13	30-Jan-14	Medium	Low	Medium	Active	Low	1,000,000	5,000,000	10,000,000	Medium	20%	Medium	1,000,000	Mitigate	Sevier Lake most likely dry during operations.	Agapito
028	T	Technical	Cost	Mining and Operations - Long-term impact of water recharge on brine grade consistency.	6-Jun-13	30-Jan-15	Low	Low	Low	Active	Low	50,000	100,000	150,000	Low	20%	Low	20,000	Mitigate	Modeling ongoing.	Agapito
029	T	External	Quality	Civil/Geotechnical - Flood waters overtopping pond dikes (1.4 m high; no armor).	6-Jun-13	30-Jan-14	High	Low	Medium	Active	Medium	1,000,000	5,000,000	10,000,000	Low	10%	Medium	500,000	Mitigate	Consider contingency plan to fortify dikes if endangered.	Agapito
030	T	Technical	Cost	Civil/Geotechnical - Dike seismic instability.	6-Jun-13	30-Jan-14	High	Very Low	Low	Active	Low	50,000	100,000	150,000	Low	5%	Low	5,000	Mitigate	Design dikes for seismic activity.	Agapito
031	T	External	Cost	Civil/Geotechnical - Wind-generated waves on interior of pond dikes (nonarmored).	6-Jun-13	30-Jan-14	Medium	Very Low	Low	Active	Low	50,000	100,000	150,000	Low	10%	Low	10,000	Mitigate	Requires a good maintenance program to maintain dikes.	Agapito
032	T	Technical	Schedule	Evapotranspiration - If the current value used for ET changes, the hydrologic model will have to be rerun and possibly recalibrated.	6-Jun-13	1-Sep-13	Low	Low	Low	Active	Low	10,000	20,000	40,000	Low	20%	Low	4,000	Mitigate	Confirm estimates with Dave Butts and Wood Miller.	Agapito
033	O	Commercial	Cost	Land/Lease Tenure - Subject to final execution of Unit Agreement.	6-Jun-13	1-Jun-14	Low	Low	Low	Active	Low	10,000	20,000	40,000	Low	20%	Low	4,000	Accept		Peak Minerals
034	T	Commercial	Cost	Phase 2 trench and Phase 3 well construction could be needed earlier than scheduled.	6-Jun-13	1-Jun-14	Medium	Medium	Medium	Active	Medium	1,000,000	10,000,000	20,000,000	Medium	10%	Medium	1,000,000	Mitigate	Monitoring of trench performance.	Peak Minerals
035	T	Commercial	Cost	Well brine grade may not support production rate at 300,000 tpy in Years 20 to 30.	6-Jun-13	1-Jun-14	High	Medium	Medium	Active	Medium		1,000,000	50,000,000	Low	10%	Medium	100,000	Mitigate	Impact in Years 20 to 30 with minimal impact on IRR or NPV.	Peak Minerals

Total Expected Value	9,600,000	Active items only
In Risk Contingency	9,600,000	
In Funded Liabilities	0	
In Management Reserve		

CH2MHILL.

The significant risks identified in the risk workshop and captured in this matrix are denoted as "High" and shown in red. Significant risks and risk mitigation are described as follows.

Risk No. 008 – Extractable Resource. The risk is that the amount of brine that can be readily extracted may not be sufficient for a 30-year mine life. Mitigation Action: Perform additional testing on the Playa during the Feasibility Study, including deep wells into the LRZ to characterize hydraulic properties.

Risk No. 011 – Delay in permit issuance due to longer review by UDAQ. This is a risk to meeting the start-up schedule and has cost implications due to speed to market. Mitigation Action: This will be mitigated with close coordination with UDAQ and by submitting a technically complete application.

Risk No. 012 – Delay in Air Permit issuance due to longer requirement for preconstruction monitoring. This is also a risk to meeting the start-up schedule and has implication due to speed to market. Mitigation Action: This will be mitigated with coordination with UDAQ to minimize delays.

Risk No. 013 – Delay Permit issuance due to extensive non-governmental organization (NGO) comments. This is a risk to meeting the start-up schedule and has cost implications due to speed to market. Mitigation Action: This will be mitigated by submitting a comprehensive plan.

Risk No. 016 – Recharge water from river and precipitation needs to demonstrate that it is adequate to support a sustainable project. Mitigation Action: This will be mitigated with additional analysis and fieldwork to verify that there is sufficient recharge water available to support the 30-year mine life. The testing will include long-term trench tests with recharge and production trenches.

24.8.1 Pond Development

Uncertainty of weather conditions must be considered a risk factor in an operation that is to use solar evaporation in its extraction process. Adverse weather conditions that affect the net evaporation rates cannot be predicted, but the historic weather records and trends support an environment conducive for solar evaporation. These risks have been mitigated through the incorporation of conservative estimates on the pond development time in the project schedule.

24.8.2 Permitting/Regulatory

The major risk to EPM's ability to develop the leases is the federal permitting and NEPA process. Permitting may be delayed due to protests from NGOs or untimely regulator review. This could result in a delay for the commencement of the project. Permitting risks are primarily schedule-related. There appears to be minimal risk of not receiving the required permits and approvals.

24.8.3 Recharge Water

Based on the data collected to date, it appears that there likely is adequate recharge water to support the proposed potash production rate. However, if it is determined that there is not sufficient recharge water available from the assumed sources, additional water would need to be acquired from one of the other identified sources of readily available water.

24.8.4 Brine Extraction Plan

The extraction of brine is based on the data collected to date. If the extraction rates for trenches or the wells are less than current estimates, the length of the trenches and the number of wells could increase. This would result in a potential increase in capital costs.

24.8.5 Recovery

The overall recovery of SOP is the culmination of the recovery at each step of the process. Additional test work is required to advance the process design. The recovery risk will be mitigated through process test work to support the process plant design.

Interpretation and Conclusions

The Sevier Lake Playa SOP Project is a large brine resource anticipated to be capable of supporting mining and processing operations for a minimum of 30 years. The efforts of a second drilling and fieldwork test program, bench-scale testing of important evaporation and other process-related parameters, and significant hydrology modeling and analysis supports the strong fundamentals and potential of the project. Average annual SOP production of 300,000 tonnes (330,693 tons) is forecasted with an estimated NPV of US$629 million (after tax, inflated, 8 percent discount rate) and an estimated IRR of 20 percent (after tax, inflated). The mineral resource estimate includes 31.486 Mt (34.707 Mton) of SOP in the measured and indicated categories, a 7 percent increase from previously published estimates.

Risks to the project include scheduling risks due to potential permitting delays, the risk of insufficient recharge water, and the risk associated with sustaining the flow rate and brine grade during mining. However, a comprehensive groundwater modeling effort was conducted to support this Technical Report. The models incorporated layer elevations derived from intercepts logged from over 400 boreholes and wells drilled during the exploration program. Initial modeling determined that acceptable brine mass rates could be extracted. Risks are discussed in detail in Section 24.9 of this Technical Report.

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Recommendations

It is recommended that additional field and labouratory work be completed to finalize the understanding of the playa hydrology necessary to advance resources to reserves. In addition, final geotechnical work needs to be completed to a level sufficient to finalize civil design work on the playa. Concurrently, it is recommended that additional process work be completed to validate the flow sheet design. Ancillary product alternatives also need to be further evaluated to see which can be incorporated into the flow sheet. This work should then be incorporated into a feasibility study.

The environmental work necessary to obtain the permits required for authorizing the construction of the project should continue as outlined in Section 20.

26.1 Geohydrology

1. Drill additional sonic wells for an estimated cost of $486,875 to accomplish the following:

- Characterize the LRZ as Measured or Indicated, assuring sampling in the LRZ is isolated from the URZ. Sample over multiple intervals and evaluate flow attributed to coarse-grained sediments
- Further evaluate the interface between the URZ and the LRZ to determine flow characteristics
- Characterize the “fat clay” layer for thickness, resource, recharge, and flow
- Drill additional holes around the perimeter of the playa to define the transition from playa sediments to alluvium

2. Complete production testing of deep wells into the LRZ with nested observation wells in four to six locations, and perform appropriate well-to-well aquifer stress tests to estimate hydraulic properties for the LRZ alone. Estimated costs for this program are US$423,850.
3. Complete a full-scale, long-term demonstration trench test with a neighboring recharge trench within 250 m (820 ft) from the production trench. The test duration should be at least 6 months, the trench should be 7 m (23 ft) deep and approximately 500 m (1,640 ft) long to simulate a full-sized production trench. Prior to initiating the test, a test protocol document should be produced that identifies all aspects of the test and the expected performance of the test trench. Estimated costs are US$526,850.
4. Design tests to verify the assumed parameters in the hydrogeologic model. This may include both field and labouratory tests to evaluate dispersivity and retardation coefficients. The estimated cost to verify these parameters is US$56,600.

26.2 Geotechnical and Civil Design

1. Generate a new topographic base map of the project area based on an aerial flyover, with a minimum of 2 foot contour intervals for an estimated cost of US$100,000.

2. Conduct a minimum of two SDRI tests within the preconcentration pond area. These tests could be done contemporaneously with other field permeability/infiltration test methods to establish a reliable correlation with alternative testing methods. Estimated costs are US$20,550.

3. Perform three to four additional triaxial shear strength tests on each of the stratigraphic units encountered in the upper 12 m (40 ft). This includes the fat clay layer, the upper fissured clay layer, and the lower fissured clay layer. Estimated costs are US$27,150.

4. Perform subsurface investigations at the existing salt pond and adjacent areas on which the production ponds will be constructed. Several test pits are recommended to verify the thickness of salts present and to characterize the underlying materials. Estimated costs are US$11,330.

5. Conduct geotechnical investigations of the Sevier River diversion area to include two boreholes, using drilling methods capable of obtaining relatively undisturbed, thin-walled tube samples. Labouratory testing to assess and characterize the foundation materials would include index, consolidation, and strength tests. Estimated costs are US$17,970.

6. Conduct geotechnical investigations along the recharge canal alignment, including boreholes in the vicinity of the primary pump structures for the east-to-west pipelines, and several along the alignments of the canal and pipelines. Estimated costs are US$62,900.

7. Conduct a pan evaporation test on the lake using brine at the north and south ends of the lake near the location of the preconcentration and production ponds. This would improve the pond-sizing model and better refine the overall brine concentration process. Estimated costs are US$30,000.

26.3 Process Design

1. The variability in the analytical results of brine samples was fairly high, although consistent with the analytical methods used. It is recommended that at the next stage of the project, additional investigation be performed to obtain more repeatable brine analytical sampling results using an alternative labouratory analysis with higher detection limits for key analytes, including sulphate. Results of the testing would help to refine process designs based on more accurate feed chemistry. Estimated costs for additional sampling are US$20,000.

2. Complete additional pond simulation tests, and model reviews, to verify the expected minerals feeding the process from the solar ponds. Estimated cost is US$50,000 for testing, sampling, and analytical support.

3. Analyze the effects of the addition of sodium sulphate, or residual brine from the final crystallization pond, at various addition ratios to optimize potassium recovery in the solar crystallization ponds. Results of the test would assist with prediction of potassium recoveries and recovery costs. Estimated cost is US$100,000 for testing and analytical support.

4. Use the information provided by the test work mentioned above to maximize recovery of potassium in flotation and crystallization by identifying optimal conversion conditions and the availability of the brine for flotation. Results include identification of key process parameters and costs associated with successful flotation. Estimated cost is US$100,000 for testing and analytical support.

5. Additional flotation work should be performed to refine the reagents identified in the preparation of the Technical Report. In the next stage of testing, brine used in flotation should be equilibrated with typical feed prior to flotation testing. Test results include the potential for improved potassium flotation recovery and grade resulting from combined collectors. The estimated cost is US$60,000 for testing and analytical support.

6. Further study of the leonite/SOP crystallization process to optimize retention times and temperatures is recommended to maximize leonite yield. The estimated cost is US$100,000 for testing and analytical support.

7. Preliminary evaluation of the feasibility of lithium production from solar pond bitterns is recommended for an estimated cost of US$25,000 for preliminary testing and analytical support. If this work shows promise, additional testing would be recommended to more fully define potential recovery and operating costs. Lithium available in the bitterns as concentrated as 0.134 percent lithium and could be as much as 1,277 tonnes (1,408 tons) per year.

8. Ancillary product recovery may enhance the overall value of the project as the brine from the Sevier Playa could result in several products other than SOP, including those listed in Table 26-1. Sodium sulphate flotation, and crystallization or selective precipitation testing on the bitterns is suggested. These tests are estimated at US$50,000, including analytical support. Additional testing to more fully define potential recoveries and operating costs may be recommended based on the results.

TABLE 26-1
Alternative Product Recovery

Potential Product	Availability	Requirements	Comment
NaCl (halite)	Relatively pure and abundant in pre-concentration ponds	Harvest from ponds and wash to remove impurities	Low value product, but low cost of production.
Na_2SO_4 (sodium sulphate)	Could be produced in first production pond	Flotation needed to separate from other salts	Low value product, but may be used for enhanced leonite production
Leonite: $K_2SO_4{\cdot}MgSO_4$ $4H_2O$	Low-grade product in flotation concentrate	Recover from flotation product stream	Reduced amount of feed to crystallization; less SOP production and smaller crystallizers needed
Leonite: $K_2SO_4{\cdot}MgSO_4$ $4H_2O$	High-grade product from 4-effect crystallizer	Recover from leonite product stream	Reduced feed to SOP would result in less SOP, less SOP mother liquor, and lower purge requirements
$MgSO_4$ (magnesium sulphate)	Available in second or third production ponds	Flotation needed to recover magnesium sulphate from other salts	
$MgSO_4$ (magnesium sulphate)	Dissolved in bitterns with K_2SO_4 and Li	May need to be removed from solution for Li recovery	Need to evaluate Li recovery and determine if $MgSO_4$ and K_2SO_4 can be recovered as co-products
$MgSO_4$ (magnesium sulphate)	Present in leonite crystallization mother liquor with potassium sulphate	Recover by selective crystallization or precipitation	Development of potential will require significant test work
$MgCl_2$ (magnesium chloride)	Present in residual solution from production ponds - bitterns	Evaporation, either in crystallizer or solar ponds	May require additional processing to remove contaminants. May concentrate lithium further
Lithium	Available in pond bitterns (2 g/L)	Separation from dissolved K and Mg salts	Selective precipitation, resin ion exchange, solvent extraction, or membrane processing

26.4 Feasibility Study

A feasibility study to include design services and additional reporting is recommended to further the design and refine the cost estimate. The cost of the feasibility study is estimated at US$2.0 million.

26.5 Environmental Permitting

Continuation of environmental permitting activities is recommended for an estimated cost of US$1.5 million.

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Appendix A
Groundwater Flow and Transport Modeling Report, Sevier Lake Playa Brine Mining Project, Utah

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GROUNDWATER FLOW AND TRANSPORT MODELING REPORT SEVIER LAKE PLAYA BRINE MINING PROJECT, UTAH

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November 2013

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GROUNDWATER FLOW AND TRANSPORT MODELING REPORT SEVIER LAKE PLAYA BRINE MINING PROJECT, UTAH

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LIST OF ACRONYMS AND ABBREVIATIONS

amsl – above mean sea level
bgs – below ground surface
BLM – Bureau of Land Management
cfs – cubic feet per second
°C – degrees Celsius
EC – electrical conductivity
EPA – United States Environmental Protection Agency
ET - evapotranspiration
ETg – evaporation from groundwater
°F – degrees Fahrenheit
ft. – feet
g – gram
GHB – general head boundary
gpd = gallons per day
gpm – gallons per minute
in. – inch
K = hydraulic conductivity
K_d – distribution coefficient
kg – kilogram
L – liter
LAK – MODFLOW lake package
LRZ – lower resource zone
L LRZ – lower part of lower resource zone
L URZ – lower part of upper resource zone
m – meter
mg – milligram
mg/L – milligrams per liter
ml – milliliter
mm – millimeter
MODFLOW – Modular Three-Dimensional Finite-Difference Ground-Water Flow Model
mt – million tons
ORP – oxidation reduction potential
RMS – residual mean square
PEA – Preliminary Economic Assessment
PFS – Preliminary Feasibility Statement
PEST- Model-Independent Parameter Estimation and Uncertainty Analysis
ppm – parts per million
SFR – MODFLOW stream-flow routing package
T – transmissivity
URZ – upper resource zone
U LRZ – upper part of lower resource zone
U URZ – upper part of upper resource zone
USGS – United States Geological Survey
UTM – Universal Transverse Mercator
WGS84 – World Geodetic System

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1. INTRODUCTION

A series of groundwater flow models were developed for EPM Mining Ventures Inc. (EPM) to support the Preliminary Feasibility Study ("PFS") for the production of Sulphate of Potash ("SOP") from its Sevier Lake Playa Sulfate of Potash Project (the "Project") located in southwestern Utah.in accordance with National Instruments 43-101 Standards for Disclosure for Mineral Project (NI 43-101). The project proposes to pump brine from trenches embedded in playa lake beds and concentrate the potash by solar evaporation. The purpose of the groundwater models was to provide data to assist in determining the following:

- A sustainable brine extraction rate;
- The volume of recharge required to maintain head in playa aquifer;
- The rate of brine concentration dilution from the injection of replacement water;
- Extraction and recharge trench spacing;
- The relative contribution of the upper and lower zones to the overall brine resource;
- Evaluation of deep trenches versus wells to extract brine from the lower resource zone;
- Well field density and sustainable extraction rate in the case the lower zone is accessed through wells.

2. INITIAL PLAYA-WIDE GROUNDWATER FLOW MODEL

Previous data collected during the 2011 – 2012 timeframe (CH2M Hill, July 2012), as well as data collected specifically for the modeling effort during the Spring 2013 field season, were used to develop a site-specific hydrogeologic conceptual model of Sevier Lake Playa. Based on the conceptual model and the aquifer stress test model, a playa-wide numerical groundwater flow model was developed.

2.1 Conceptual Model

In general, data indicate the system is layered, with at least two main water bearing zones containing brine of sufficient grade for extraction. The boundaries of the uppermost water bearing zone (fissured clay), referred to as the upper resource zone (URZ), appear to be well-constrained by the data collected thus far. The top of the upper resource zone appears to be at least partially confined by a fat clay layer, up to 3.7 m (12 ft.) in thickness. The boundaries of the lower resource zone (LRZ) are less well understood, but the contact with the overlying upper resource zone is generally gradational, occurring at depths of perhaps 10.7 to 15.2 m (35 to 50 ft.) bgs. Whether the contact is gradational, or constitutes an aquitard separating the two water bearing units has been somewhat explored and little data are available to support a playa-wide aquitard dividing the upper and lower resource zones into two distant regions of flow.

Based on some data indicating depth of refusal for a series of direct-push drill holes comingled with data from similar boreholes that were advanced to depths of approximately 40 feet bgs, reference is made to "a relatively dry, layer of stiff clay" which separates the upper and lower resource zones (March Consulting Associates, 2012). However, because a great many of drill holes were advanced to approximately 40 feet bgs and did not record a depth of refusal, there is no way to determine whether a depth of refusal existed below the drill hole termination depth or existed at all. In any case, refusal was reported as a qualitative characteristic with no specific data attached, was not well-correlated with "dry, stiff clay" and no hydrologic properties data were collected or are available to determine the hydrologic characteristics of such a division if present.

Hydrologic properties of sufficient quality for model input are available for a limited number of sites from the 2011-2012 time frame, but are spatially limited to the horizontal direction (x,y). Specific capacity data and associated transmissivities derived from these measurements are available for 36 sites throughout the Sevier Lake Playa. These data are potentially useful for helping understand spatial variability, but without a clear understanding of the degree that well construction issues affect the results, the use of these data were limited.

These data were supplemented by hydrophysical testing and a long-term (8.8 day) trench-to-trench aquifer stress test performed during the first half of 2013.

2.2 Initial Playa-Wide Model Construction

The groundwater model for the Sevier Lake Playa was performed with two separate codes; initial model development was done in MODFLOW-2005 in order to couple stream-flow and lake interaction to gain an early understanding of playa lake dynamics. This modeling was followed with transport modeling performed with MODFLOW-SURFACT, which lacks some of the features of MODFLOW-2005, but does incorporate a robust transport simulation capability as well as advanced solvers. The model domain, grid, and layers are summarized in the following sections.

Groundwater Vistas version 6.5.1, (ESI, 2011) was used at the pre-and post-processor to build the model grid, implement boundary conditions, and process model output.

2.2.1 Model Discretization

The Groundwater Vistas computer modeling application was utilized to construct the model grid and layers. The initial grid was setup with 100 m (x, y) cells with an extent in the x dimension (east-west) of 25,000 cells and an extent in the y dimension (north-south) of 43,500 cells (Figure 1). Table 1 summarizes the parameters used in the construction of the grid.

Table 1. Groundwater Model Grid Construction Parameters.

Construction Parameter	X (meters)	Y (meters)	Total
Cell size	100	100	—
Extents	25,000	43,500	1087.5 km^2
Number of cells	250	435	108,750
Coordinates (SW corner)	304,868	4,288,076	—
Coordinates (NE corner)	329,868	4,331,576	—

NOTES:
Coordinates in WGS84, UTM

The groundwater model initially consisted of seven layers (Figure 2). Construction details are presented in Table 2.

2.2.2 Areal Recharge and Evapotranspiration

Precipitation directly to the Playa was reported in the NI 43-101 Technical Report (March Consulting Associates, 2012, with an effective date of November 16, 2012) as approximately 20 cm (0.2 m) per year, summarized over a ten-year period. The initial value of areal recharge was based on an estimate from another study (CH2M Hill, 2012) utilizing an analysis of recharge in mud versus salt encrusted areas, which computed a 0.02 m/year rate. This value indicates that about 10% of the precipitation value was therefore presumed to actually infiltrate to groundwater. For the steady state model, this value was converted to a daily rate (5.45E-5 m/day) and specified as a property into the model. The recharge package is set to act upon the highest active layer in the model in order to interact correctly when lake cells dry out, otherwise recharge would terminate at the top of any dry lake cell.

Evapotranspiration from groundwater was specified at a rate 0.285 m/year, converted to a daily rate of 0.00078 m/day for model input. This estimation was based on values obtained from literature sources presented in Table 3. The extinction depth was specified at 1.9 meters (about half the depth to the bottom of the fat clay).

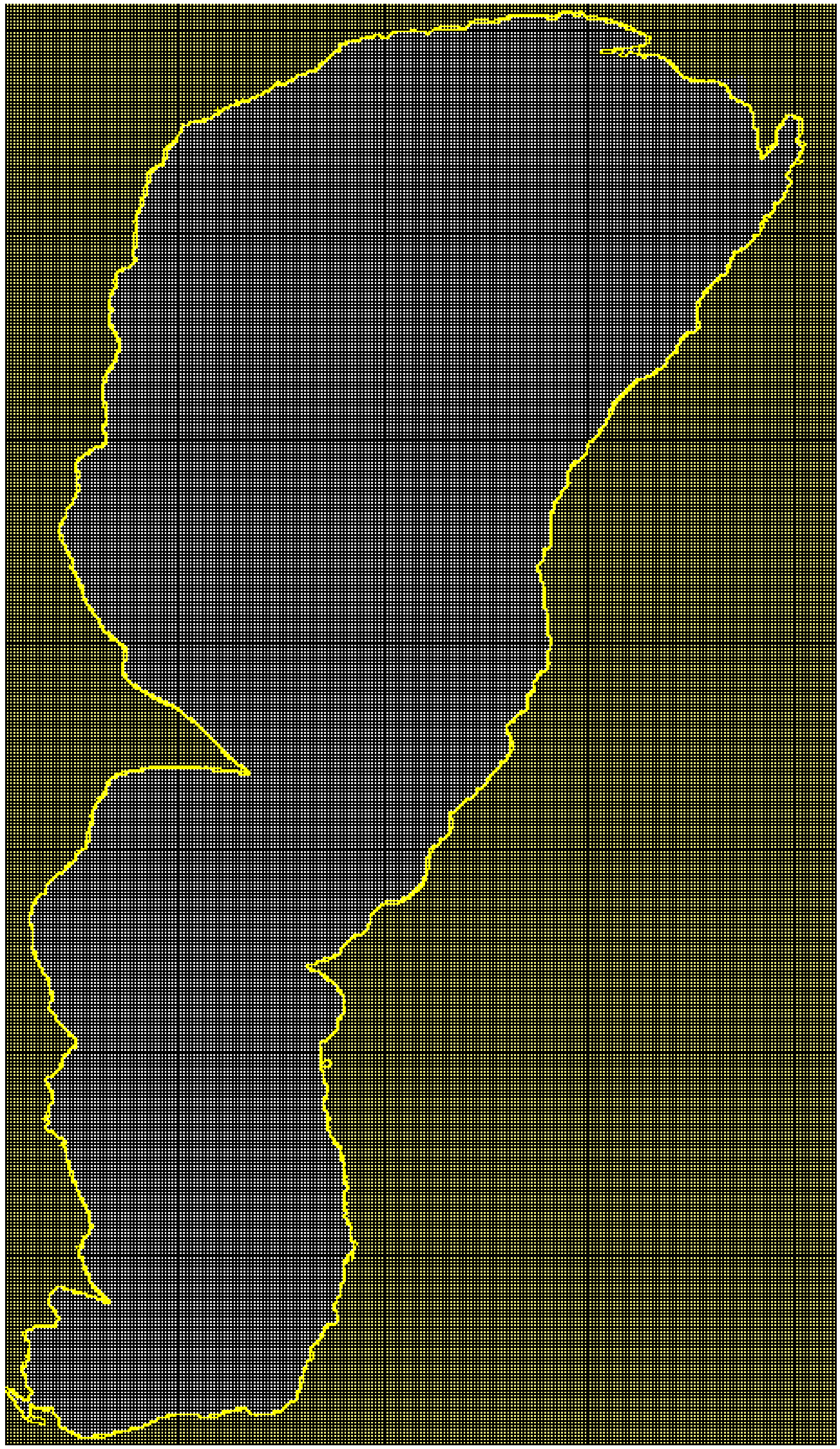

Figure 1. Model Domain. No-Flow Boundary Condition On Outside of Yellow Line.

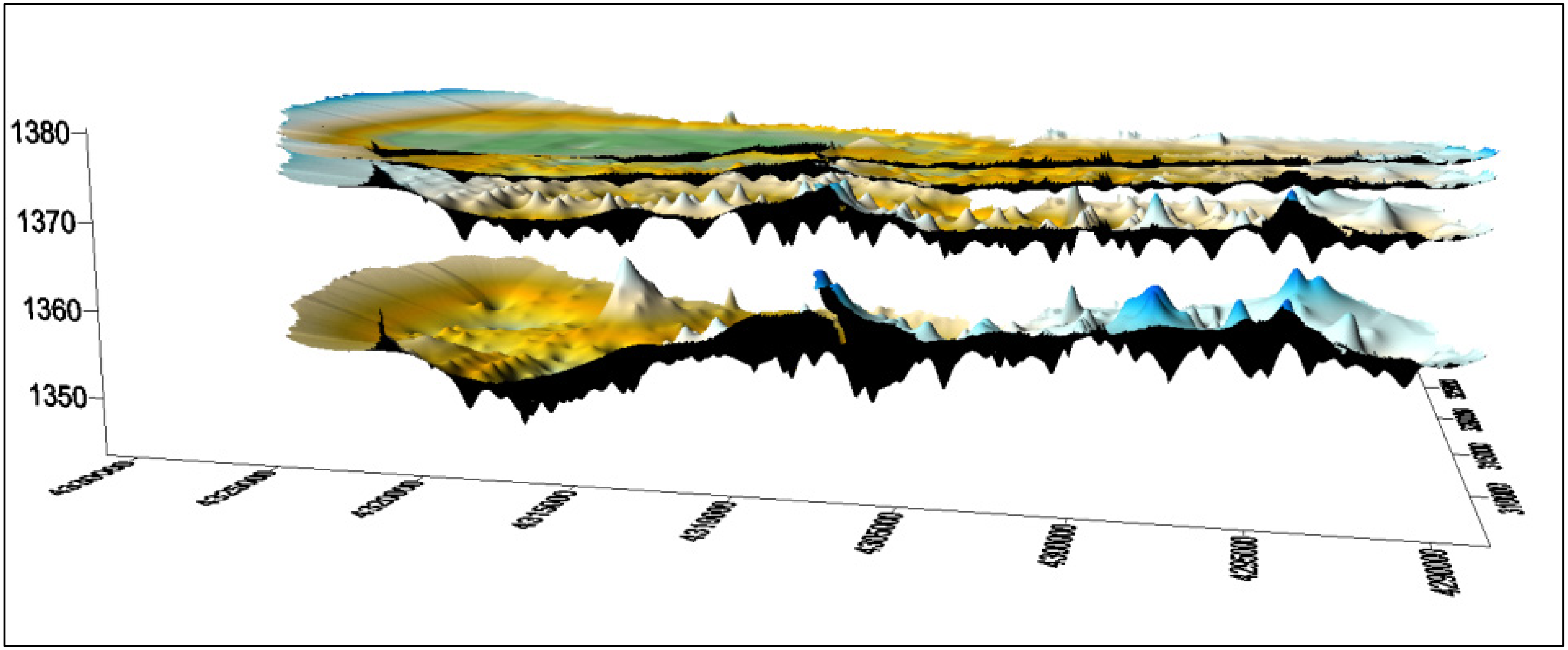

Figure 2. Three-Dimensional Depiction of Model Layer Bottoms including layer 1 (playa lake), layer 2 (surficial fat clay), layer 4 (URZ), and layer 6 (LRZ).

NOTE:

The top of Layer 1 (lake) and bottom of layer 7 cannot be shown because they have no relief. The elevation of these layers is set to 1381 m and 1300 m amsl respectively. The bottoms of the upper URZ (Layer 3) and the middle aquitard (layer 5) are not shown for the sake of clarity.

Table 2. Description of Groundwater Model Layers.

Layer	Name	Tops and Thicknesses	Comments
1	Lake	zMax: 1,381.00 zMin:1377.69	The lake layer was constructed by pulling the 1381 m contour line from the USGS DEM of the area and importing that line into ArcGIS. Data from several GPS-based surveys of the interior playa surface were joined to the line which was assumed to represent the high water mark of the playa lake if completely full. These data were gridded with a kriging algorithm, and imported into Groundwater Vistas. The constructed surface formed the bathometry of the lake bottom, while the top of the layer was set to 1381 m amsl.
2	Fat Clay	zMin: 1373.34 zMax: 1377.69 Varies, 0.4 to 3.25	The top of the fat clay is modeled as the playa surface (the lake bottom as described above). The fat clay bottom elevation was constructed as follows: Based on available drill data, the top of the URZ is generally assumed to be 3.66 m bgs (12 feet). However, because the thickness of the URZ is variable, assuming a constant thickness for the fat clay of 3.66 m would resulted in the top of the upper URZ (and in some cases, the top of the lower URZ) penetrating the bottom of the fat clay when gridded and contoured. Therefore the fat clay thickness was assumed to never exceed 3.66 m, and an equation was developed based on an assumed proportion of the fat clay to the URZ 3.66/12.19 m (12/40 feet), giving a percentage of 0.3. The thickness of the fat clay at all locations where URZ thickness data were available was then calculated by multiplying the URZ thickness by 0.3. The calculated values were then limited to a maximum of 3.25 m for a small safety factor, and then subtracted from the elevation of the playa surface at those points to calculate the elevation of the bottom of the fat clay. These data were gridded with a kriging algorithm, contoured and imported into Groundwater Vistas.
3	Upper URZ	Variable, 0.53 to 4.69	This layer was constructed directly in Groundwater Vista by assuming that the thickness of the upper URZ was represented by the interval 3.66 to 6.71 m bgs (12 to 22 feet). The total thickness of the URZ (upper and lower zones) is assumed to be represented by the interval 3.66 to 12.2 m bgs (12 to 40 feet). The upper URZ represents a percentage equal to 0.35 of the total assumed thickness of the URZ. Represents the most permeable and densely fissured zone of the upper clay aquifer.
4	Lower URZ	Varies, 0.99 to 8.72 . zMin:1363.46 zMax:1375.76	Data for URZ bottom were obtained from the drill hole database. The selected data corresponded to lithology code BR1, and horizon code of 100, indicating full penetration. These data were gridded with a kriging algorithm, contoured and imported into Groundwater Vistas. This layer has similar properties to the upper URZ but is hypothesized to contain less fissuring and slightly less permeability.
5	Middle aquitard	Varies, 1 to 2 meters. zMin: 1363.46 zMax: 1375.76	This layer corresponds to a depth of refusal which was obtained from direct push drilling. Its hydraulic properties are unknown but are assumed to represent that of an aquitard between the URZ and the LRZ. The thickness of this aquitard (if it exists) is unknown, but was assumed to vary between 1 and 2 meters for purposes of the model. This was calculated by calculating thickness using a random number generator which randomly assigned thicknesses which varied between 1 and 2 meters to drill hole locations which were assigned a lithology code of BR1, and a horizon code of 100, indicating full URZ penetration. These thicknesses were subtracted from the bottom elevation of the URZ to generate values for the bottom elevation of the aquitard. These data were gridded with a kriging algorithm, contoured and imported into Groundwater Vistas.
6	LRZ	Varies, 0.68 to 24.9	Data for LRZ bottom were obtained from the drill hole database. These data were selected from rows with a lithology code of BR2, and a horizon code of

		zMin: 1347.48 zMax:1365.61	200, indicating full LRZ penetration. These data were gridded with a kriging algorithm, contoured and imported into Groundwater Vistas. This layer represents intercalated lean and fat clay, silty clay, sandy clay, and silty-sandy-gravelly clay.
7	Deep Lacustrine	zMax: 1365.61 zMin: 1300.00	Lacustrine sediments undifferentiated. Only a couple boreholes penetrated these strata and little is known regarding their hydrologic characteristics, other than they produced some brine. This layer is not considered a resource at this time.

NOTES:
bgs = below ground surface, URZ = upper resource zone, LRZ = lower resource zone.
All elevations in meters above mean sea level (amsl).

Table 3. Literature Sources Used for Estimation of ET from Groundwater.

Value (m/year)[1]	Description	Source
0.03048	ET from groundwater, Great Basin, USA	Heilweil, V.M. et al., (2010)
0.1676	ET total, Dugway, Utah, USA	Malek, E., (2003)
0.1524	ET (mean annual rate), Sarcobatus Flat playa, Death Valley, CA USA	Laczniak, R.J. et al., (2001)
0.74	Evaporation, Estancia Basin, central New Mexico, USA	Menking, K.M. et al., (2000)
0.23	ET, Moist playa, Pilot Valley, Utah, USA	Malek, E. et al., (1990)
0.82	Evaporation, Estancia Basin, central New Mexico, USA	DeBrine, B.E., (1971)
0.039	Groundwater discharge by ET, Death Valley, CA USA	DeMeo, G.A. et al., (2003)
0.104	Groundwater evaporation, Owens Lake, CA, USA	Tyler, S.W. et al., (1997)
0.285	Mean value	

NOTES:
m = meters

2.2.3 Boundary Conditions

Several boundary conditions were implemented in the model as described below in each sub-section.

2.2.3.1 No-Flow Boundaries

The entire model is surrounded by no-flow cells at the playa boundary. This condition is carried through all layers of the model. Water can therefore only enter and exit the model through the surficial layer, reflecting the current understanding of the Sevier Lake Playa hydrologic system.

2.2.3.2 Stream Boundary

A head-dependent boundary condition was implemented at the northeast corner of the model where the Sevier River entered the playa. The stream boundary condition was implemented in the model by the USGS MODFLOW Stream-Flow Routing (SFR1) package (Prudic, et al., 2004). Where stream inflow or outflow to and from lakes is a required element of the groundwater system, the SFR1 package can be linked with the LAK3 Package which was implemented at the last reach of the last segment of each of branch of the river. This is probably the most complicated part of the model to implement, yet the most obvious and directly observable hydrologic boundary. The Sevier River branches into two sections north of the playa boundary, one heading west-southwest and other directly south. Both branches terminate at low spots on the playa surface (Figure 3).

This boundary condition was constructed by digitizing the course of the Sevier River as it traverses the playa and importing that shapefile into Groundwater Vistas. The Sevier River was divided into two headwater SFR segments to represent each branch of the river. Channel widths were estimated based on measurements made from digital aerial photographs. Review of aerial photographs indicates that many segment divisions based on width could possibly have been made. However based on the uncertainty of flow at any one time and the particular channels occupied at a particular flow rate, there was little to gain from such an analysis.

Table 4. Properties Assigned to Each On-Playa Segment of the Sevier River.

NSEG (segment no.)	HCOND (m/day)	THICK (m)	ELEV (m amsl)	WIDTH (m)
1 (East) - start	1.8E-05	0.01	1380.85	30
1 (East) - end	1.8E-05	0.01	1375.96	230
2 (West) - start	1.8E-05	0.02	1380.94	55
2 (West) - End	1.8E-05	0.01	1376.70	100

NOTES:
HCOND = hydraulic conductivity of the streambed.
THICK = thickness of the streambed material.
ELEV = elevation of the top of the streambed (meters amsl).
WIDTH = average width of the stream channel

Therefore, an initial and final channel width was assigned to each segment and the SFR package was allowed to linearly interpolate channel width at each reach using those values. Physical and hydrologic properties assigned to each segment and interpolated for each reach of the segment are presented in Table 4.

Stream flow routing parameters assigned to each segment are presented in Table 5. The estimate for stream flow was obtained from the base case estimation provided by "Recharge Estimates, Enhancements, and Assumptions for Sevier Lake" (CH2M Hill, 2012). Table 6 presents an accounting of the apportionment of flow based on this estimation.

A freshwater evaporation rate of 0.0039 m/day (56 in./year) obtained from a separate study (Miller, 2013) was applied to each specific stream segment (length multiplied by average channel width) and subtracted from the beginning segment flow to arrive at the inflow at the next segment downstream. No losses from infiltration were assumed upstream from the playa boundary. The SFR package calculated all gains and losses from the playa boundary to the respective desiccation point of each respective segment.

2.2.3.3 Lake Boundary Condition

A lake boundary condition was implemented to represent the playa lake which seasonally occupies many areas of low elevation on the playa and rapidly changes stage and location as a result of precipitation or the action of wind moving the water around. This boundary was constructed by placing lake cells in the top layer of the model using the MODFLOW LAK3 Package (Merrit and Konikow, 2000). Where stream inflow or outflow to and from lakes is a required element of the groundwater system, the SFR1 package was linked with the LAK3 Package.

The elevation of the top of the lake was assumed to be equal to the 1380 m amsl contour line obtained from the USGS DEM for the Sevier Lake Playa Area. The elevation of the bottom of the lake was set to surface obtained from survey data of the playa surface.

A literature search on modeled stream-lake interactions identified a USGS study currently underway at Walker Lake in western Nevada (Allander et al., 2012). The USGS personnel working on this project communicated that they requested and implemented a change to the LAK package to better represent stream and lake coupling for terminal lake systems where lake stage, volume, and surface area is highly variable and controlled by lake bathometry[1]. In addition, previous versions of the LAK package could not account for dynamic lake size and dynamic stream length. In the case of Walker Lake, there is many times where the Walker River desiccates before reaching Walker Lake, and other times where there is a direct hydraulic connection. If stream and lake boundary conditions are fixed in space, an estimate must be made of the average conditions for the position of the stream terminus and the maximum surface area of the lake.

[1] Personal communication, Kip Allander (USGS) to J. Kaminsky (Whetstone Associates, Inc.), April 29, 2013.

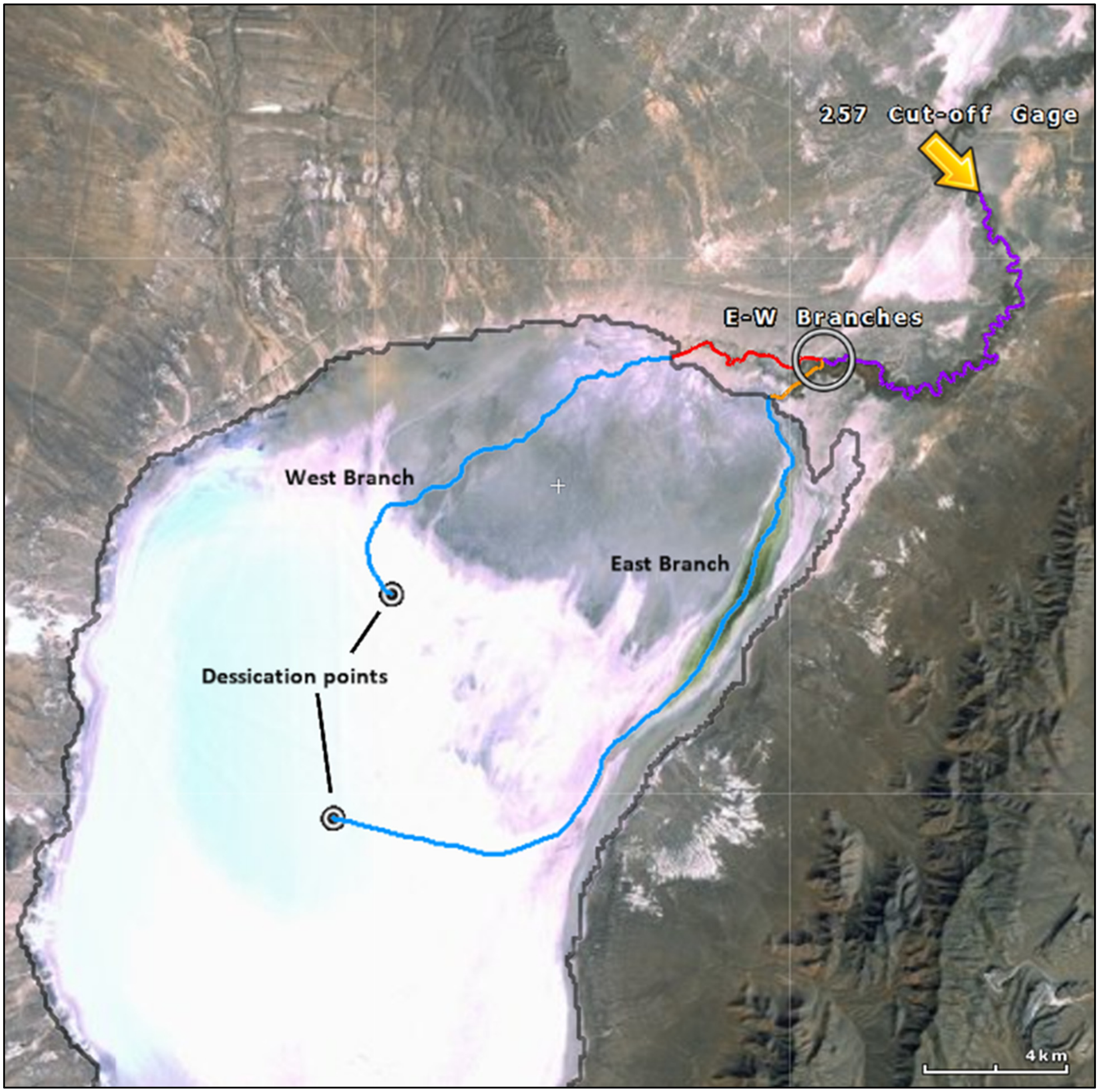

Figure 3. Natural Sevier River Channels Digitized for the SFR Package Boundary Condition.

Table 5. SFR Package Parameters from Each Segment.

NSEG	ICALC	OUTSEG	IUPSEG	IPRIOR	NSTRPTS	FLOW (m^3/day)	RUNOFF (m^3/day)	ETSW (m/day)	PPTSW (m/day)	ROUGHCH
1 (East)	1	-1	0	--	256	2.85E04	0	0.0039	5.56E-04	0.015
2 (West)	1	-1	0	--	146	6.69E03	0	0.0039	5.56E-04	0.015

NOTES:

NSEG = segment number.
ICALC = stream depth calculated with Manning's equation assuming a wide rectangular channel.
OUTSEG = integer value of the downstream segment which receives tributary inflow from the last downstream reach of this segment. If this segment discharges to a lake, the parameter is set to the negative value of the lake identification number.
IUPSEG = integer value of the upstream segment from which this segment receives water from. If the segment in question is a headwater segment the parameter is set to zero.
IPRIOR = parameter used when IUPSEG < 0 and defines the prioritization scheme for diversion.
RUNOFF = Volumetric rate of diffuse overland runoff that renters the stream segment.
ETSW = volumetric rate per unit area removed of water removed by evaporation directly from the stream channel.
PPTSW = volumetric rate per unit area of water added by precipitation directly on the stream channel.
ROUGHCK = Manning's roughness coefficient for channel.

Table 6. Flow Assumptions for Sections of Sevier River

Metric	Quantity[1]	Notes	Source
Sevier River flow upstream from playa boundary	15 cfs	Assumed to be the flow at the last gage before the playa boundary (257 cut-off gage).	CH2M Hill (2012)
Channel dimensions - 257 Cut-off gage to Sevier River E-W branches	Average width: 16 m Length: 16,139 m	Estimated from measurements taken from aerial photos	Whetstone (this model).
Flow at E-W branches of Sevier River	14.62 cfs	Flow at 257 cutoff minus evaporation.	Whetstone (this model).
East Branch Sevier River flow to Playa Boundary	11.7	Estimated at 80% of total flow available at the E-W division.	Whetstone (this model).
Channel dimensions - East branch to playa boundary	Average width: 15 m Length: 1,757 m	Estimated from measurements taken from aerial photos	Whetstone (this model).
East Branch Sevier River flow at Playa Boundary	11.66 cfs	Flow at E-W division minus evaporation.	Whetstone (this model).
Segment 1 - Channel dimensions - West branch from playa boundary to desiccation point	Begin width:30 m End width: 230 m Length: 19,824 m	Flow, infiltration, and evaporative loss computed by SFR package.	Whetstone (this model).
West Branch Sevier River flow to Playa Boundary	2.92 cfs	Estimated at 20% of total flow available at the E-W division	Whetstone (this model).
Channel dimensions - West branch to playa boundary	Average width: 25 m Length 5,135 m	Estimated from measurements taken from aerial photos	Whetstone (this model).
West Branch Sevier River flow at Playa Boundary	2.74 cfs	Flow at E-W division minus evaporation.	Whetstone (this model).
Segment 2 - Channel dimensions - West branch from playa boundary to desiccation point.	Begin width 55 m End width: 100 m Length: 11,678 m	Flow, infiltration, and evaporative loss computed by SFR package	Whetstone (this model).

NOTES:

1. cfs= cubic feet per second; m = meters. Calculated downstream values do not imply that an actual measurement was made, or imply a known precision.

Otherwise, when the lake surface area increases due to wetter conditions, the lake will inundate the lower reaches of the inflowing stream and the model has no way to properly account for a moving boundary where lake, stream and groundwater interactions occur. Such is the case for the Sevier Lake Playa.

To deal with dynamic river length, Walker River is routed to desiccation point of Walker Lake where it discharges. Stream bed leakage is toggled to zero when the stream is below the lake surface, conceptually turning river into a pipe beneath lake. Lake volume is iteratively simulated using lake water budget determinations. Stage and area of lake are determined from stage-area-volume relation. New stage and area values are used in next iteration of lake computations.

A decision was made to implement this modification of the LAK package. Each segment of the Sevier River that flows onto the playa was routed to a respective desiccation point which was identified from aerial photographs. When compared to playa surface survey data, these two points corresponded to topographic low spots. Because the lake could conceptually occupy the entire playa surface (which it has during the 1980s), the entire lake surface up to the 1380 m contour line was assigned a lake boundary cell in layer 1. Stage, volume and surface area relations were computed by creating a solid composed of the flat lake surface at elevation 1381 m amsl representing the top, and bottom and sides represented by the playa surface, which is slightly bowl shaped. A series of 151 successive horizontal slices were taken of the solid in order to generate the data required by the lake package. These data were captured in a text file and specified in the

LAK input file with the new keyword TABLEINPUT and then assigned IUNIT 45 in the MODFLOW name file.

Table 7 presents the parameters used for specifying the LAK package boundary condition. Precipitation (PRCLAK) is specified as the daily rate (m/day) based on annual precipitation of 8 inches per year. Evaporation from the lake surface is specified as daily rate on the assumption of brine rather than freshwater. This value was obtained from estimates of the freshwater evaporation rate (56 inches/year) and converted to a rate for brine using a conversion factor of 0.6 (Gwynn, 2006), and then converted to a daily rate for input into the model. The lakebed was assigned a hydraulic conductivity of 1.8E-05 m/day (based on SDRI data) and a thickness of 0.1 m.

The RNF factor represents recharge to the lake water body that is assumed to enter the lake as surface run-off generated from surrounding catchment areas. This water was estimated by digitizing catchment areas based primarily on USGS hydrologic units. Areas for 13 catchments were measured and summed for a total of 1573.5 km^2. The area of the playa lake at full stage was calculated at 490.9 km^2. The watershed is therefore 3.2 times the size of the playa lake at full stage. It is assumed that 6.3% of precipitation falling on surrounding watersheds becomes available for run-off to the lake.

Table 7. LAK Package Boundary Condition Parameters.

THETA	NSSITR	SSCNCR (m)	STAGES (m amsl)	SSMN (m amsl)	SSMX (m amsl)	PRCPLK (m/day)	EVAPLK (m/day)	RNF	WITHDRW (m^3/day)
0	75	1.000e-03	1377.0	1376.0	1381.0	5.560e-04	2.300e-03	-0.2	0.0

NOTES:

THETA = Solution for computation of lake stages, 0 = explicit.
NSSITR = Maximum number of iterations for Newton's method solution for equilibrium lake stages.
SSCNR = convergence criteria for Newton's method.
STAGES = Initial stage of lake at beginning of a run.
SSMN = Minimum stage allowed for lake in steady-state solution.
SSMX = Maximum stage allowed for lake in steady-state solution.
PRCPLK = rate of precipitation per unit area at the surface of lake.
EVAPLK = rate of evaporation per unit area from the lake surface.
RNF = overland runoff from an adjacent watershed. If RNF < 0, its absolute value is used as a dimensionless multiplier applied to the product of the lake precipitation rate per unit area and the surface area of the lake.
WITHDRW = Volumetric rate of water removal (or addition) from lake by means other than rainfall, evaporation, surface outflow, and groundwater seepage. Positive values indicate augmentation, negative values indicate withdrawal.

From these assumptions, the RNF factor is calculated by:

$$RNF = \frac{watershed\ area}{lake\ area} x\ fraction\ of\ precip\ becoming\ runoff = \frac{1573.5}{490.9} x\ 0.063 = 0.2$$

2.2.3.4 General Head Boundaries

Based on work performed and reported in other studies (Table 7 of CH2M Hill, 2013), mountain block recharge was hypothesized to provide a limited source of groundwater recharge to the playa. This hypothesis was tested by assuming such water would enter the sides of the model in layers two through seven. This boundary condition was implemented with general head boundaries on the cells on the inside of the no-flow playa boundary.

The general head boundaries were developed using water level data from selected from 44 wells available outside the area of the playa and are presented in Table 8. Of these wells, appropriately located well pairs were identified for the computation of the required input to the GHB package.

Freshwater head corrections were made to measured water levels due to solute-induced variable-density conditions outside the playa.

Table 8. Well Data for GHB Data Input

Well ID (pairs are indicated by shading)	Gradient Direction with respect to playa	Spring 2013 Potentiometric Elevation (m amsl)	Feb-Mar 2012 Sample Round (TDS mg/L)	Estimated density at 10 °C (g/cm³)	Estimated Mean Screen Elevation (m amsl)	Freshwater Head - Corrected Head ($h_{f,i}$) (m amsl)
Amasa Well	away	1,368.242	52,600	1.041	1,354.240	1,368.813
SN-13-LL5		1,377.954	198,250[3]	1.162	1,360.768	1,380.735
UDOT 3	away	1,354.852	2,820	1.002	1,310.226	1,354.938
SN-13-LL5		1,377.954	198,250[2]	1.162	1,360.768	1,380.735
UDOT 3	away	1,354.852	2,820	1.002	1,310.226	1,354.938
SN-13-LL3		1,379.041	182,333[2]	1.148	1,365.758	1,381.006
North Cricket	toward	1,398.095	760[4]	1.000	1,341.372	1,398.114
SN3-12-53R		1,377.3441	184,500	1.150	1,360.543	1,379.861
Headlight Gap Well	toward	1,380.077	122,000	1.097	1,351.653	1,382.829
Erehwon Well		1,379.764	100,000[1]	1.079	1,349.792	1,382.124
Dike Access	away	1,369.649	13,800	1.010	1,273.085	1,370.661
RR7-1		1,379.314	66,600	1.052	1,334.494	1,381.639
Crystal Peak Rd Well	away	1,354.777	3,410	1.002	1,351.956	1,354.784
Wishing Well		1,360.132	51,500	1.040	1,352.829	1,360.423
Black Hills Well	away	1,350.560	536	1.000	1,296.536	1,350.568
PVC Shoal Well		1,377.618	38,200	1.029	1,376.542	1,377.650
Miller Canyon	away	1,350.455	1,150	1.001	1,345.978	1,350.458
SN3-12-049		1,377.356	141,667[2]	1.146	1,360.086	1,379.876

NOTES:

1. Estimated from Nautllus and Headlight Gap wells results.
2. Value from Norwest resource database because CH2M Hill analytical result from well water sampling was not available.
3. Estimated from average of DP3-008 DP3-009 from Norwest Resource Database.
4. Based on Candland Spring.

The fresh water head calculations were performed using the following equation (Post et al. 2007):

$$h_{f,i} = \frac{p_i}{p_f} h_i - \frac{p_i - p_f}{p_f} z_i \qquad \text{[Eq. 1]}$$

where $h_{f,i}$ is the fresh water head, p_i (kg/m^3) is the density of the water in the piezometer tube, p_f is the freshwater density, h_i is the hydraulic head, and z_i is the elevation head that represents the mean level of the well screen.

Based on these data, the boundary conditions generally represented inflow to the playa from the east, north, and south, and outflow to east side of the playa. However, the nature of GHBs is that the direction of flow is dependent on the direction of the gradient. When heads are higher on the inside of the playa in comparison to the outside, the flow can be directed out of the model.

Nine separate GHB boundary conditions were developed for the model and are in Figure 4.

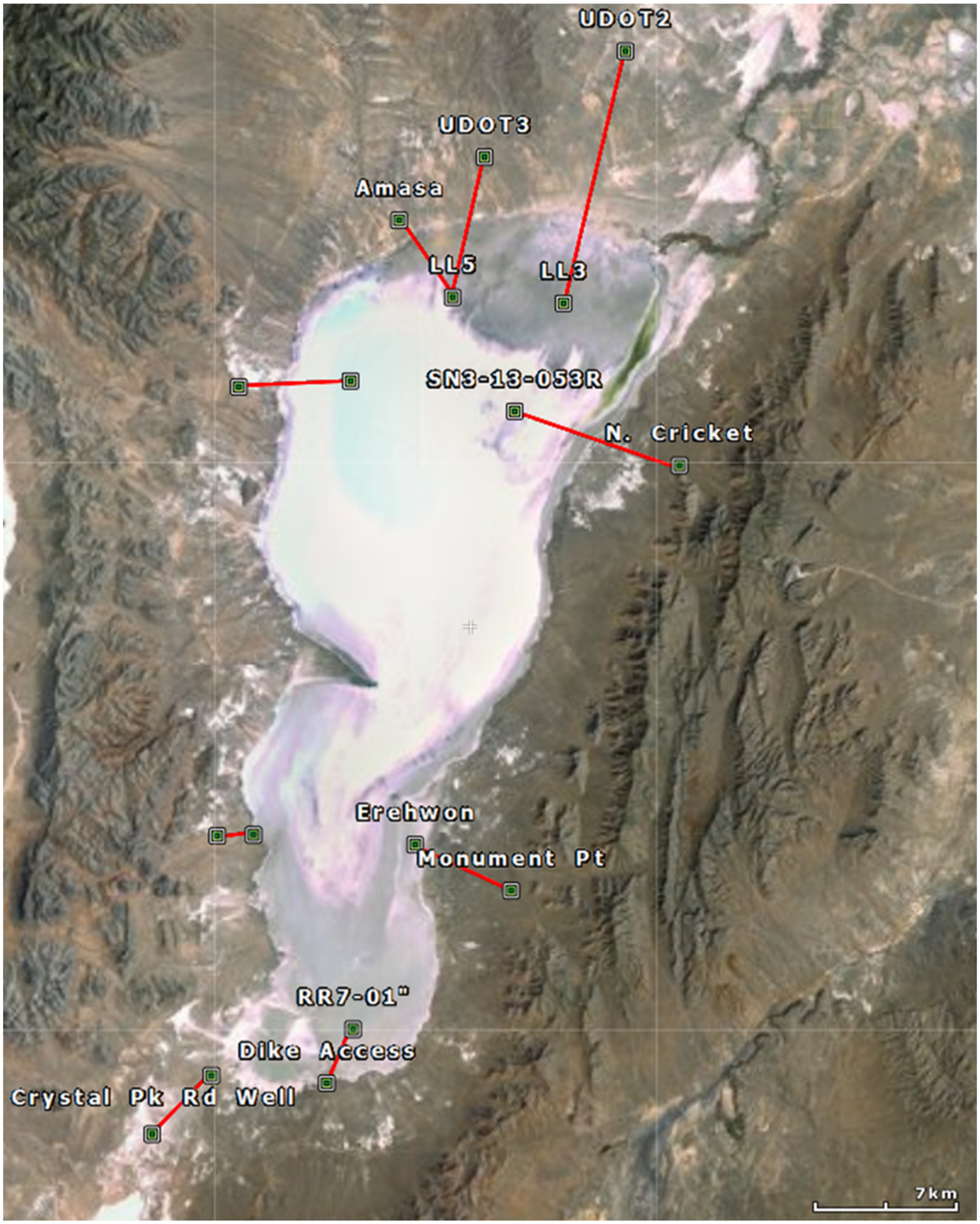

Figure 4. Locations of GHB Measurements for Evaluation of Possible Lateral Recharge to Playa.

These GHBs were assigned to layers if the layer bottom was not above the calculated GHB head, which indicated that the layer was probably not in hydraulic communication with strata from which the head value was obtained. Estimated hydraulic conductivities were applied to each GHB, using aquifer stress test data when available and estimations based on lithology where no data were available.

Subsequent model simulations with the GHBs in place created a large amount of groundwater mounding around the periphery of the playa in each layer. Attempts at reducing the amount of mounding to match observed heads using PEST-based parameter estimation of hydraulic conductivity were unsuccessful. The conclusion drawn from the analysis was that wells outside the playa boundary are not in communication with playa sediments, and the playa boundary represents a physical quasi-no-flow boundary through which very little enters the playa groundwater system.

As a result of the simulations the GHBs were removed from the model. Until better data are available from well pairs appropriately located and screened across the boundary of the playa and aquifer stress testing establishes data supporting that such wells are indeed in communication, there is little basis to place any other boundary condition around the periphery of the playa other than no-flow boundaries.

Some wells off the playa boundary do exhibit elevation solute concentration which would suggest some connection between playa water and water hosted in basin-fill sediments and probably recharged from up-gradient sources toward the mountain front. However, without additional data, the source of elevated concentrations cannot be constrained.

2.3 Initial Estimates of Model Parameters

Limited data were available for parameterizing the model. At the time of the initial model construction, the data set consisted of several well-based aquifer stress tests, two trench-based aquifer stress tests, and 36 transmissivity values estimated from single well specific capacity data using assumed well efficiencies. These data were of limited use due to uncertain bed thickness and the uncertainly associated with well efficiencies of 70% assumed for each well. The recognized difficulty in installing wells in a clay aquifer, unknown skin effect and maintaining acceptable hydraulic communication also cast additional uncertainty on well-based data.

Other sources of uncertainty include:

- Partially penetrating wells or trenches;
- Inability to maintain a constant pump rate;
- Unknown aquifer geometry (e.g., confined vs. unconfined);
- Undocumented delayed leakage;
- Discharge from pumping re-entering the subsurface within the radius of pumping influence; and
- Performing a new aquifer stress test while the aquifer was recovering from some earlier stress test(s) conducted within the radius of influence of the pumping and observation wells.

The available hydraulic properties at the time of initial steady-state model simulations are presented in Table 9. These data are a mixture of previous year's field data where noted (CH2M Hill, 2012b), reanalyzed previously existing field data, and a few values from the 2013 field season.

During the 2013 field effort, a long-term trench-based aquifer stress test was conducted and initially evaluated using the distance-drawdown modification of the Cooper-Jacob straight-line solution (Cooper and Jacob, 1946). This analysis yielded four values of transmissivity and storativity in four orthogonal directions.

Because the test duration was relatively long, and the site was densely populated with observation wells completed in the upper part of the upper resource zone, these data (Table 10) are regarded as being more reliable than values obtained elsewhere for the upper URZ.

Based on review of the entire available data as presented in Table 9 and Table 10, as well as consideration of the conditions under which data were collected, the values presented in Table 11 were input into the model for the initial calibration effort.

Table 9. Range in Available Field Hydraulic Conductivity Values.

Layer	Hydraulic Conductivity (m/day)	Specific Storage (m^{-1})	Location, Analytical Methods, Source
1 - Lake	4.86E-05	--	Vertical value based on mean SDRI result from SDRI #2 and #3 through 6/7/2013. Used only for lake bed conductance.
2 – Fat Clay	4.86E-05	--	Vertical value based on mean SDRI result from SDRI #2 and #3 through 6/7/2013.
3 – Upper URZ	69	2.9E-04	TT7-MW1, Theis (1935) confined, CH2M Hill (2012b). K and S_s were calculated with b = 8 ft. (2.44 m).
3 – Upper URZ	53	2.9E-04	TT7-MW1, Cooper and Jacob (1946) confined straight-line, CH2M Hill (2012b). K and S_s were calculated with b = 8 ft. (2.44 m).
3 – Upper URZ	4.6	8.0E-05	TT7-MW1, Barker (1988) dual porosity
3 – Upper URZ	3.9	8.3E-05	TT7-MW3, Barker (1988) dual porosity
3 – Upper URZ	69	2.9E-04	TT7-MW3, Theis (1935) confined, CH2M Hill (2012b). K and S_s were calculated with b = 8 ft. (2.44 m).
3 – Upper URZ	53	2.9E-04	TT7-MW3, Cooper and Jacob (1946) confined straight-line, CH2M Hill (2012b). K and S_s were calculated with b = 8 ft. (2.44 m).
3 – Upper URZ	1.8	1.2E-05	TT7-MW6, Barker (1988) dual porosity
3 – Upper URZ	7.0	8.8E-06	TT7-MW6, Moench (1984) dual porosity
3 – Upper URZ	54.7	1.1E-03	TT7-MW6, Theis (1935) confined. K and S_s were calculated with b = 7 ft. (2.13 m).
3 – Upper URZ	3.2	2.4E-05	TT7-MW7, Barker (1988) dual porosity
3 – Upper URZ	7.2	8.5E-05	TT7-MW2, Moench (1984) dual porosity
3 – Upper URZ	35.7	6.5E-04	TT7-MW2, Theis (1935) confined. K was calculated with b = 8 ft. (2.44 m).
3 – Upper URZ	**15.1**	**1.2E-04**	**Geomeans**
4 - Lower URZ	14.9	2.2E-02	DP3-12-232MW1, Moench (1985) Case 3, leaky confined, no flow above, constant head below, CH2M Hill (2012b). K and S_s were calculated with b = 5 ft. (1.52 m).
4 - Lower URZ	25.6	5.4E-06	TT7-MW4, Cooley and Case (1973) leaky confined overlain by water table aquitard
4 - Lower URZ	0.4	3.0E-08	TT7-MW4, Moench (1984) dual porosity
4 - Lower URZ	14.2	3.2E-04	TT7-MW4, Moench (1984) dual porosity
4 - Lower URZ	0.9	1.5E-07	TT7-MW4, Moench (1985) Case 3, leaky confined, no flow above, constant head below, CH2M Hill (2012b). K and S_s were calculated with b = 15 ft. (4.57 m).
4 - Lower URZ	7.8	4.0E-05	TT7-MW4, Moench (1984) dual porosity
4 - Lower URZ	14.1	5.5E-05	TT7-MW4, Theis (1935) confined
4 - Lower URZ	0.5	6.5E-10	TT7-MW5, Moench (1984) dual porosity
4 - Lower URZ	14.2	3.2E-04	TT7-MW5, Moench (1984) dual porosity
4 - Lower URZ	0.9	1.5E-07	TT7-MW5, Moench (1985) Case 3, leaky confined, no flow above, constant head below, CH2M Hill (2012b). K and S_s were calculated with b = 15 ft. (4.57 m).
4 - Lower URZ	40.5	5.4E-06	TT7-MW5, Neuman Witherspoon
4 - Lower URZ	12.3	3.3E-05	SN3-13-02, Moench (1984) dual porosity
4 - Lower URZ	20.6	5.5E-05	SN3-13-02, Theis (1935) confined. K and S_s were calculated with b = 15 ft. (4.57 m).
4 - Lower URZ	**6.1**	**7.1E-06**	**Geomeans**
5 – aquitard	--	--	--
6 - LRZ	0.9	--	SN3-12-045(1), Papadopulos-Cooper (1967) confined, CH2M Hill (2012). K was calculated with b = 45 ft. (13.72 m).
6 - LRZ	0.9	--	SN3-12-045(1), Theis (1935) confined, CH2M Hill (2012b). K was calculated with b = 45 ft. (13.72 m).
6 - LRZ	1.2	--	SN3-12-045(1), Cooper and Jacob (1946) confined straight-line, CH2M Hill (2012b).). K was calculated with b = 45 ft. (13.72 m).

6 - LRZ	1.1	--	SN3-12-045(1), Theis (1935) confined recovery, CH2M Hill (2012b).). K was calculated with b = 45 ft. (13.72 m).
6 - LRZ	1.1	2.77E-06	SN3-12-045(4), Papadopulos-Cooper (1967) confined, CH2M Hill (2012).). K and S_s were calculated with b = 45 ft. (13.72 m).
6 - LRZ	1.1	2.77E-06	SN3-12-045(4), Theis (1935) confined, CH2M Hill (2012b).). K and S_s were calculated with b = 45 ft. (13.72 m).
6 - LRZ	1.4	8.2E-08	SN3-12-045(4), Cooper and Jacob (1946) confined straight-line, CH2M Hill (2012b).). K and S_s were calculated with b = 45 ft. (13.72 m).
6 – LRZ	1.2	--	SN3-12-045(4), Theis (1935) confined recovery, CH2M Hill (2012b).). K was calculated with b = 45 ft. (13.72 m).
6 - LRZ	1.1	8.6E-07	Geomeans

NOTES:

1. Data from Aquifer Testing Report (Draft) (CH2M Hill, 2012b) as reported but in some cases recalculated with a smaller saturated thickness when only T or S were available. Where not referenced, results are from reinterpretation of raw data.

Table 10. Cooper-Jacob (1946) Analysis of Long-term Trench Aquifer Test.

Layer & Direction	Transmissivity (ft^2/day)	Storativity	Saturation Thickness (ft.)	Hydraulic Conductivity (ft./day)	Specific Storage (ft^{-1})	Hydraulic Conductivity (m/day)	Specific Storage (m^{-1})
3 – Upper URZ - North	438	0.020	8	55	0.0025	17	0.0084
3 – Upper URZ - South	325	0.046	8	41	0.0057	12	0.019
3 – Upper URZ - East	401	0.018	8	50	0.023	15	0.0074
3 – Upper URZ - West	528	0.014	8	66	0.0017	20	0.0057
Geomean	417	0.022	8	52	0.0028	16	0.009

Table 11. Initial Hydraulic Properties for Initial Steady-State Model Simulations.

Layer	$K_{x,y}$ (m/day)	K_z (m/day)	Specific Storage (m^{-1})[6]	Specific Yield[6]	Source
1 – Lake[1]	--	4.86E-05	--	--	1
2 – Fat Clay[1]	4.86E-04	4.86E-05	--	--	1
3 – Upper URZ[2]	20	2	--	--	2
4 - Lower URZ[2]	12	1.2	--	--	2
5 – middle aquitard[3]	0.001	0.001	--	--	3
6 – LRZ[4]	2	0.2	--	--	4
7 – Deep lacustrine[5]	0.1	0.01	--	--	5

NOTES:

1. Based on early SDRI saturated 1D infiltration rate data. Horizontal value estimated at one order of magnitude higher than vertical value.
2. Estimates based on previous results from well-to-well and trench-to-well based aquifer stress tests computed with many different analytical solutions (Table 9) plus limited 2013 data (Table 10). Value for Kz set to one order of magnitude lower than horizontal value.
3. Estimation, no data for aquitard, other than if it is present, it probably represents a value several order of magnitude smaller value than URZ. Vertical value set equal to horizontal.
4. Estimated from a small number of aquifer stress tests from wells completed in the LRZ and computed with many different analytical solutions (Table 9).
5. Estimation, based on visual description of hard, dry clay layer at bottom of LRZ and analytical results from deep wells indicating the presence of brine water.
6. Not required for steady-state flow.

3. CALIBRATION

3.1 Visual Sensitivity Analysis of Lake Stage

The model previously described was used to predict various playa lake stages by varying the precipitation, evaporation, or Sevier River inflow to the playa by small amounts and observing the resulting surface of the lake (if present). This allowed a qualitative insight to the sensitivity of these parameters which is important for future infrastructure planning, considering there may be significant time of the year where certain areas of the playa are occupied by standing water.

3.1.1 Varying Evaporation

Sevier River inflow and lake precipitation rate were held constant while the lake evaporation rate was varied. At evaporation rates greater than 8.19E-04 m/day, no lake formed. At rates below this a lake began to form at the desiccation point. The evaporation rate was incrementally decreased to a value of 7.8E-04 m/day which resulted in full stage conditions (Figure 5). It is obvious from the data that lake stage is very sensitive to the brine evaporation rate applied to the lake, suggesting that climatic conditions exert a large influence on lake presence and persistence.

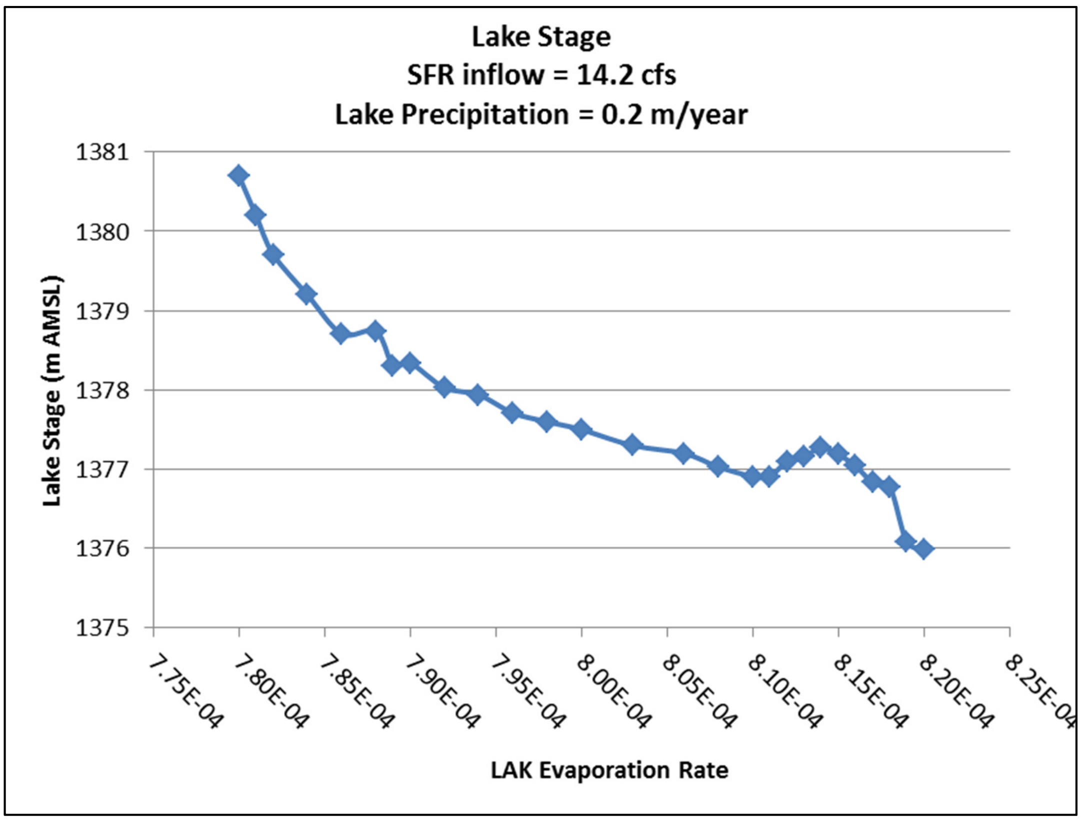

Figure 5. Computed Lake Stage Versus Varying Lake Evaporation Rate.

3.1.2 Varying Sevier River Inflow

The amount of Sevier River inflow was varied in segment 2 (west branch) while lake precipitation and evaporation rates were held constant. The total flow rate for the Sevier River inflow (both segments summed) was incrementally increased from the base rate of 14.145 cfs to a total of 19.792 cfs, which resulted in full stage conditions (Figure 6).

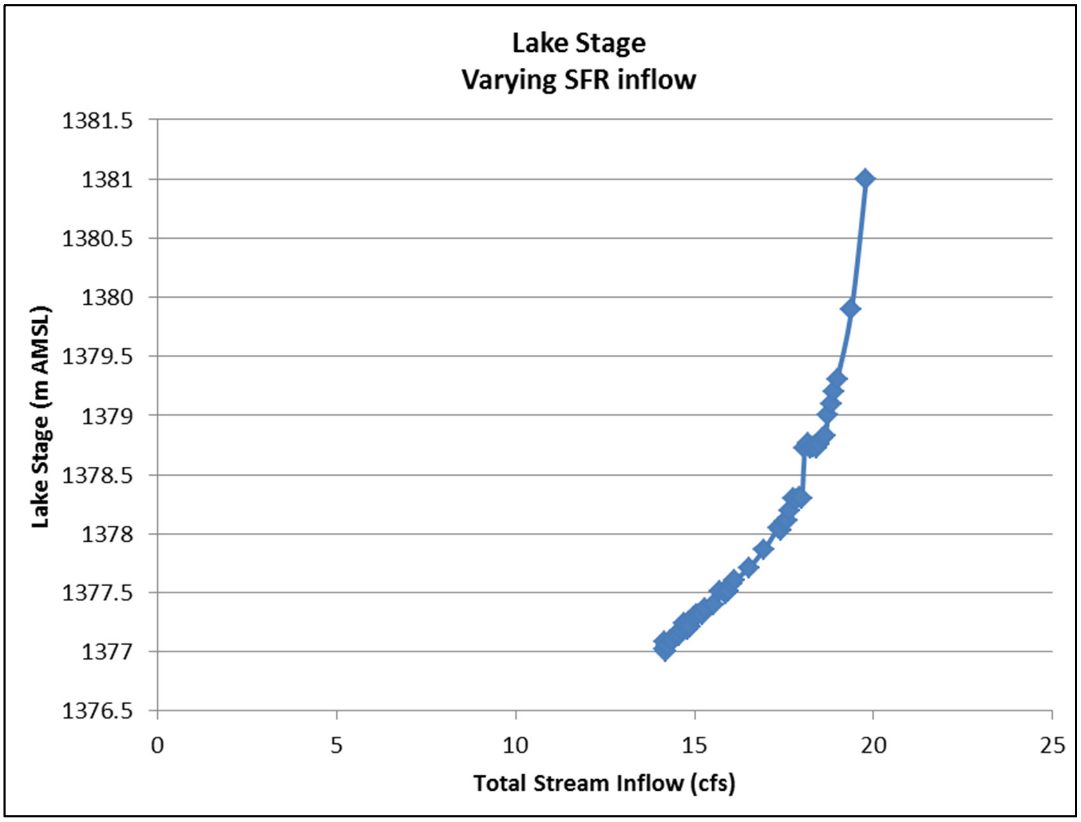

Figure 6. Computed Lake Stage Versus Varying Sevier River Inflow Rate.

3.2 Head Calibration

Head calibration was performed using limited water level data. Though data were available from several rounds of water level measurements, the wells measured during any one round were not spatially well-distributed and are generally biased to the center of the playa.

The initial analysis focused on the value of head in layer 2 (fat clay), layer 3 (upper URZ), and layer 6 (LRZ). Available wells for head calibration were selected from spring 2012 water level measurement round and are presented in Table 12 along with computed heads, final residual values, and statistical data from PEST. Figure 7 and Figure 8 present graphical results based on the data presented in Table 12.

These data indicate the following:

- High sum of squares indicating a relatively high degree of error across all measurements
- The residual mean value indicates that the average difference between observed and simulated heads was approximately -1.2 m, indicating that observed heads on average were low in comparison to the corresponding simulated values.
- The minimum residual value in this case indicated the maximum absolute error in observed head value, which was approximately -2 m lower in comparison to the corresponding simulated head value.
- The maximum residual value in this case indicated the minimum absolute error in observed head value, which was approximately -0.5 m lower in comparison to the corresponding simulated head value.
- The range of observations however is small and taking in account the error in GPS-based survey of the playa surface and hand measurements of casing stick up, this is likely a large part of the error.

Table 12. Sevier Lake Playa Wells Initial Calibration Results.

WELL ID	Easting (WGS84, UTM)[1]	Northing (WGS84, UTM)[1]	Layer	Observed Head (m amsl)[2,3]	Simulated Head (m amsl)[3]	Residual
DP3-12-033	314073	4323879	3	1377.37	1378.524	-1.15459
DP3-12-035	312247	4323919	3	1377.458	1378.541	-1.08296
DP3-12-050	324084.8	4321812	3	1378.117	1378.65	-0.53332
DP3-12-055	319515.6	4321928	3	1377.568	1378.536	-0.96813
DP3-12-057	317680.2	4321957	3	1377.333	1378.517	-1.18394
DP3-12-059	315859.1	4322003	3	1377.217	1378.509	-1.29202
DP3-12-063	312203.1	4322091	3	1377.26	1378.525	-1.26478
DP3-12-068	318121	4321042	3	1377.242	1378.514	-1.27247
DP3-12-091	319913.7	4319166	3	1377.464	1378.513	-1.04873
DP3-12-093	318085.8	4319209	3	1376.422	1378.496	-2.07362
DP3-12-096	315345.7	4319280	3	1377.041	1378.491	-1.45047
DP3-12-099	312598.6	4319339	3	1377.053	1378.511	-1.45784
DP3-12-101	310769.9	4319383	3	1377.254	1378.524	-1.26998
DP3-12-104	319435.5	4318262	3	1377.486	1378.494	-1.0083
DP3-12-107	316692	4318332	3	1377.065	1378.476	-1.41113
DP3-12-110	313950.3	4318393	3	1377.129	1378.497	-1.36817
DP3-12-128	320312.2	4316417	3	1377.257	1378.5	-1.24326
DP3-12-142	318915.2	4315539	3	1377.239	1378.496	-1.25682
DP3-12-166	319792	4313684	3	1377.413	1378.508	-1.09539
DP3-12-168	317961.8	4313732	3	1377.132	1378.503	-1.3706
DP3-12-175	311572.2	4313877	3	1377.324	1378.516	-1.19207
DP3-12-178	319315.4	4312785	3	1377.434	1378.508	-1.07452
SN3-12-133-01	315238.6	4316992	6	1377.571	1378.488	-0.9168
SN3-12-226-1	316042.4	4308278	6	1377.801	1378.519	-0.71793
PVC Shoal	306591	4300954	2	1377.429	1378.655	-1.22632

Number of Observations	Range in Observations	Sum of Squares	RMS[4] Error	Residual Mean	Minimum Residual	Maximum Residual
25	1.69	37.8	1.23	-1.197	-2.07	-0.533

NOTES:

1. WGS84 = World Geodetic System, UTM = universal Transverse Mercator
2. Observed head data from spring 2013 water level measurements
3. M amsl = meters above mean sea level
4. RMS = residual mean square, measure of the difference between data and the model of that data

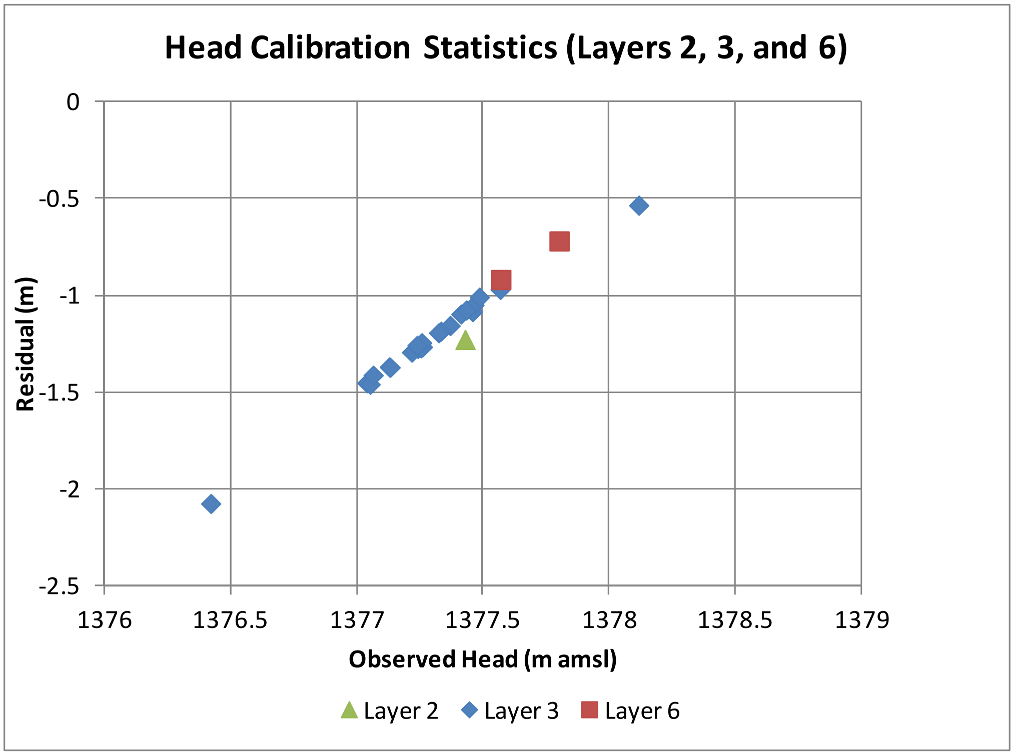

Figure 7. Observed Head vs. Residual Head in Upper Fissured Clay, Lower Fissured Clay and LRZ.

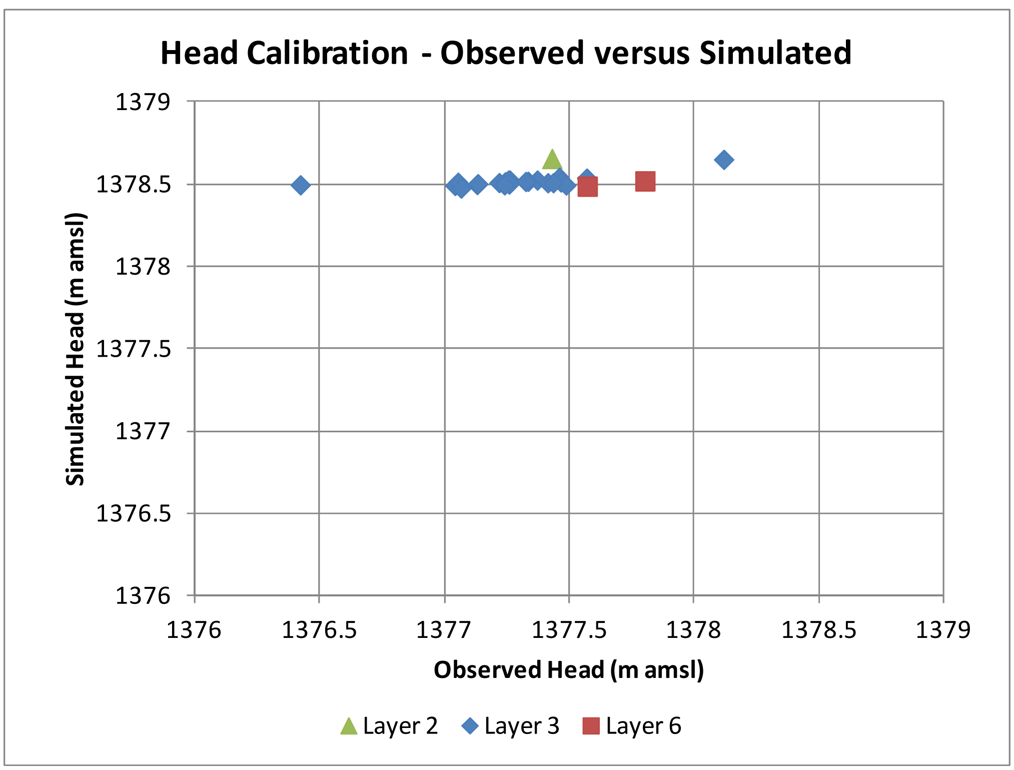

Figure 8. Observed Head vs. Simulated Heads Upper Fissured Clay, Lower Fissured Clay and LRZ.

3.2.1 Adjustments to Recharge

The initial value of areal recharge 5.45E-05 m/day) was based on an estimate utilizing an analysis of recharge in carbonate mud versus salt encrusted areas (CH2M Hill, 2012). A sensitivity analysis was performed which combined areal recharge with horizontal hydraulic conductivity in zones 2 and 5 (layer 3, upper URZ, layer 6, LRZ) and vertical hydraulic conductivity in zones 1 and 5 (layer 2, fat clay, layer 6, LRZ). The results from PEST are presented in Table 13 and indicate that a slightly better fit to observed heads would result from lowering the recharge value. A lowered areal recharge value is in line with the fact that simulated heads were all too high in comparison to observed heads, suggesting that larger than required areal recharge could be a factor.

Table 13. Sevier Lake Playa Wells Calibration Results - Areal Recharge Adjustment.

Name	Easting (WGS84, UTM)[1]	Northing (WGS84, UTM)[1]	Layer	Observed Head (m amsl)[2,3]	Computed Head (m amsl)[3]	Final Residual
DP3-12-033	314073	4323879	3	1377.37	1378.524	-1.08597
DP3-12-035	312247	4323919	3	1377.458	1378.541	-1.04614
DP3-12-050	324084.8	4321812	3	1378.117	1378.65	-0.58792
DP3-12-055	319515.6	4321928	3	1377.568	1378.536	-0.89992
DP3-12-057	317680.2	4321957	3	1377.333	1378.517	-1.10946
DP3-12-059	315859.1	4322003	3	1377.217	1378.509	-1.21521
DP3-12-063	312203.1	4322091	3	1377.26	1378.525	-1.23054
DP3-12-068	318121	4321042	3	1377.242	1378.514	-1.18749
DP3-12-091	319913.7	4319166	3	1377.464	1378.513	-0.87452
DP3-12-093	318085.8	4319209	3	1376.422	1378.496	-1.90259
DP3-12-096	315345.7	4319280	3	1377.041	1378.491	-1.27782
DP3-12-099	312598.6	4319339	3	1377.053	1378.511	-1.40085
DP3-12-101	310769.9	4319383	3	1377.254	1378.524	-1.23969
DP3-12-104	319435.5	4318262	3	1377.486	1378.494	-0.76841
DP3-12-107	316692	4318332	3	1377.065	1378.476	-1.11828
DP3-12-110	313950.3	4318393	3	1377.129	1378.497	-1.24055
DP3-12-128	320312.2	4316417	3	1377.257	1378.5	-1.03291
DP3-12-142	318915.2	4315539	3	1377.239	1378.496	-1.12437
DP3-12-166	319792	4313684	3	1377.413	1378.508	-1.03632
DP3-12-168	317961.8	4313732	3	1377.132	1378.503	-1.31657
DP3-12-175	311572.2	4313877	3	1377.324	1378.516	-1.16898
DP3-12-178	319315.4	4312785	3	1377.434	1378.508	-1.03533
SN3-12-133-01	315238.6	4316992	6	1377.571	1378.488	-0.73472
SN3-12-226-1	316042.4	4308278	6	1377.801	1378.519	-0.70201
PVC Shoal	306591	4300954	2	1377.429	1378.655	-1.13009

Number of Observations	Range in Observations	Sum of Squares	RMS[4] Error	Residual Mean	Minimum Residual	Maximum Residual
25	1.69	31.8	1.13	-1.099	-1.90	-0.588

NOTES:
1. WGS84 = World Geodetic System, UTM = universal Transverse Mercator
2. Observed head data from spring 2013 water level measurements
3. M amsl = meters above mean sea level
4. RMS = residual mean square, measure of the difference between data and the model of that data

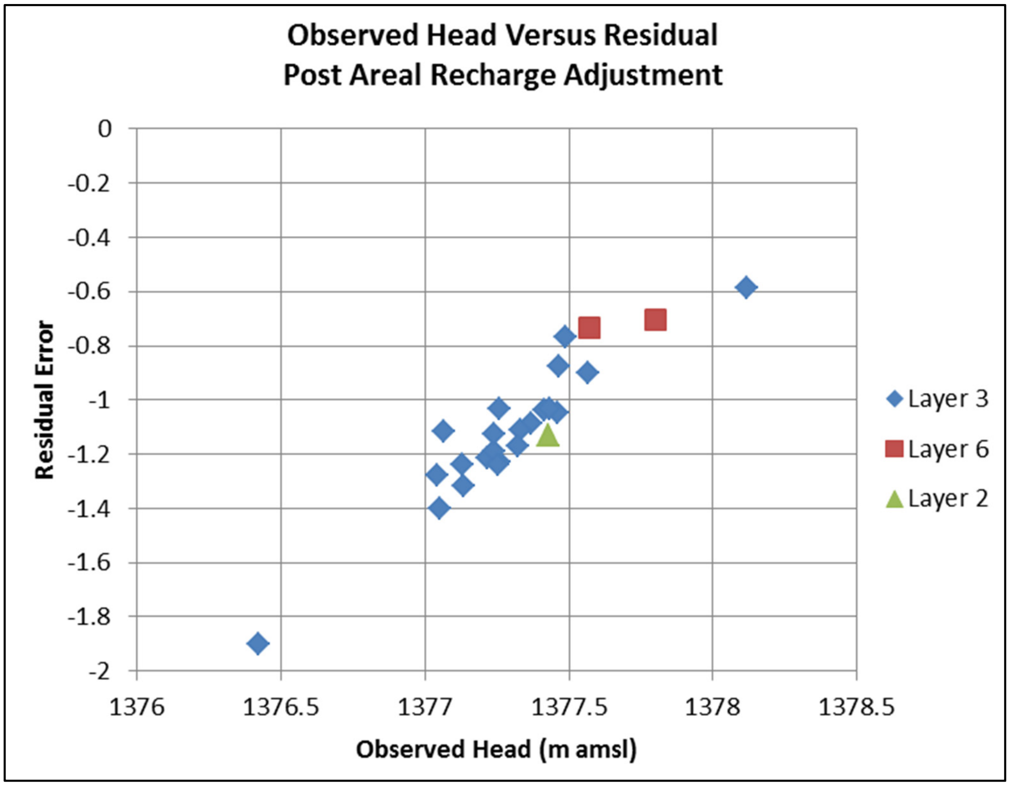

Figure 9. Observed Head Versus Residual Error after adjusting Areal Recharge.

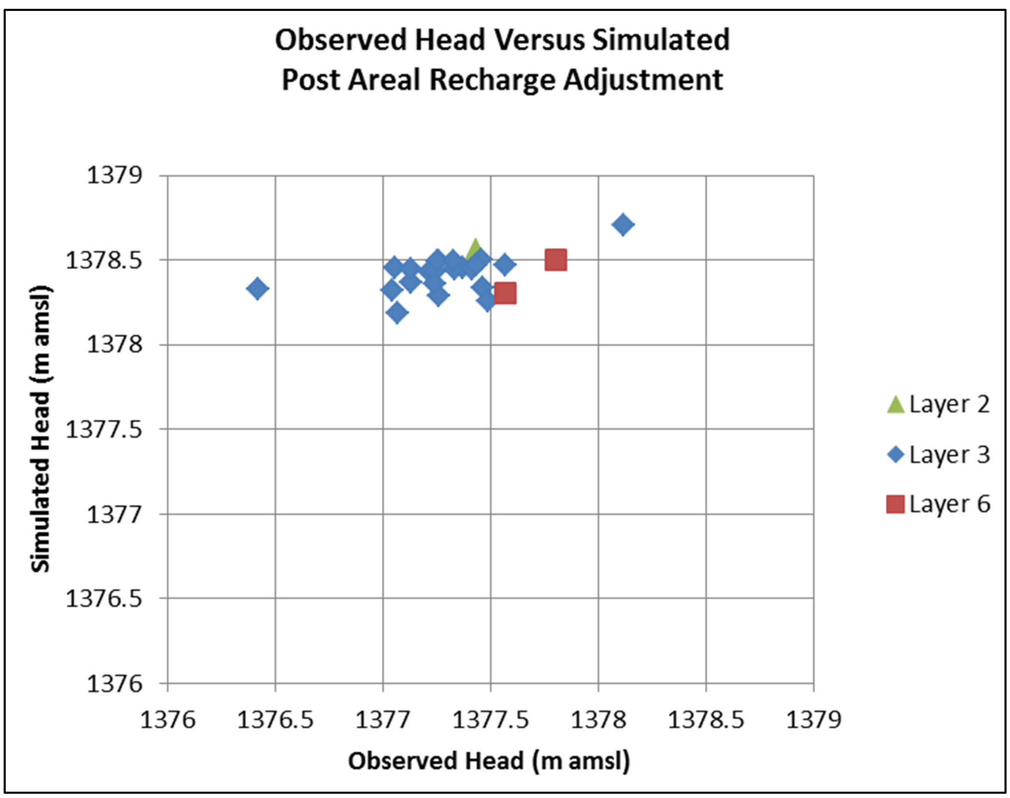

Figure 10. Observed Versus Simulated Heads After Areal Recharge Adjustment.

Review of the statistical output from PEST shows that based on the mean residual error and the sum of squares, a small improvement in fit of simulated to observed heads was realized. The adopted value of recharge was accepted at 1E-06 m/day, adjusted from the previous estimate of 5.45E-05 m/day.

3.2.2 Adjustment to Evapotranspiration and ET Depth

The initial rate of areal evapotranspiration for groundwater (ETg) was chosen as 7.8E-04 m/day and was based on the average value from eight published studies of evapotranspiration in semi-arid to arid regions (see Table 3). The initial value of ET extinction depth was set in the model equal to 1.95 meters. This approach is based on the following assumptions:

When the water table is at or above a specific elevation, termed the ET surface (i.e. the playa surface), evapotranspiration loss from the water table occurs at a maximum rate specified by the ET rate. When the depth of the water table below the ET surface exceeds a specified depth (i.e., the extinction depth), evapotranspiration from the water table ceases. Between these two limits, evapotranspiration from the water table varies linearly.

After initial head calibrations involving hydraulic conductivity and recharge were performed, simulated heads were still high based on the wells from the Spring 2012 water level round., The 1.95 meter value for ET extinction depth was increased to 2.5 meters, based on a visual check of wet and dry cells in layers 1 and 2. Subsequent to this, a PEST calibration and sensitivity analysis was performed. It was determined from PEST that heads are more sensitive to ET extinction depth than ET rate (Figure 11).

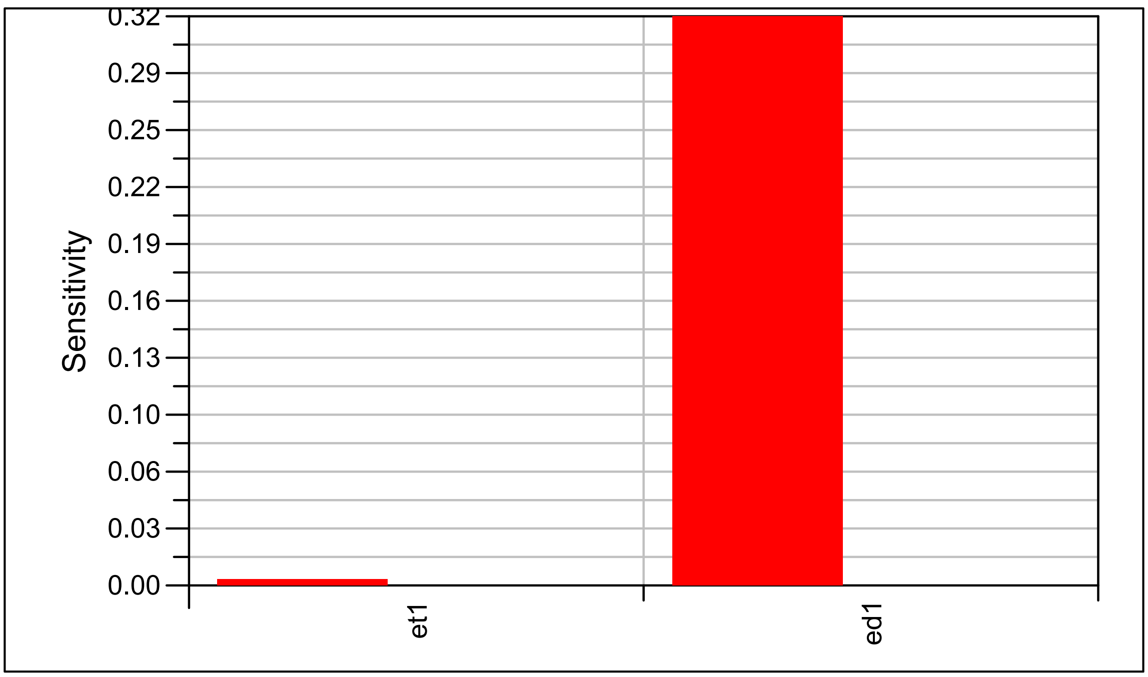

Figure 11. Results of Sensitivity Analysis of ET Rate (et1) and ET Depth (ed1).

To improve the fit of simulated heads to observed heads, PEST estimated that the ET depth should be increased to 5 meters, and the ET rate should be lowered a value of 1E-03 m/day. This seemed somewhat radical, and to double-check this before changing the ETg value, a sensitivity analysis was performed with the built-in tools in Groundwater Vistas which systematically modified ET extinction depth and vertical conductivity of the surficial fat clay (layer 2) while comparing the results to observed heads. This analysis predicted that a better fit would result from a multiplier of about 1.5 applied to the ET depth (currently at 2.5 m). Based on these results, the ET extinction depth was then adjusted to a value of 3.75 m bgs.

The results from the subsequent PEST head calibration are presented in Table 14.

Table 14. Sevier Lake Playa Wells Calibration Results - ET Adjustment.

Name	Easting (WGS84, UTM)[1]	Northing (WGS84, UTM)[1]	Layer	Observed Head (m amsl)[2,3]	Computed Head (m amsl)[3]	Final Residual
DP3-12-033	314073	4323879	3	1377.37	1378.524	-0.87462
DP3-12-035	312247	4323919	3	1377.458	1378.541	-0.66874
DP3-12-050	324084.8	4321812	3	1378.117	1378.65	0.278175
DP3-12-055	319515.6	4321928	3	1377.568	1378.536	-0.7024
DP3-12-057	317680.2	4321957	3	1377.333	1378.517	-0.99782
DP3-12-059	315859.1	4322003	3	1377.217	1378.509	-1.1266
DP3-12-063	312203.1	4322091	3	1377.26	1378.525	-0.98403
DP3-12-068	318121	4321042	3	1377.242	1378.514	-1.08014
DP3-12-091	319913.7	4319166	3	1377.464	1378.513	-0.71952
DP3-12-093	318085.8	4319209	3	1376.422	1378.496	-1.88407
DP3-12-096	315345.7	4319280	3	1377.041	1378.491	-1.30493
DP3-12-099	312598.6	4319339	3	1377.053	1378.511	-1.25693
DP3-12-101	310769.9	4319383	3	1377.254	1378.524	-0.96262
DP3-12-104	319435.5	4318262	3	1377.486	1378.494	-0.72493
DP3-12-107	316692	4318332	3	1377.065	1378.476	-1.25822
DP3-12-110	313950.3	4318393	3	1377.129	1378.497	-1.21064
DP3-12-128	320312.2	4316417	3	1377.257	1378.5	-0.863
DP3-12-142	318915.2	4315539	3	1377.239	1378.496	-1.02802
DP3-12-166	319792	4313684	3	1377.413	1378.508	-0.81632
DP3-12-168	317961.8	4313732	3	1377.132	1378.503	-1.19569
DP3-12-175	311572.2	4313877	3	1377.324	1378.516	-0.96323
DP3-12-178	319315.4	4312785	3	1377.434	1378.508	-0.84126
SN3-12-133-01	315238.6	4316992	6	1377.571	1378.488	-0.77342
SN3-12-226-1	316042.4	4308278	6	1377.801	1378.519	-0.49879
PVC Shoal	306591	4300954	2	1377.429	1378.655	0.125115

Number of Observations	Range in Observations	Sum of Squares	RMS[4] Error	Residual Mean	Minimum Residual	Maximum Residual
25	1.69	24.4	0.989	-0.893	-1.88	-0.279

NOTES:

1. WGS84 = World Geodetic System, UTM = universal Transverse Mercator
2. Observed head data from spring 2013 water level measurements
3. m amsl = meters above mean sea level
4. RMS = residual mean square, measure of the difference between data and the model of that data

These data indicate the following:

- High sum of squares indicating a relatively high degree of error across all measurements, but an improvement over the initial statistics.
- The residual mean value indicates that the average difference between observed and simulated heads was approximately -0.89 m, indicating that observed heads on average were low in comparison to the corresponding simulated values. This represents somewhat of an improvement over the initial statistics.
- The minimum residual value in this case indicated the maximum absolute error in observed heads value, which was approximately -1.9 m lower in comparison to the corresponding simulated value.
- The maximum residual value in this case indicated the most positive (high) value of error in values of observed heads, which was approximately 0.28 m higher in comparison to the corresponding simulated head value.

As mentioned earlier, the range of observations is small. Given the relatively flat lying playa and taking in account the error in GPS-based survey of the playa surface and hand measurements of casing stick up, the overall error is within expectations. The contribution to error from one well (DP3-12-093) did overshadow results from the other wells. The statistical results could have been improved by throwing out that data point as an outlier.

3.2.3 Final Parameter Estimates

In some case, on-going field work and research from other workers provided new or updated estimates of parameters while the model was undergoing refinement and calibration. This created a complicated task in moving forward with the modeling while understanding the effect that additional or new parameters had on simulation results. These adjustments are briefly summarized below. The final values are tabulated in Table 15.

The vertical conductivity in layer 1 was originally based on SDRI saturated infiltration rate data, which was collected and refined over time as additional data from each site and new sites became available during 2013. For layer 1, this applied only to the lake bed conductance value. Otherwise it has no application in layer 1 because this layer is occupied by the lake boundary condition. The final value of 1.8E-05 m/day was used during final steady-state calibrations.

The vertical hydraulic conductivity (K_z) in the fat clay (layer 2) was based on SDRI saturated infiltration rate data as described above and the value of horizontal hydraulic conductivity ($K_{x,y}$) was estimated as one order of magnitude greater than the vertical value. The final value of 1.8E-05 m/day for K_z was used during final steady-state calibrations.

The hydraulic conductivity in layer 3 (upper URZ) was adjusted upwards slightly as a result of the sensitivity analysis and calibration. The value for the lower URZ (layer 4) was left at the value of the original estimate, as it represents about half the value of the URZ which is what the available field data suggest.

There are no data for layer 5 (the middle aquitard). If it exists, it is likely not fissured and thus represents hydraulic properties closer to fat clay than the fissured clay. Hydraulic conductivity was set to a value several orders of magnitude smaller value than URZ. The vertical value was set equal to horizontal.

The adopted $K_{x,y}$ value for layer 6 (LRZ) was estimated from sensitivity analyses. The performed analysis indicated a lower sum of squares residual if $K_{x,y}$ were multiplied by a factor of 0.3. The K_z estimate for layer 6 was set to one order of magnitude less than the horizontal value.

The estimate for $K_{x,y}$ for layer 7 was based on visual description of hard, dry clay layer at the bottom of LRZ, though deep samples (e.g., SN1-400, RR7-1") still indicated the presence of brine. Because only a few holes penetrated this depth, whether this layer is playa-wide, or whether clayey silts, sands and/or gravels exist below this zone is not known. It therefore possible that the depth of the LRZ could be extended if the presence of such permeable zones is established and heads can be tied to observations higher up in the LRZ. The vertical K estimate for layer 7 was set to one order of magnitude less than the horizontal value. This layer is not a resource that is actively modeled so no sensitivity analysis was performed.

The initial estimate of precipitation was calculated by Whetstone (8.22 in/year). This value is used directly only for water that may be added to the lake and stream boundary conditions through direct precipitation on any free water surface represented by these boundary conditions. This value was changed to 8.0 in./year by request of Agapito to fit the design criteria of the pond sizing. This change was made during calibration, but was in place during the final calibration runs.

The lake package run-off factor was not initially applied correctly. The final value (-0.16) selected was in place during calibration but is not the same number used during the visual calibration of lake stage as a function of varying lake evaporation and stream discharge as described earlier. This probably affects the timing of a particular lake stage elevation.

Table 15. Final Parameters, Post Steady-State Model Calibrations.

Parameter	Layer						
Parameter	1 – Lake[1]	2 – Fat Clay[2]	3 – Upper URZ	4 - Lower URZ	5 – Middle Aquitard[3]	6 - LRZ	7 – Deep Lacustrine[4]
K x,y (m/day)	--	1.8E-04	23.6	12	0.001	0.6	0.1
K z (m/day)	1.8E-05	1.8E-05	2	1.2	0.001	0.2	0.01

Precipitation	5.56E-04 m/day (8.0 inches/year) - applicable to LAK & SFR pkgs only.
Lake evaporation[5]	2.3E-03 m/day (37 inches/year) - applicable to LAK pkg only.
Stream Evaporation[6]	3.900e-003 m/year (56 inches/year) - applicable to SFR pkg only.
Run-off Factor (RNF)	-0.16 (dimensionless) - applicable to LAK pkg only.
Areal Recharge	1E-06 m/day (0.365 mm/year)
Areal ET	7.8E-04 m/day (0.285 m/year, 11.24 inches/year)
ET Extinction Depth[7]	3.75 m (linear assumption)
Unsaturated Soil Parameters[8]	Residual saturation = 0.334, Alpha = 0.0069; beta = 1.659, applicable to BCF4 pkg.

NOTES:

1. The value of Kz is used to calculate conductance though lake bed bottom in Lake Package.
2. The value of Kz is based on the geomean of final SDRI saturated 1D infiltration rate data. Horizontal value estimated at one order of magnitude higher than vertical value.
3. Estimation, no data for aquitard, other than if it is present, it probably represents a value several order of magnitude smaller value than URZ. Vertical value set equal to horizontal.
4. Estimation, based on visual description of hard, dry clay layer at bottom of LRZ, but yet analytical results from deep wells indicate the presence of brine water.
5. Miller (2013) freshwater value multiplied by 0.6 to estimate value for brine.
6. Miller (2013) freshwater value.
7. Estimate.
8. Values calculated from laboratory water retention curve data (IGES, 2012).

3.3 Transient Calibration

3.3.1 Introduction

As mentioned earlier, a long-term trench based aquifer stress test was conducted in 2013. The site was instrumented with multiple observation wells in order to generate high quality data for the upper URZ.

Because of low-quality survey data and the lack of well-spaced water level data available during the same timeframe, it was decided that transient calibration would benefit from an in-depth analysis of the data obtained from the long-term trench-based aquifer stress test. A site-specific groundwater model at a small scale was constructed and calibrated to the stress and recovery data to provide hydraulic properties data to the larger playa-wide groundwater model. Because the site could be modeled at a small scale, the effect of survey error could more or less be neglected and drawdown could be substituted for head elevation in order to calculate required aquifer flow and storage parameters if a level ground surface could be assumed in the vicinity of the test site. The site-specific groundwater model construction and parameter estimation results are described in a separate document (Whetstone Associates, 2013).

The following sections provides summary information about the design, calibration, and results of the site-specific groundwater flow model simulating the 8.8 day pumping phase and 5.2 day recovery phase of the trench stress test.

3.3.2 Description of Site and Testing

The pumped trench is located at 308133.4 m Easting and 4293988.5 m Northing (WGS84 UTM) (Figure 12). The aquifer stress test consisted of an 8.8 day aquifer stress test in a trench excavated into the upper part of the upper resource zone (U URZ) to a depth of 20 feet below ground surface (bgs).

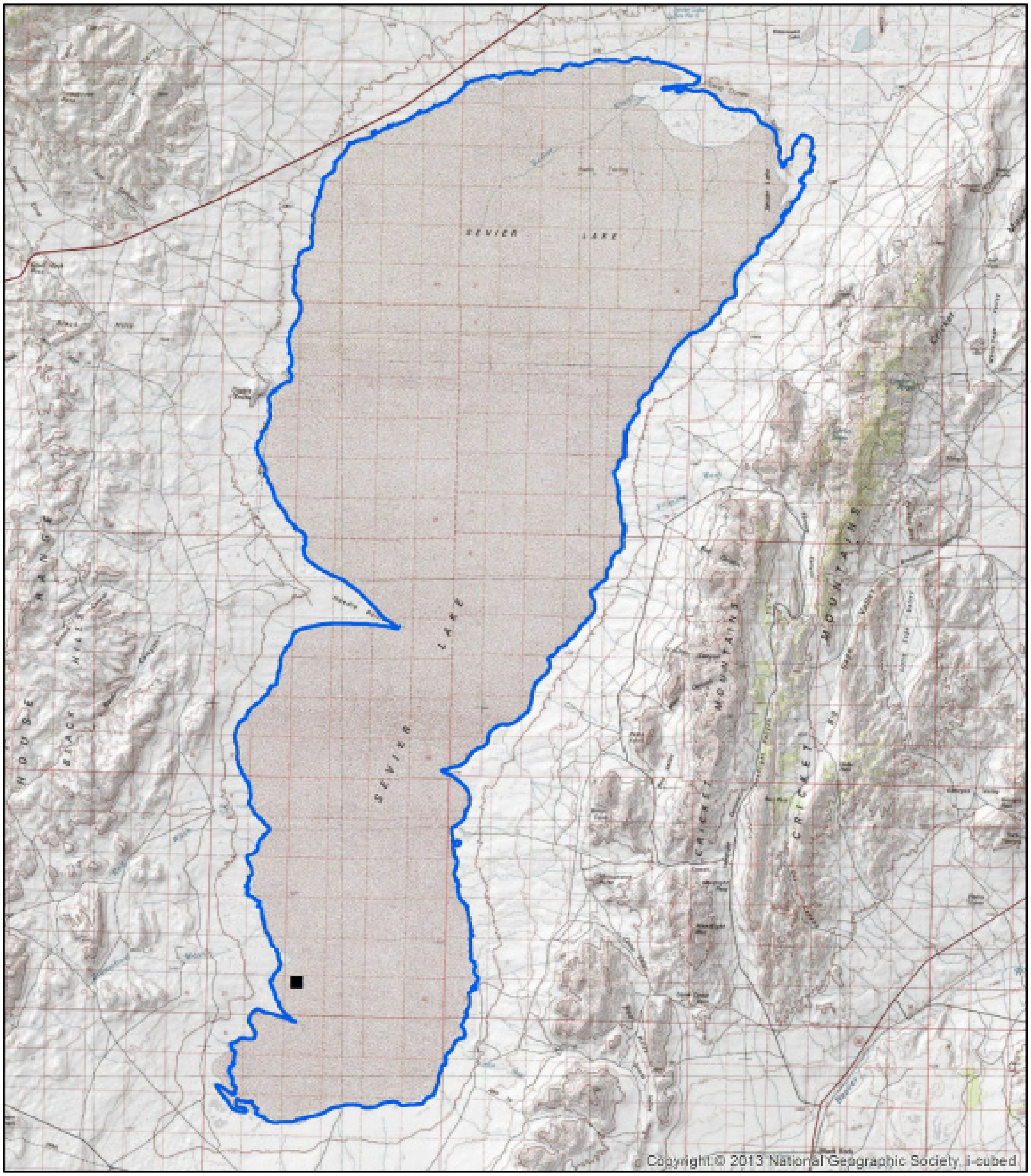

Figure 12. Location Map for the Long-Term Trench Test Site (Site Location Marked By Black Square).

Two benched trenches were excavated for the test. The two trenches were spaced 54 feet apart, center-to-center, and were approximately 34 feet long by 24 feet wide at ground surface. Depth to the first bench was approximately four feet bgs, with a wall-to-wall distance of 24 feet. The intermediate bench was 10 feet bgs, with a wall-to-wall distance of 10.5 feet. Depth to the third bench (the bottom) was 20 feet bgs, with a wall-to-wall spacing of six feet. Field observations during excavation indicate the trenches did not make water prior to penetrating the URZ. A photograph of trench test site is shown in Figure 13.

The trench-based aquifer stress test was performed in the east trench between May 7 and May 20, 2013 and included an 8.8 day pumping period followed by monitoring of recovery water levels for 5.2 days. The average discharge rate was approximately 25 gpm and was constant except for intermittent shutdowns to refuel or work on the pump. The total shutdown time over the 8.8 days was 4.2 hours which is approximately 2 percent of the total pumping time. Produced water was discharged to the playa surface approximately 150-200 feet west of the pumping and observation trenches. Field notes indicate that a small amount of the discharge water flowed into the observation trench on an intermittent basis. The flow was not quantified by the observer. Drawdown and recovery in the trenches and observation wells were monitored at one minute intervals using pressure transducers.

Figure 14 diagrammatically depicts the layer configuration assumed for the modeling effort. The fat clay was modeled as low-permeability clay between the surface and 10 feet below ground surface (bgs). The U URZ and L URZ represent one unit of fissured clay between 10 and 40 feet bgs. However, it is thought that fissuring dies out with depth and thus the U URZ and L URZ have similar properties but the L URZ may have less permeability. In the model the U URZ is differentiated from the L URZ to represent the bottom of the trench. A third unit, the stiff clay, is described as stiff competent clay beneath the L URZ and is presented in the model as a no-flow boundary.

It was assumed that the aquifer is isotropic, i.e., $K_x = K_y = K_z$, for all model layers and hydraulic conductivity and storage values were evenly distributed in each layer across the model domain, except for the area occupied by the trenches. Because of the small scale at which the model was constructed, the values of hydraulic conductivity and storage for cells occupied by the trenches were set to arbitrarily high values of 1000 ft./day and 1 respectively to simulate large voids filled with water

Constant head boundaries were specified at the north and south edges of the model grid in layers 1 through 3 to establish a gradient of 0.0002 ft./ft. across the model domain. The specified head at the northern boundary was one foot bgs. The head at the southern boundary was 3feet bgs. The east and west edges of the model and the bottom of layer 3 are implied no-flow boundaries.

3.3.3 Calibration and Parameter Estimation Results

The purpose of the transient model was to provide an accurate and reliable estimate of hydraulic conductivity and a storage parameter in the upper fissured clay. A statistical analysis of the calibration was performed after the model simulation was run. Table 16 presents the results. Figure 15 presents observed versus simulated drawdown at the end of pumping.

A sensitivity analysis was performed to evaluate the relative sensitivity of the model calibration to the predicted values of hydraulic conductivity and specific storage for the U URZ and L URZ. Values for these parameters were systematically varied, one at a time, for each layer ± 10% and 20%. The results of the sensitivity analysis indicate that the predicted K values for the U URZ are well constrained. In other words, relatively small changes to K in layer 2 result in poorer calibration of the model. The model is relatively insensitive to changes in specific storage in layers 2 and 3 and hydraulic conductivity in layer 3. This observation indicates that the values have associated uncertainty that could exceed 20 percent.

Data obtained from the tracer test trench site provided adequate data for a transient model calibration to the pumping and recovery data. A transient model is also a tool to obtain an estimate of storage. The final estimate of hydraulic conductivity in the upper fissured clay is 26 ft./day (7.9 m/day), for the lower fissured clay 20 ft./day (6.1 m/day) and the final specific storage estimate for both layers is 0.0017 ft-1. Table 17 presents the final parameters obtained from the calibrated site-specific model.

Figure 13. Photograph of Test Trench Site.

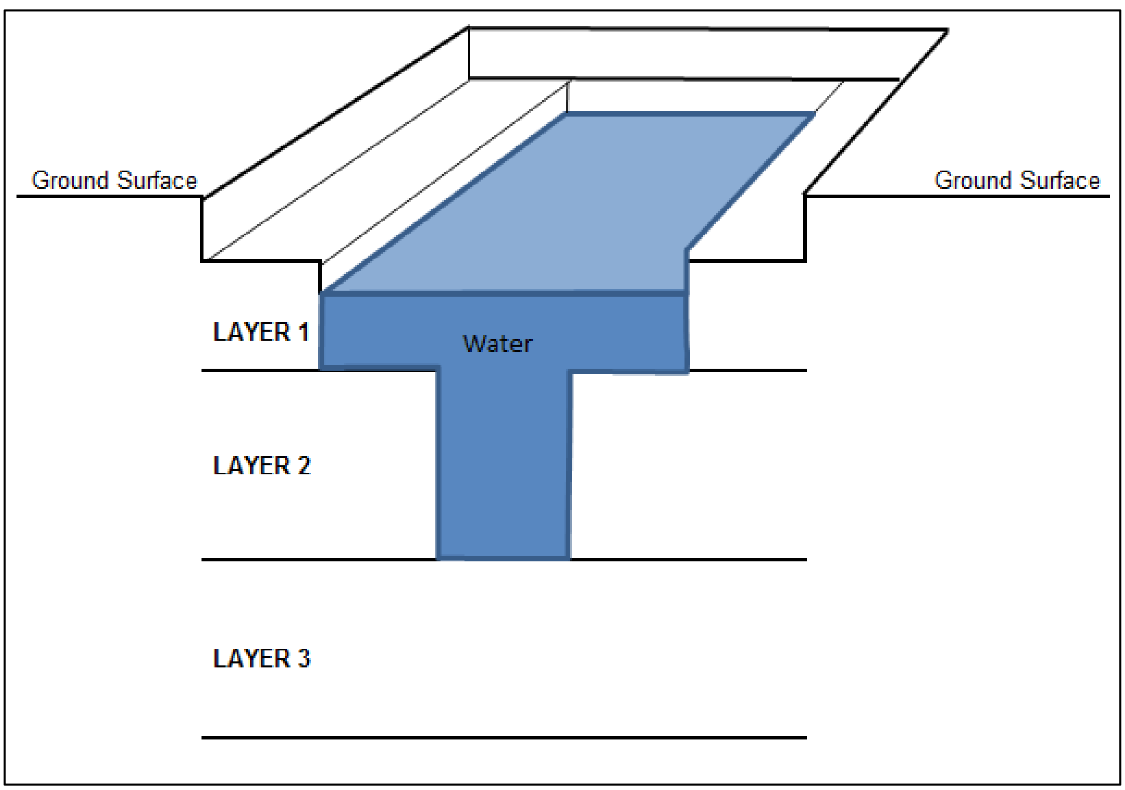

Figure 14. Perspective Diagram of Trench Conceptual Model.

Table 16. Calibration Statistics at the End of Pumping.

Calibration Target	Model Layer	Observed Drawdown (ft.)	Simulated Drawdown (ft.)	Residual Drawdown (ft.)
DPE1	2	3.325	2.788982	0.54
DPE2	2	4.065	3.651993	0.41
DPE3	2	4.932	4.64688	0.29
DPE4	2	5.903	5.597681	0.31
DPW1	2	2.951	2.547056	0.40
DPW2	2	3.235	3.283384	-0.05
DPW3	2	4.787	5.244661	-0.46
DPW4	2	5.351	6.088935	-0.74
DPN1	2	3.694	3.614897	0.08
DPN2	2	4.337	4.585051	-0.25
DPN3	2	5.353	6.025097	-0.67
DPS1	2	3.597	3.553888	0.04
DPS2	2	4.726	4.626064	0.10
DPS3	2	5.816	5.824795	-0.01
			Residual Mean:	0.0
			Absolute Residual Mean:	0.31
			Root Mean Squared Error:	0.39

NOTES:
Statistical analysis performed with built-in tools in Groundwater Vistas.

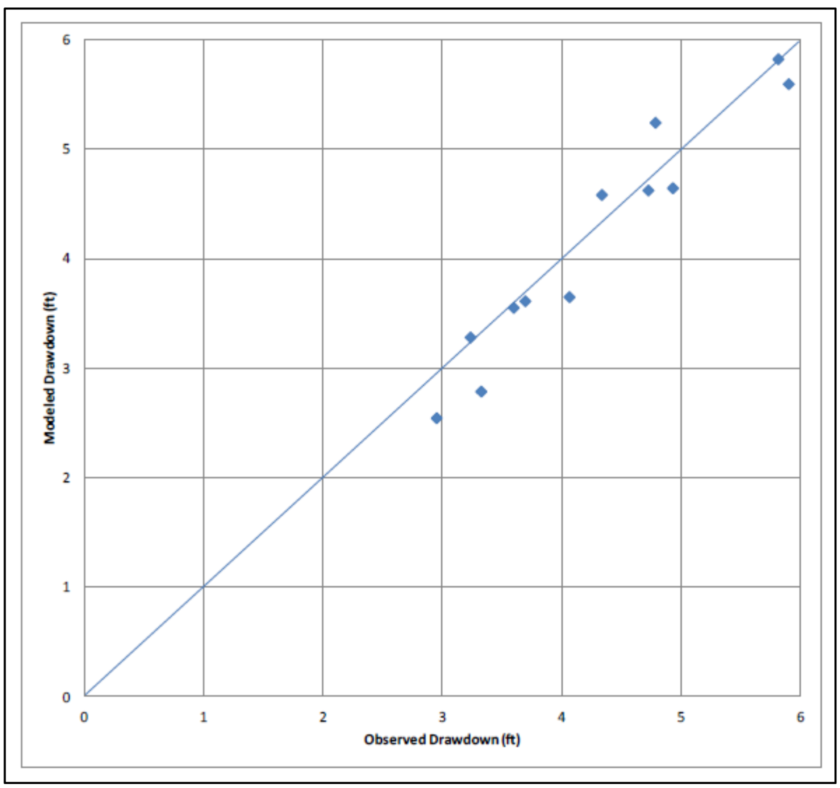

Figure 15. Observed vs. Simulated drawdown at the End of the Pumping Phase.

Table 17. Parameter Estimates, Post-Model Calibration.

Layer	Thickness (ft.)	Hydrostratigraphic Unit	Hydraulic Conductivity (ft./d)	Specific Storage (ft^{-1})	Specific Yield
1	10	Trench[1]	1000	N/A	1
1	10	FC	0.0000595	N/A	0.08
2	12	Trench[1]	1000	0.08	N/A
2	12	UFC	26	0.0017	N/A
3	15	LFC	20	0.0017	N/A

NOTES:

1. Not true physical layers of the hydrogeologic system. These layers are used within the model to simulate the effects of two large voids of water embedded in layers 1 and 2.

3.4 Summary of Sources of Uncertainty

There were several uncertainties in the model that prevented a better calibration, however the parameter estimates of hydraulic conductivity and storage are within the range obtained from other analytical solutions and are reasonable.

1. In the week after the initial excavation and before pumping began, depths to bottom became shallower due to wall sloughing. The trenches were cleaned out to approximately 20 feet bgs prior to the initiation of testing. Therefore, it could be assumed that additional sloughing occurred during the test again resulting in trenches becoming shallower with time during the duration of stress and recovery. This would have the effect of decreasing transmissivity over time.
2. Initial water level elevations were uncertain at the piezometers. Only depths to water below top of casing and drawdown were known. The tops of casing were not surveyed, the playa surface was not surveyed, and there exact depths to water below ground surfaces are unknown without an assumption of a level playa surface.
3. The initial water level elevations was uncertain at the observation trench because depths to water were measured with an inclined slotted pipe run into the bottom of the trench. Depth to water in such a situation would be greater than if the depth to water had been measured in a vertical standpipe. Based on photographic evidence, the standpipe was inclined 30 degrees from vertical. A correction factor of 0.9 feet could be applied to ambient head in the observation trench. Because it was not known whether the measured field values reflected a correction for slant, this ambient water level elevation was left as is.
4. The initial water level elevation at the pumping trench was unknown. Similar to the observation trench, an inclined standpipe was used to obtain water levels. However, the field personnel neglected recording a value for measurement point stickup above ground surface. The ambient water level elevation (head) in the pump trench was estimated by assuming that the ambient head in the observation trench is correct. Then, if a flat playa is assumed, and a flat piezometric surface is assumed, the ambient head in the pumping trench could be set equal to the observation trench about 50 feet to the west. However, inspection of available photographs indicates that the assumption of a flat playa surface may not be entirely correct. An alternative method was proposed and adopted which involved taking the average heads in the four closest piezometers and assuming that elevation for the ambient head in the pumped trench.

3.5 Calibration of Trench-to-Trench Test to Playa-Wide Model

Before accepting the results of the calibrated trench-based aquifer stress test and incorporating those parameters into the playa-wide model, the playa-wide model was calibrated to the trench test. To achieve this, the trenches and observation wells were imported into the playa-wide model at the correct geographic location. The hydraulic conductivity and storage values for layers 1 through 3 were set to the values obtained from the calibration (see Table 17). Values for other layers were kept at values used previously or adjusted slightly.

The parameter values now proposed for use in the playa-wide model are compared to the values obtained at the end of the playa-wide steady-state calibration presented earlier in Table 15. The differences are as follows:

- Fat Clay – Same values of K used.
- Upper Fissured clay – hydraulic conductivity is lowered to match calibrated value from trench-to-trench stress test.
- Lower fissured clay - hydraulic conductivity is lowered to match calibrated value from trench-to-trench stress test.
- Aquitard - Same values of hydraulic conductivity used.
- LRZ – Horizontal value of K changed upwards from 0.6 to 1 m/day to better reflect additional data coming in from 2013 hydrogeologic field work. Vertical hydraulic conductivity estimated at 0.1 m/day.
- Layer 6 – values changed one or magnitude downward to behave more as a no-flow boundary than as a source of water. Horizontal K was changed from 0.1 m/day to 0.01 m/day, vertical k was changed from 0.01 m/day to 0.001 m/day

In addition, because values for storage parameters were not obtained from the earlier steady-state simulation, and because MODFLOW-SURFACT requires values for both storage parameters when using LAYCON values that correspond to convertible layers, estimates for the missing storage parameters had to be made. Table 18 presents the values (converted to SI units) used for initial calibration runs to the trench test dataset (shaded values indicated estimates obtained from the calibrated site-specific model).

Table 18. Parameters Used for Initial Calibration of Playa-Wide Model to Trench Stress Test Model.

Layer	Hydrostratigraphic Unit	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Specific Storage (m^{-1})	Specific Yield[3]
1	Fat Clay[1]	1.8E-004	1.8E-005	0.0015	0.08
2	Upper Fissured Clay	7.9	7.9	0.0056	0.08
3	Lower Fissured Clay	6.1	6.1	0.0056	0.08
4	Aquitard	0.001	0.001	1E-007	0.03
5	LRZ[2]	1	0.1	2.7E-006	0.06
6	Deep Lacustrine	0.01	0.001	1E-006	0.02

NOTES:

1. Fat clay vertical conductivity value obtained from SDRI 1-D infiltration testing. Horizontal K estimated at one order of magnitude greater. Specific storage is an estimate.
2. LRZ horizontal conductivity value and specific storage value from latest aquifer stress results.
3. All values of specific yield except for fat clay are estimated.

Heads for all the observation wells (and the two trenches) at various times during the trench aquifer stress test were imported into the playa-wide model to provide target values to calibrate against. In accordance with field observations at the trench test side, initial heads were set to 0.5 meter below land ground surface. Table 19 presents the stress periods configured for the playa-wide model calibration. The starting stress period duration with these starting heads was set to one day. Pumping began in stress 2 period 2 and followed the pattern of pumping recorded for the test for a total of 13 stress periods. The final stress period was the 5.15 day recovery period.

Figure 16 presents a plot of observed versus simulated heads. Ideally the plot should be a straight line oriented at a 45 degree value, indicating that the simulated values match the observed values. These data indicate a strong bias that all heads are simulated too low and therefore perhaps some improvement could be made to selected parameters.

Table 19. Stress Period Configuration and Pumping Data for Playa-Wide Model Transient Calibration.

Stress Period[1]	Time Begin (days)	Duration (days)	Time End (days)	Discharge rate (m^3/day)	Volume Pumped (m^3)	Cumulative Volume (m^3)
1	0	1	1	0.0	0.0	0.0
2	1	0.496	1.496	136.3	67.6	67.6
3	1.496	0.102	1.598	0.0	0.0	
4	1.598	0.487	2.085	136.3	66.5	134
5	2.085	0.0583	2.143	0.0	0.0	
6	2.143	0.835	2.978	136.3	113.8	247.8
7	2.978	0.0125	2.991	0.0	0.0	
8	2.991	0.0743	3.065	136.3	10.1	257.9
9	3.065	0.0201	3.085	0.0	0.0	
10	3.085	0.0681	3.153	136.3	9.3	267.2
11	3.153	0.0236	3.177	0.0	0.0	
12	3.177	6.6722	9.849	136.3	909.5	1176.7
13	9.849	5.15	15	0.0	0.0	

NOTES:

1. Stress Period 1 is pre-pumping. All other periods with zero discharge were due to non-planned pump stoppages. Stress Period 13 is recovery.

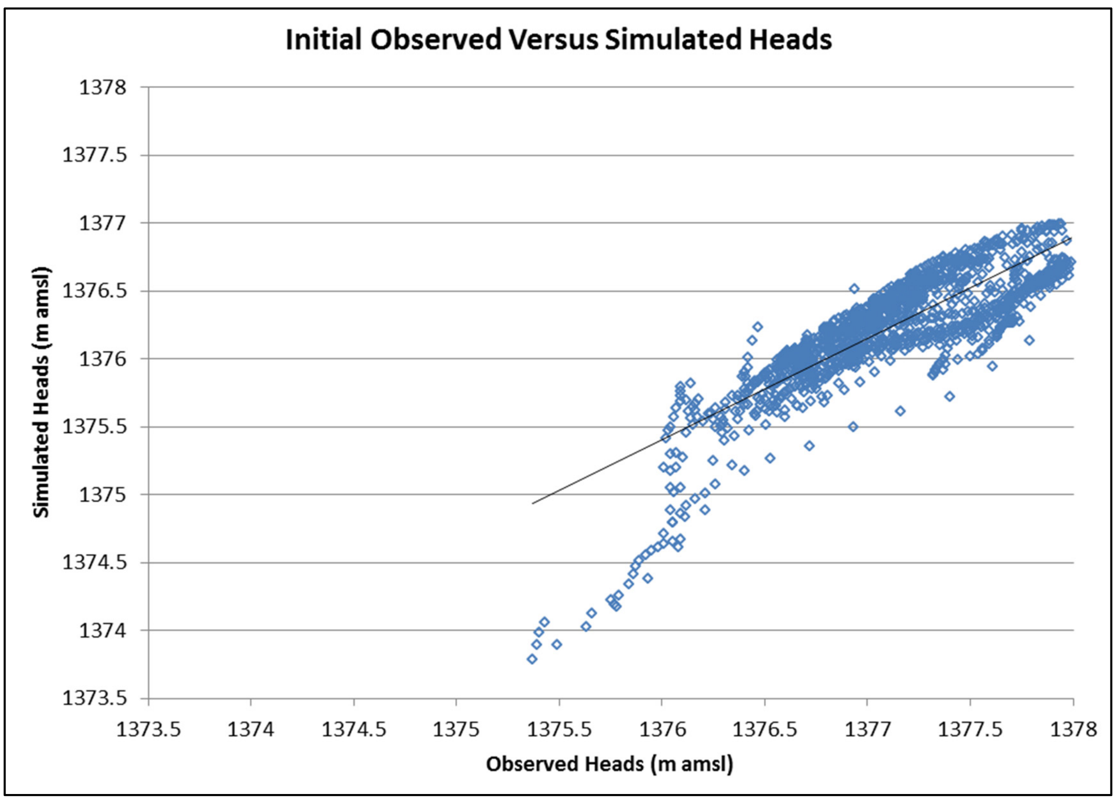

Figure 16. Observed vs. Simulated Heads from Initial Calibration to Trench-Based Stress Test Data.

Figure 17 shows head contours in layer 2 (upper fissured clay) plotted with residuals at the end of pumping (stress period 12). Contour interval is 0.1 m, maroon color indicates dry cells. The simulated heads are low as positive residual values indicate that the simulated heads are lower than observed by the value shown. In other words, the simulated heads have a positive residual head value when compared to the observed heads at the same time.

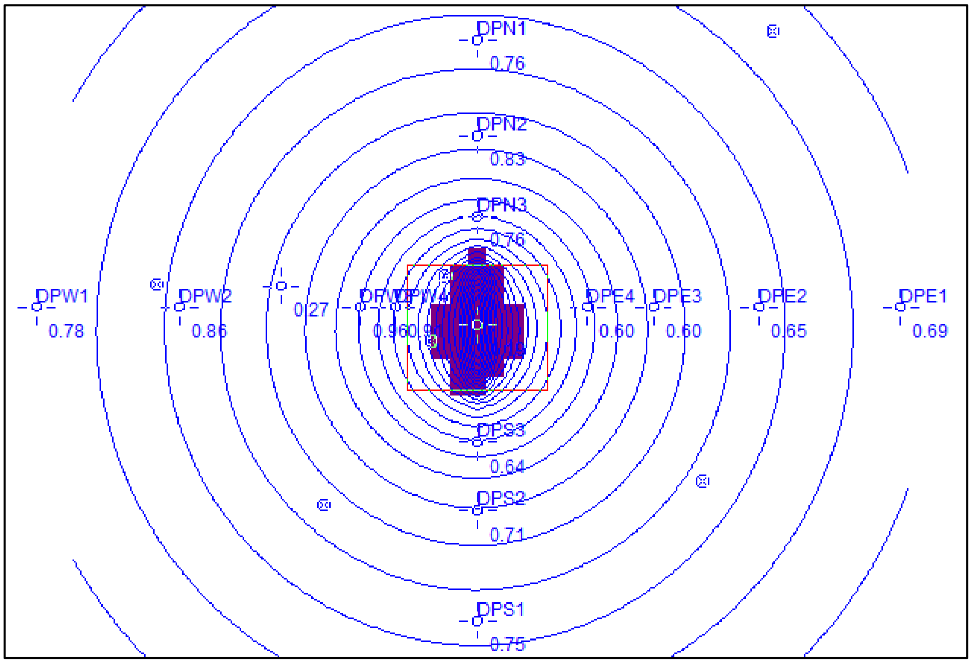

Figure 17. Head Contours at the End of Pumping with Residual Values Plotted.

Figure 18 shows head contours with residuals at the end of recovery. These data indicate that simulated heads are also low in comparison to the observed heads by the value shown as the residual. In other words, the simulation is producing too much drawdown in comparison to the field observations.

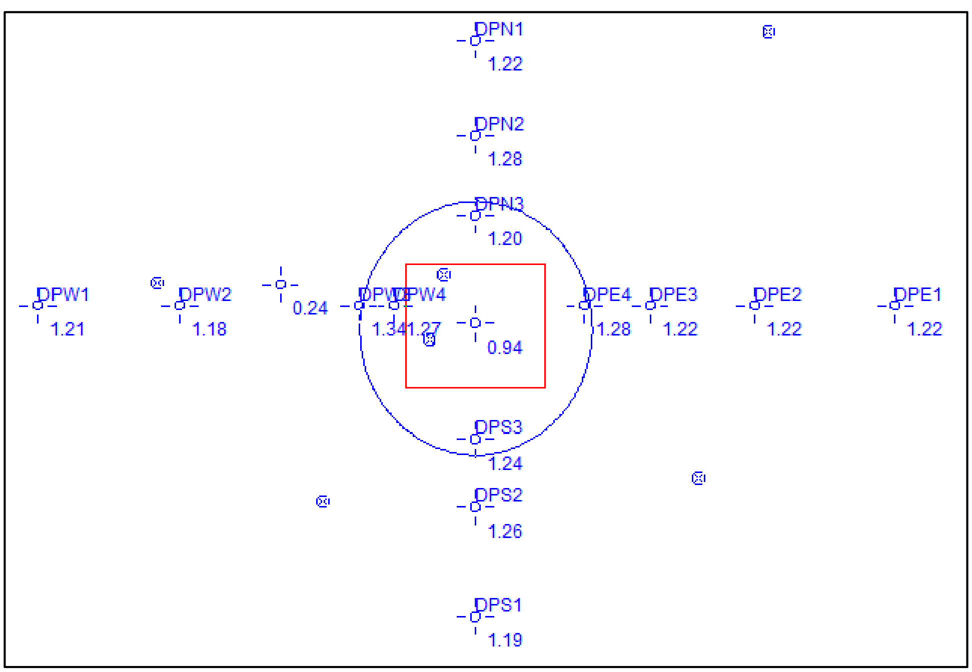

Figure 18. Head Contours at the End of Recovery with Residual Values Plotted.

Several parameters were selected for the sensitivity analysis based on subjective judgments of how well the parameters were originally constrained, and how much control these data had on future results if changed to values thought to be in the range of plausibility.

To accomplish a rough sensitivity analysis of the selected parameters, each parameter was adjusted up or down by percentage steps according to the amount of change observed in the previous step. The results are presented in Table 20 and indicate that there was little sensitivity to specific yield for the fat clay (layer 1) but improvements could be made if specific storage was increased in both the upper fissured clay (layer 2) and the lower fissured clay (layer 3). Those changes were made and the sensitivity analysis repeated. After these changes were made, the sum of squared residuals improved from the initial value of 1273.5 to 961.3

Table 20. Results of Initial Sensitivity Analysis To Selected Parameters From Trench-based Trench Test.

Fat Clay Specific Yield	Change	Sum of Squared Residuals	Comment
0.08	--	1273.5	Original value
0.04	-50%	1273.8	Lowered original by 50%
0.02	-50%	1274.4	Lowered by additional 50%
Upper URZ Specific Storage	**Change**	**Sum of Squared Residuals**	**Comment**
0.0056	--	1273.5	Original value
0.0028	-50%	1383.6	Lowered original by 50%
0.0014	-50%	1455.3	Lowered by additional 50%
0.0084	50%	1192.3	Raised original by 50%
0.013	50%	1086.7	Raised by additional 50%
Lower URZ Specific Storage	**Change**	**Sum of Squared Residuals**	**Comment**
0.0056	--	1273.5	Original value
0.0084	50%	1157.7	Raised original by 50%
0.011	30%	1075.6	Raised by additional 30%
Upper URZ K	**Change**	**Sum of Squared Residuals**	**Comment**
7.9	--	1273.5	Original value
7.5	-5%	1318.0	Lowered original by 5%
7.1	-5%	1365.1	Lowered by additional by 5%
Lower URZ K	**Change**	**Sum of Squared Residuals**	**Comment**
6.1	--	1273.5	
6.2	1.6%	1258.7	Raised original by 1.6%
6.3	1.6%	1243.9	Raised by additional 1.6%

Attention was then turned to adjustments to layer 2 and 3 hydraulic conductivity. Step wise adjustments were made in the same fashion as before. The previous analysis did not explore raising the value in layer 3, so both decreases and increases were made during this round. Results of these trials are presented in Table 21.

This analysis showed greater sensitivity to the lower fissured clay hydraulic conductivity and that small improvement could be made by increasing this value to 6.3 m/day. The sum of squared residuals improved from the initial value of 961.3 to 942 by making this adjustment to hydraulic conductivity in layer 3. Figure 19 presents a plot of observed versus simulated heads. Comparison to Figure 16 showing the data before sensitivity analysis adjustments were made, shows small improvement.

Table 21. Results from Second Round of Sensitivity Analysis (Hydraulic Conductivity).

Upper URZ K	Change	Sum of Squared Residuals	Comment
7.9	--	961.3	Original value
8.0	1.25%	954.6	Raised original by 1.25%
8.1	1.25%	948	Raised by additional 1.25%
7.5	-5%	989.3	Lowered original by 5%
7.0	-6%	1027.5	Lowered by additional by 6%
Lower URZ K	**Change**	**Sum of Squared Residuals**	**Comment**
6.1	--	961.3	Original value
6.2	1.6%	951.5	Raised original by 1.6%
6.3	1.6%	942	Raised by additional 1.6%

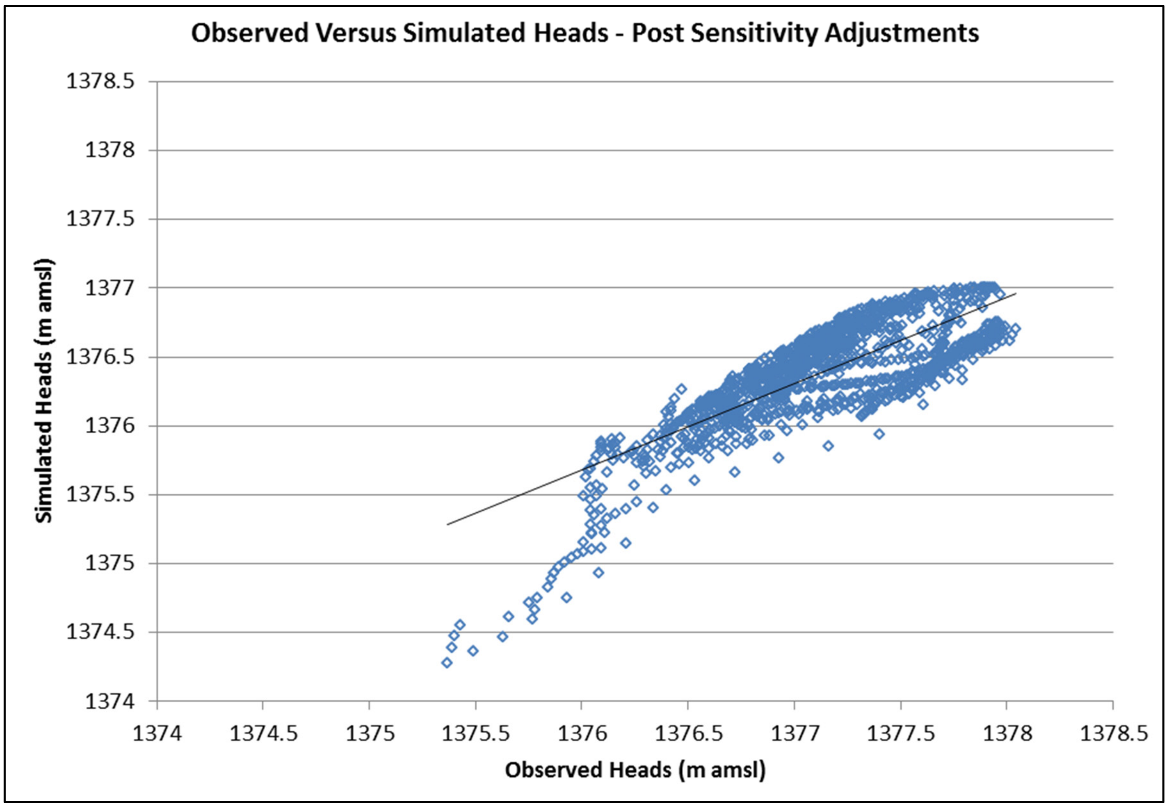

Figure 19. Observed vs. Simulated Heads from Trench-Based Stress Test, Post Sensitivity Analysis.

Figure 20 shows new simulated head contours in layer 2 (upper fissured clay) plotted with residuals at the end of pumping (stress period 12). Contour interval is 0.1 m, maroon color indicates dry cells. The plotted residual values indicate that the simulated heads are still lower than observed by the value shown. Comparison to Figure 17, however, shows that improvements were made by making these adjustments, notably with regard to the number of dry cells.

Figure 21 shows a plot of simulated head with residuals at the end of recovery. Comparison of these data to the original residuals at the end of recovery (Figure 18) shows little change resulted from these adjustments.

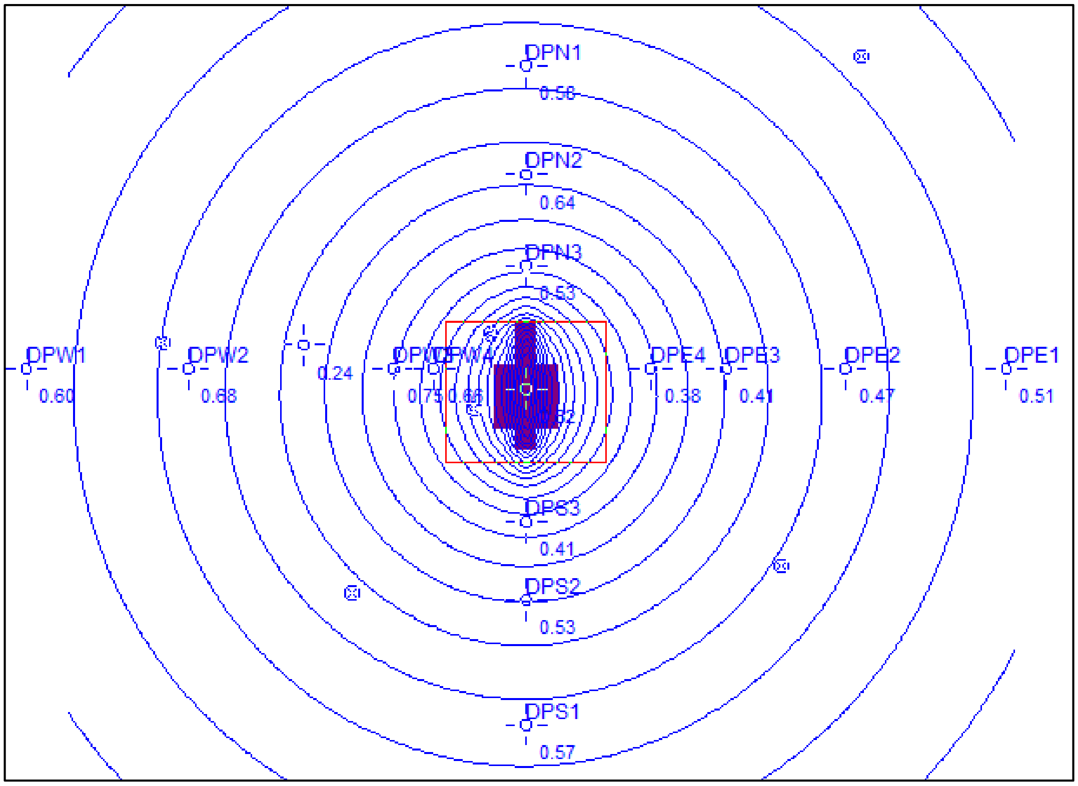

Figure 20. Head Contours at the End of Pumping with Residual Values Plotted – After Sensitivity Analysis Adjustments.

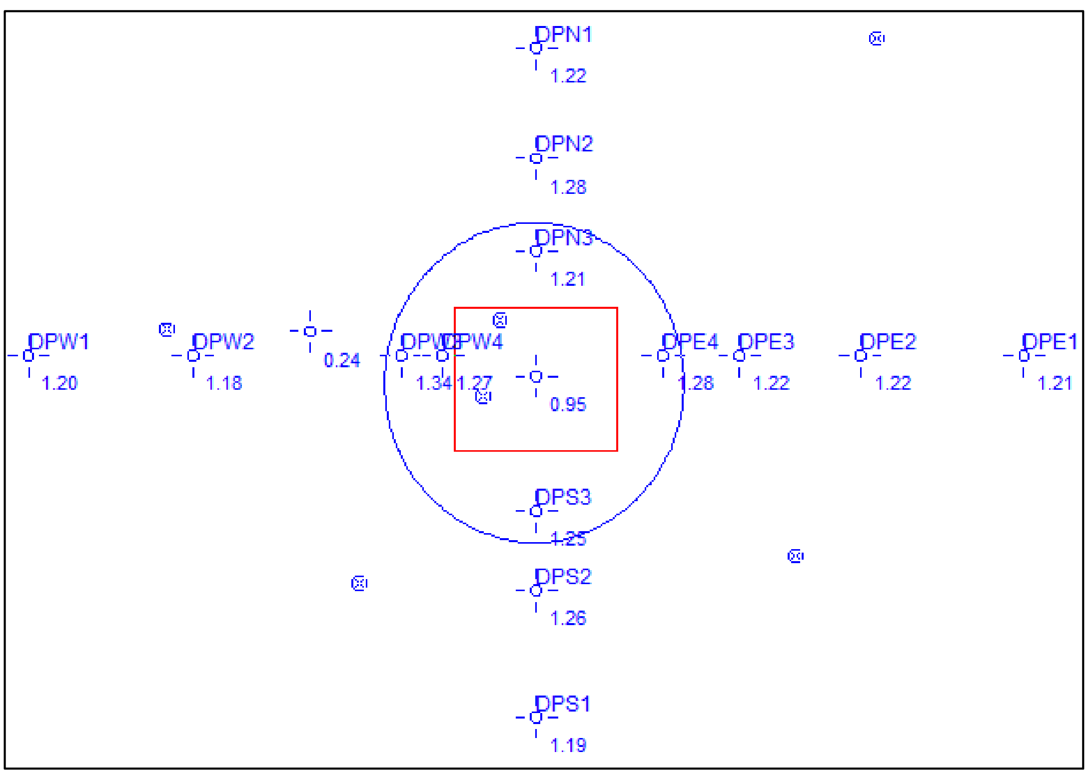

Figure 21. Head Contours at the End of Recovery with Residual Values Plotted – After Sensitivity Analysis Adjustments.

As a final check, the hydraulic conductivity in the upper fissured clay (layer 2) was changed to last value used in the sensitivity analysis (7 m/day), and the model was rerun. The results showed a minor increase in sum of squares residuals.

Therefore it was decided that no additional work would be performed on attempting to constrain parameters as the initial values from the calibration of the trench test seemed fairly accurate and in the end required little adjustment to the original values estimated from the test.

4. PREDICTIVE FLOW SIMULATIONS

4.1 Introduction

The design assumption detailed in planning documents was that brine would be extracted through a network of extraction trenches. Make up water would be supplied through a complementary network of recharge trenches supplied by water diverted from the Sevier River. The extraction trench system would supply brine to pre-concentration ponds to begin the process of evaporating the brine to eventually extract the desired end products.

Each extraction trench is designed to produce 0.09 gallons per minute (gpm) per lineal foot (ft.) of trench, with an assumed total length of trenches to produce a discharge rate to the pre-concentration ponds of approximately 33,000 gpm. This requires approximately 70 lineal miles of extraction trench. It was further assumed that the extraction trenches would initially be 20-ft. deep, with an option to convert to 40-ft deep trenches later in the project.

Objectives for initial predictive flow simulations were as follows:

1. Determine a sustainable rate for extraction trenches without supplemental makeup water from recharge trenches.
2. Determine a sustainable rate for extraction trenches with supplemental makeup water from recharge trenches.
3. Determine the effect of deeper extraction compared to shallow extraction. At some point during mine operations, it may be required to deepen trenches from the 20-ft depth to depths on the order of 40 ft. bgs.
4. Determine the effect of trench spacing. To guide the development of the mining system, three trench spacings were considered. The base case of 500 m spacing, an intermediate spacing of 750 m, and a maximum spacing of 1000 m.
5. If possible, determine the effect of the presence of a hypothesized aquitard between the upper resource zone (URZ) and the lower resource zone (LRZ). This aquitard is hypothesized based on refusal of direct push-drilling, but without any accompanying physical data to support its existence. The data obtained from refusal was qualitative at best, and was intermingled with drill data which reflected drill holes which were advanced to a depth of approximately 40-ft bgs. Therefore, the refusal depth (if present at all) was not available from these drill holes. Other than the refusal data, there is little to no lithologic or hydrogeologic evidence available to support the presence or absence of this layer.

Typical scenarios used to achieve the above objectives included

1. Seven layer model with three layer extraction from five trenches without recharge trenches - east side, basin edge
2. Six layer model with three layer extraction from five trenches with recharge trenches – east side, basin edge
3. Six layer model with three layer extraction from five trenches with recharge trenches – basin center

To address the above, the previous described groundwater model developed by Whetstone Associates was used and configured to simulate a series of extraction and recharge scenarios as described in the following sections of this technical memorandum.

To minimize the time required developing the physical layout in the model itself and because design was still in flux at the time of modeling, two sub-areas were selected to simulate the performance of the recharge and extraction trenches:

- Area 1 - The first series of trenches included in the preliminary Phase 1 system were selected for the simulations. The preliminary Phase 1 design specified the pre-concentration ponds to be located in the west side of the northern lobe of the playa. In the northern part of the playa, the simulated trenches lie in along the eastern edge of the playa. This is in an area where the thickness of the upper resource zone (URZ) is somewhat thinner than the playa-wide average (Figure 22).

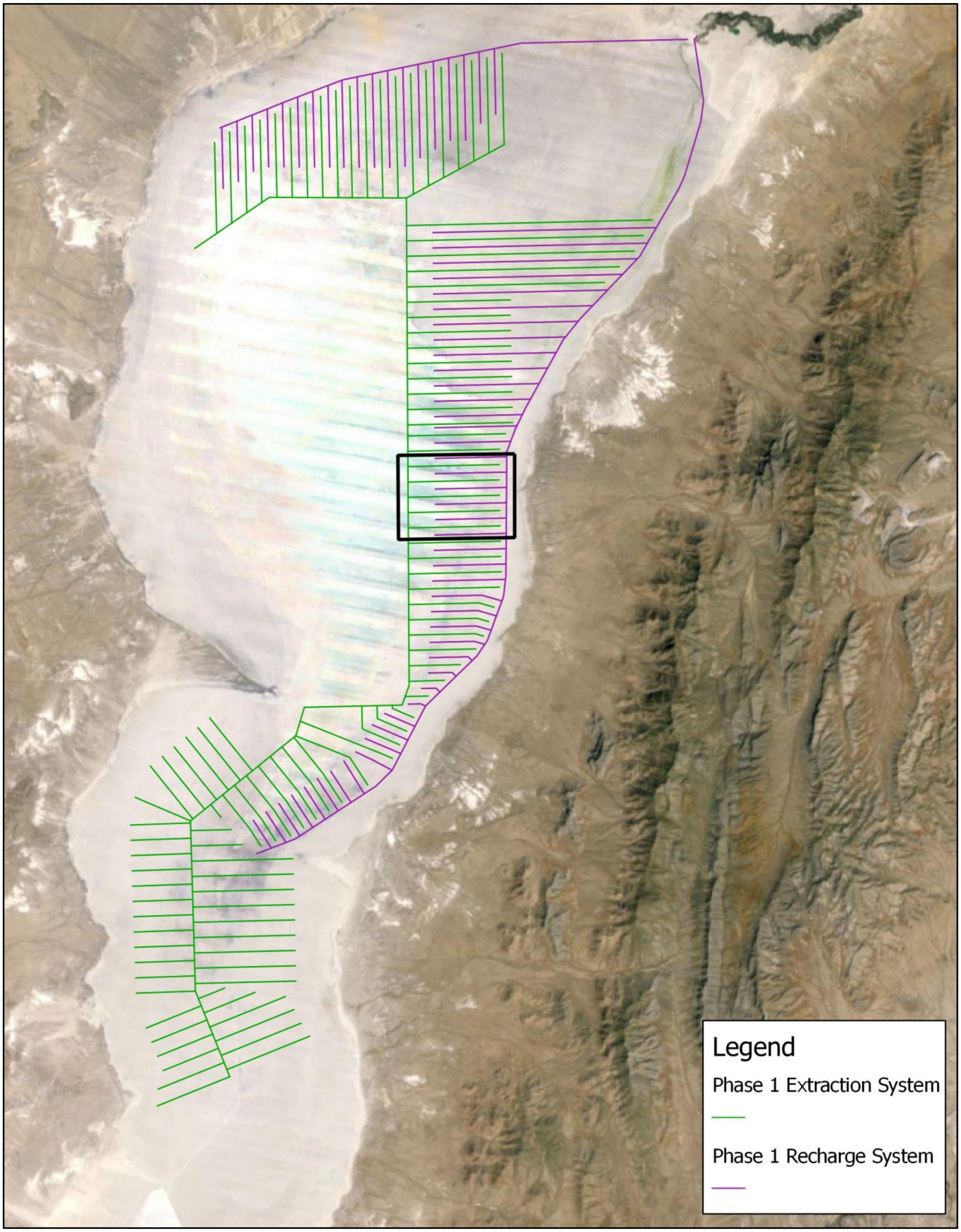

Figure 22. Map of Sevier Lake Playa Showing Phase I (Basin Margin) Trench Extraction and Recharge Distribution System. Focus Area is Delineated By the Black Box.

- Area 2 – A set of trenches located south of Needle Point in an area where the thickness of the URZ was thicker than the playa-wide average, but did not represent the maximum thickness observed on the playa. This particular arrangement reflected a revised alternative trench layout where the pre-concentration ponds were located at the northern end of the north lobe of the playa in the area of the Luma leases (Figure 23).

Modeling sub-sets of the trenches instead of trenches over the entire playa reduces the amount of simulation time, requires less time expended on changing trench configurations (boundary conditions), and reduced memory requirements as finer grid spacing would only be required in the area of the trench subsets rather than the entire model.

4.2 Modeling Approach and Configuration

The trench system was constructed in GIS based on design documents. Two sets of shapefiles were generated; one set for extraction trenches and the other for recharge trenches. The shapefiles for the recharge trench system were configured with additional attributes for the specification of various parameters such as flow rate, bed elevation, boundary layer thickness, stage, etc. Both sets of shapefiles were then exported from GIS and imported into Groundwater Vistas.

4.2.1 Extraction trench simulation Methodology

The extraction trench system was of simple design. Each extraction trench was represented by analytical element (AE) line boundary, assigned a rate, width, boundary thickness, and boundary hydraulic conductivity, which provides necessary parameters for the WEL package. The shapefiles for the extraction trenches were constructed simply to guide the placement of the extraction trenches at the appropriate length and spacing. The segments were nominally 3000 m long (9,843 feet) in length and 6 meters in depth (20 feet) and were variously configured to communicate with multiple layers.

The extraction trench boundary layer thickness was assigned a value of 0.5 m, with the hydraulic conductivity of the boundary layer assigned a value of 0.665 m/day, one order of magnitude lower than the calibrated value for the upper URZ obtained from the small-scale model from the tracer trench site (Whetstone Associates, 2013). The justification for the lower value of hydraulic conductivity was to represent siltation of the trench which would reduce the possibility of direct connection with fissures in the in the URZ.

4.2.2 Recharge Trench Simulation Methodology

Several different approaches were tried to simulate a trenches that would maintain an appropriate stage throughout the simulations. However, there seemed little other option than to use implausibly large amounts of water through the canal system to keep heads high. The excess water was then removed at the end of a recharge segment by several different methods:

1. Specification of an undefined tributary segment (e.g., zero) where the excess water would be routed.
2. Specifying a real segment containing one reach and occupying the same cell as the last reach of a recharge trench. All excess water in the last reach of the recharge trench is routed to this one reach segment. The hydraulic conductivity of the one reach cell was set to zero so the water removed would no longer interact with the groundwater.
3. Specifying a real segment containing one reach and occupying the same cell as the last reach of a recharge trench. All excess water above a certain stage (equal to approximately ground surface) was routed to this one reach cell and then out of the model. The stage was calculated outside of MODLOW using WinXSPRO (Hardy, T., et al., 2005).

None of these approaches was satisfactory, thus a different solution was sought which involved the use of the LAK package. The operation of the SFR and LAK are briefly discussed below to provide necessary details to describe the particular implementation for the simulations described herein.

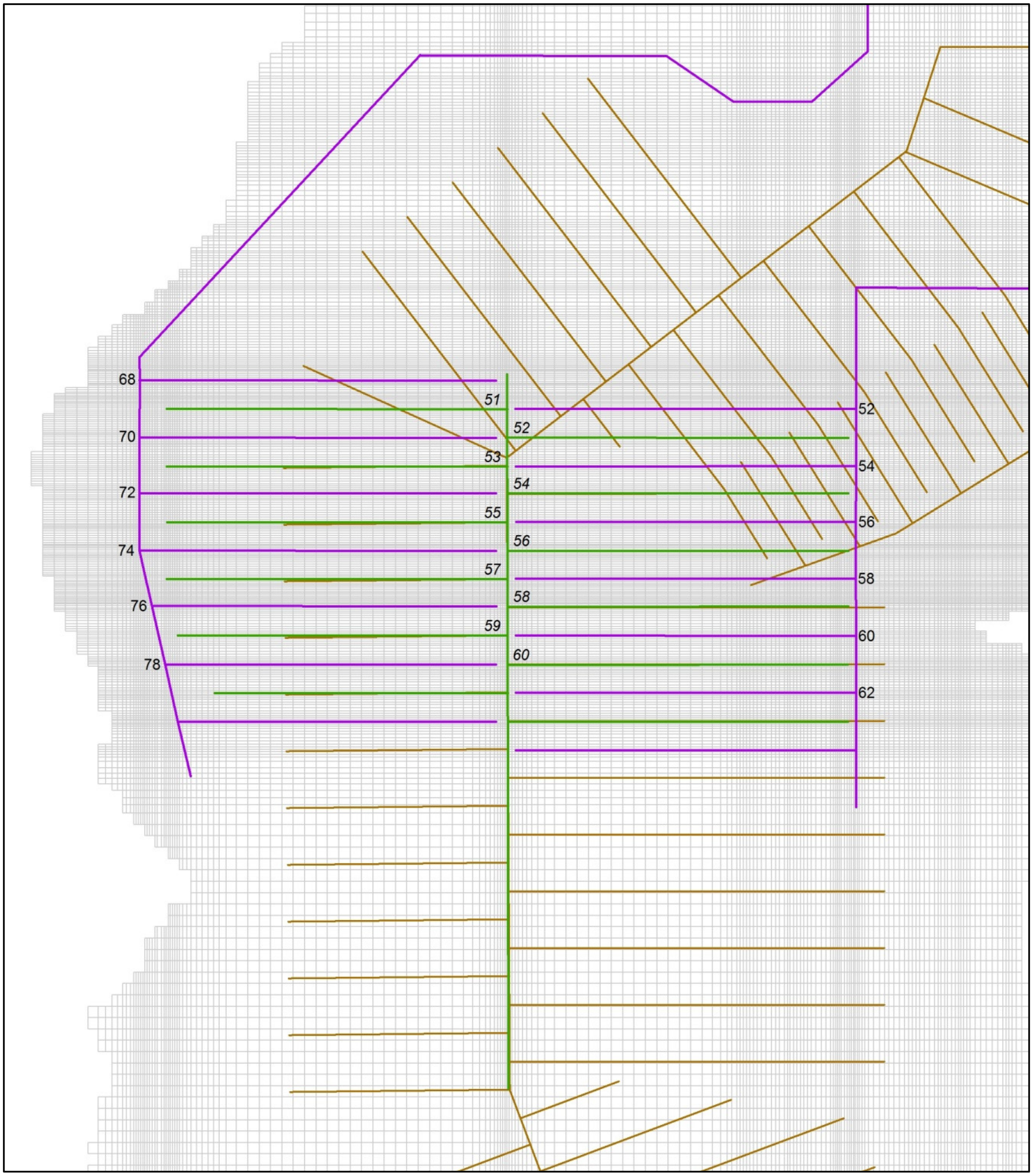

Figure 23. South Lobe (Basin Center) Extraction (Green) and Recharge (Purple) Distribution Systems. (Phase I Distribution System is Shown in Tan Color for Reference Purposes).

Recharge trenches were simulated using the USGS MODFLOW Streamflow-Routing (SFR1) package (Prudic, et al., 2004), and the MODFLOW Lake (LAK3) Package (Merrit and Konikow, 2000). Each recharge trench in the model is constructed of a short SFR stream segment linked to LAK3 boundary condition cells designed to represent the majority of the trench. The reasoning behind this particular arrangement is that while the SFR package is a robust stream flow routing program, it is apparently not designed to optimally deal with situations where stream segments end (i.e., are dammed) within the model domain.

A network of streams defined in the SFR package is divided into reaches and segments. A stream reach is a section of a stream that is associated with a particular finite-difference cell used to model ground-water flow and transport. A segment is a group of reaches that have (1) uniform rates of overland flow and precipitation to them; (2) uniform rates of evapotranspiration from them; (3) uniform or linearly changing properties (for example; streambed elevation, thickness, and hydraulic conductivity, and stream depth and width); (4) tributary flows or specified inflow or outflow (only in the first reach); and (5) diversions (only from the last reach). Stream depth (in this case, canal/trench depth) is computed at the midpoint of each reach occupying a model cell. This approach allows for the addition and subtraction of water from runoff, precipitation, and evapotranspiration within each reach.

4.2.2.1 Stream Inflow and Outflow

Specified inflows and outflows to a simulated stream system are defined only for the first and last reach of a segment. The SFR package allows several sources of inflow to any particular stream segment or reach. These include:

1. specified inflow at the beginning of the first reach of any segment;
2. the sum of tributary flows from upstream segments into the first reach of a segment;
3. direct overland runoff to a reach;
4. precipitation that falls directly on a reach; and
5. Head-dependent groundwater leakage from the underlying aquifer to a reach as calculated by the model.

The program also allows for several types of outflow to a reach. These losses include:

1. Stream-flow out of a reach;
2. specified diversions out of the last reach of a segment;
3. evapotranspiration from a reach; and
4. Head-dependent leakage out of a reach to the underlying groundwater aquifer as calculated by the model.

All of the above were used at various places in the model for this boundary condition except that no direct run-off was specified for any stream reach.

The recharge trench configuration assumes that inflow to the recharge canal/trench network occurs at a diversion dam on the Sevier River where the river channel contacts the model boundary. Here the flow from the river can be specified and initially diverted into two segments, one toward the west and one to the south. For phase 1 simulations, all flow is specified to enter the Phase 1 main recharge canal which flows to the south along the east side of the playa; ignoring the Phase 2 segment.

Phase 1 recharge trenches are specified (by design documents) to connect only to the west side of the main recharge canal. The main recharge canal and the necessary number of lateral recharge trenches were inserted into the model using an ArcGIS shapefile with parameters embedded in the shapefile that were read into MODFLOW through input files generated by the Groundwater Vistas (ESI, 2011) pre-processor program. The model then calculates length across each cell for each reach, and interpolates the bed elevations of the streambed from initial and end values taken from design documents.

Table 22 presents parameters used in the specification of the main recharge canal.

Table 22. Parameters used in Specification of Main Recharge Canal.

Parameter	Source	Value
Beginning Streambed Depth	Design	1378.9 m amsl
End Streambed Depth	Design	1374.2 m amsl
Initial Stream Stage	Tabulated[1]	1 m above bed, varies with flow
Width	Design, Tabulated[1]	Varies with depth
Hydraulic Conductivity	SDRI data (fat clay)	1.8E-05 m/day
Boundary thickness	Estimated[2]	0.5 m
Length (per cell, reach)	Computed	Varies with angle and position of line in cell

NOTES:
1. Stage (water depth), width, and volume (flow) relations were calculated outside of MODFLOW using WinXSPro, tabulated and added to the SFR package as an input file.
2. The boundary layer is assumed to be a 0.5 m-thick low conductivity resulting from siltation.
3. m amsl – meters above mean sea level.

4.2.2.2 Boundary Conductance

A siltation layer was assumed to be present, lining the boundary of the interface between the lateral recharge trenches and the aquifer. It was assumed that the hydraulic conductivity of such a layer would likely be less than the average hydraulic conductivity for the fissured clay aquifer (6.65 m/day). However, some experimentation was required to settle on an actual value of hydraulic conductivity and thickness of this boundary layer due to numerical instability associated with some combinations of these values. Eventually a value of 0.06 m/day for hydraulic conductivity with a thickness of 1.0 m was selected on the basis of physical plausibility and the ability to achieve computational convergence with this value pair. These two parameters are used in the computation of conductance between the aquifer and the trench bed, which in turn exerts control on the exchange of water between the aquifer and the recharge trench.

4.2.2.3 Stream Depth

Stream depth is calculated by a number of different schemes. A different option may be used for each segment. All five options use the same method for computing the streambed elevation for each reach where the elevation of the streambed is specified in the first reach cell and the last reach cell and the program linearly interpolates elevations for the cells between the first and last reaches. Only the Type 4 scheme was used which uses depth-discharge and width-discharge relations for estimating stream depth and width as a function of flow.

Two different sets of relations were calculated, one for the main segments and one for the laterals. The discharge-width-stage relations were computed outside of the model using WinXSPRO (Hardy et al., 2005). The morphology of the main recharge canal is modeled as a trapezoidal channel approximately 6 m in depth, with a 2H:1V side slope and flat bottom 2 meters in width. Total width at ground surface is 23 m. Stage (water depth) and channel width at particular stages are related to flow by tabulated results from the WinXSPro program assuming a roughness coefficient of 0.015. The results from running the channel design through WinXSPRo were tabulated and brought into MODFLOW as separate data and inserted into the appropriate input table. The main canal segment bed elevations were more or less kept in the fat clay as much as surface elevation differences would allow.

Six lateral recharge trenches (No. 36 through 46), approximately 3,000 m in length were symmetrically arranged amidst the extraction trenches. The lateral recharge trenches are modeled as trapezoidal channels approximately 6 m in depth with 1.5H:1V side slopes and a flat bottom 0.5 m in width. Total width at groundwater surface is 19 m. The groundwater model was provided tabulated depth, width and flow relations obtained from running the lateral trench design through the WinXSPro program. The starting bed elevation of each recharge lateral segment was specified at the bed elevation of where it connected to the main recharge canal. Per design, the terminal end of each lateral was specified at a depth 4 m below this elevation for a slope of approximately 0.0013.

4.2.2.4 Diversions

The SFR package has five options for simulating stream depth and four options for computing diversions from a stream. The options for computing diversions are based on an actual specified amount or a percentage of flow out of the last reach of a segment. Diversion types 2 and 4 were used for the model depending on the segment connection type. Main recharge canal segments feeding other downstream main canal segments used a type 2, which assumes all flow up to a specified amount from the last reach of the upstream segment will be diverted into the segment in question. In this case, if the flow is less than the specified amount, all the flow from the upstream reach is diverted. If the flow in the last upstream reach is greater than the specified diversion flow, the specified amount will be diverted and the remainder will be left in the channel. The main recharge canal connections to laterals used a type 4 diversion. The type 4 uses a percentage to calculate the fraction of remaining flow to divert into the segment in question.

The procedure essentially consisted of specifying a trial flow rate into the headwater segment of the main recharge canal system and transmitting that water along the channel to where the lateral recharge trench segments were located. At each lateral, a customized percentage was specified to divert a certain amount into each lateral. In all cases, percentage of 99.99% was specified for the last lateral, indicating that all remaining flow in the main canal would be diverted into that lateral trench.

4.2.2.5 Stream-Lake Interconnections

Lateral recharge trenches were connected to cells containing lake boundary conditions. The USGS Stream and LAK Packages are coded to identify stream flows at the end of the lowest reaches of stream segments that become lake inflows and to identify lake outflows that become inflows to the uppermost reaches of stream segments. The OUTSEG parameter of a SFR segment which discharges to a lake is set equal to the negative value of the lake identification number (where the minus sign is used as a flag to tell MODFLOW that flow enters a lake rather than a tributary stream segment.

After the recharge network boundary conditions were imported into the model, they were replaced with depth/layer-appropriate LAK boundary conditions cells using the SFR cells as a guide (Figure 24). As shown by the example in Figure 24, two to three SFR cells, representing about 75-80 meters of trench length were left in each case to make the necessary connection from the main recharge trench to each lake representing a lateral recharge trench. The stub simply serves as a conveyance between the main recharge canal and the LAK cells representing the bulk of the lateral recharge trench, with the last reach of the stub making the connection to the lake boundary cells.

Also, now that an accurate representation of LAK package interaction with the SFR package is a critical requirement, all layers which could be significantly penetrated by trenches are modeled as confined/unconfined layer types by setting the parameter LAYCON to a value of 43. This follows guidance that if no prior knowledge is available for the head condition in a layer, the user is advised to use an input LAYCON of 43 (Hydrogeologic, Inc., 1998).

4.3 Summary of Basin-Edge Three Dimensional Scenarios

As earlier stated, the goal of these simulations was to evaluate the performance of trench depth and spacing, recharge trench flow rates, and extraction rates in order to arrive at certain configurations that would be explored further or selected for preliminary mine planning purposes.

To model these scenarios, a change had to be implemented in the model. Because layer 1 already contained a lake boundary condition over the entire extent of the playa surface, it needed to be removed to allow the SFR and LAK boundary conditions to be implemented on a trench-by-trench basis. Therefore, layer 1 was removed from the model. Layer 1 now consisted of the fat clay and remaining layers all followed suit and move up in the numbering (Table 23).

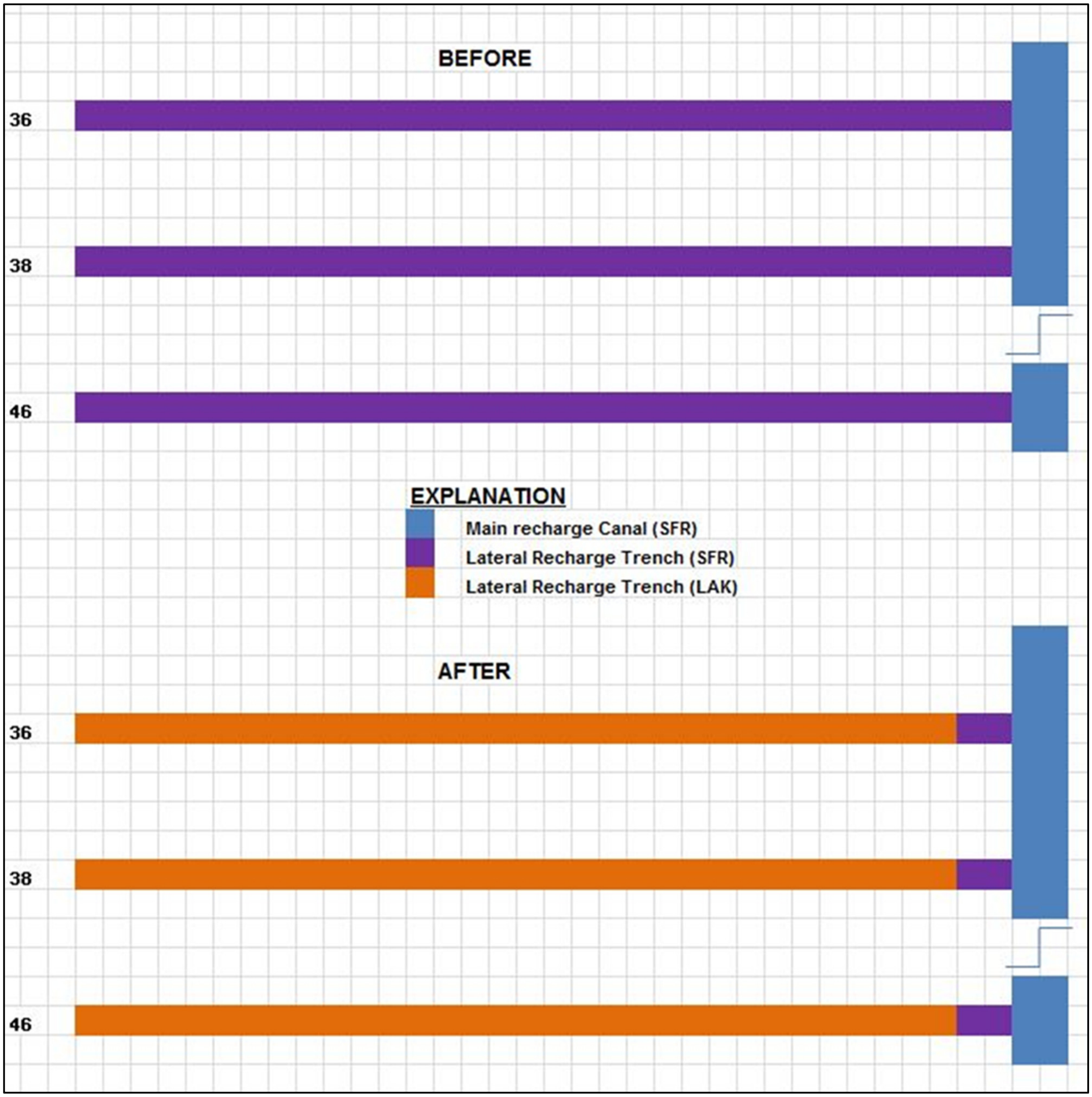

Figure 24. Before and After Replacement of SFR Boundary Condition with LAK Boundary Condition.

Table 23. Model Parameterization for Simulations with Recharge Trenches.

Parameter	Layer 1 (Fat Clay)	Layer 2 (Upper URZ)	Layer 3 (Lower URZ)	Layer 4 (Aquitard)	Layer 5 (LRZ)	Layer 6 (Lacustrine)
LAYCON[1]	43	43	43	43	40	40
Kx,y (m/day)	0.00018	7	6.3	0.001	1	0.01
Kz (m/day)	1.8E-05	7	6.3	0.0001	0.1	0.001
Specific Storage (m^{-1})	0.0015	0.013	0.011	1E-07	2.7E-06	1E-06
Specific Yield	0.08	0.08	0.08	0.03	0.06	0.04

NOTES:

1. LAYCON 43 equals the combination of integers 4 (harmonic mean inter-block hydraulic conductivity) and 3 (confined/unconfined conditions where transmissivity and storage are allowed to vary as a function of head). LAYCON 40 equals a combination of integers 4 (harmonic mean inter-block hydraulic conductivity), and 0 (strictly confined conditions where transmissivity and storage efficient are constant throughout the entire simulation).

The simulation process was iterative, beginning with single trench scenarios with no recharge trench flow, and ending with multi-trench simulations that considered two areas of differing subsurface bed thicknesses. The basin edge scenarios are described in this section, while discussion of basin-center scenarios begins in Section 4.4.

The simulations for the basin edge area culminated in a configuration which included five extraction trenches on 500 m centers with six recharge trenches interspaced on 500 m centers. Extraction was simulated from the upper 3 layers (fat clay, upper fissured, and lower fissured clay aquifers. This scenario evaluated the degree to which surface water transmitted through the network of recharge trenches could recharge the groundwater and decrease the amount of drawdown at each extraction trench.

Table 24 presents a tabulation of layer elevation and thickness data for each modeled extraction trench. These data reported for the center point of each trench and therefore actual values vary somewhat along each trench per the variation exhibited by each layer top and bottom

The design extraction rate of 0.09 gpm/lineal ft. was selected as the base case for the purpose of comparison to earlier simulations. Discharge from extraction trenches for one meter length of trench into each layer (three layers total) was calculated as 0.534 m^3/day, for a total extraction rate of 1.6 m^3/day per lineal meter of trench. Therefore,

- 1.6 m^3/day/m * 3000 m/trench= 4,800 m^3/day/trench
- 4,800 m^3/day/trench * 264.17 m^3/g = 1,268,016 gpd/trench
- 1,268,016 gpd/trench /1440 min. = 880.6 gpm/trench
- 880.6 gpm/trench / 9,843 ft. = 0.09 gpm/lineal ft. of extraction trench

The discharge value of 0.534 m^3/day was specified for each analytical line boundary representing an extraction trench in communication with layers 1 through 3.

Table 25 presents a summary of the stress periods as configured for these simulations. A steady-state stress period was inserted into the model as stress period 1 during which no extraction or stream flow was specified.

During stress period 2, variable amounts of surface water flow were allowed into the recharge trench system beginning with segment 3, the first active segment. Flow rates between 30 cfs and 7.5 cfs were specified and allowed to flow down the main recharge canal to recharge trenches 36 through 46, where the flow was equally apportioned to the recharge trenches. No residual flow allowed to continue down the main recharge canal (segment 49) past the last lateral recharge trench segment. Extraction trenches 17 through 21 were selected for this simulation, and were selected on the bases of being centrally located between the recharge trenches.

In stress period 3, extraction began in each of the five extraction trenches while still allowing the recharge system to flow at the specified rate.

Table 24. Bed Elevations and Thicknesses of Extraction at Trench No.'s 17 through 21 for Basin Edge Simulations.

Trench	Surface Elevation (m amsl)[1]	Flat Clay Bottom (m amsl)	Upper-URZ Bottom (m amsl)	Lower-URZ bottom (m amsl)	Depth bgs to bottom of URZ (m)	Penetration into layer 5 aquitard (m)[2]
ExtTrench17	1376.73	1375.05	1373.65	1371.56	5.17	0.83
ExtTrench18	1376.76	1375.1	1373.71	1371.64	5.12	0.88
ExtTrench19	1376.81	1375.15	1373.76	1371.68	5.13	0.87
ExtTrench20	1376.85	1375.17	1373.77	1371.68	5.17	0.83
ExtTrench21	1376.9	1375.16	1373.71	1371.54	5.36	0.64
		Fat Clay Thickness (m)	**Upper URZ thickness (m)**	**Lower URZ Thickness (m)**	**URZ Thickness (m)**	**URZ Thickness (ft.)**
ExtTrench17	--	1.68	1.4	2.09	3.49	11.45
ExtTrench18	--	1.66	1.39	2.07	3.46	11.35
ExtTrench19	--	1.66	1.39	2.08	3.47	11.38
ExtTrench20	--	1.68	1.4	2.09	3.49	11.45
ExtTrench21	--	1.74	1.45	2.17	3.62	11.88

NOTES:

1. m = meters, amsl = above mean sea level, ft. = feet.
2. Positive values indicate meters of penetration into layer 4 measured from below bottom of lower URZ.

Table 25. Stress Period Setup with 5 Extraction Trenches with Recharge Trench Flow for the Initial Extraction Rate (0.09 gpm/lineal ft.).

Stress Period	Type[1]	Length (days)[2]	No. of Time Steps	Time Step Multiplier[3]	Purpose
1	SS	1	1	1.2	Equilibration of constructed trenches with ambient head.
2	T	Variable	Variable	1.2	Flow in recharge system with no extraction
3	T	360	36	1.2	Flow in recharge system with extraction
4	T	Variable	Variable	1.2	Recovery, no extraction with recharge trench flow

NOTES:

1. SS = steady-state, T = transient
2. Stress period length is meaningless for steady-state stress period.
3. Time-step multiplier causes time step length to be small in early time steps and longer later on during the stress period for greater precision during times when head is changing relatively quicker.

In the final stress period, stress period 4, extraction was shut down, while still allowing the recharge trench system to flow at the specified rate. The purpose of stress period 4 was to observe recovery for a period of time after extraction discharge is terminated to characterize the degree and manner in which the recharge trenches can recover depressed post-extraction heads in the aquifer system. It is likely that this recharge trench inflow rate could differ from the rate used to balance extraction in stress period 3, and may have to be tuned as to not supply too much water (overflowing the recovering trenches) yet still supply a sufficient rate to optimize the rate of head recovery.

Table 26 presents the flow routing parameters for the defined SFR segments. Main recharge canal segments are odd-numbered while lateral recharge trenches are always even-numbered; the numbering also corresponds to the particular flow table used because the geometry of main canal segments differs from lateral segments. The numbering system requirements of the SFR package require that segments be inserted in order, hence all segments had to be specified in order to reach the location of the trenches involved in the simulation. For the purpose of the Phase 1 simulations described herein, all extraneous segments were by-passed by specifying them as headwater segments and setting the inflow rate in the first reach of each segment to zero.

Table 26. SFR Parameters for Simulated Phase 1 Segments at Basin Edge.

NSEG (Segment)	ICALC	OUTSEG	IUPSEG	IPRIOR	NSTRPTS	FLOW (m^3/day)	ET (m/day)	PRECIP (m/day)
1-2	Segments 1 and 2 are not utilized in the simulation							
3	4	5	0	--	50	Variable	3.9E-03	5.56E-04
Even segments 4 through 28 are lateral segments not utilized in the simulation. Odd segments 5 through 29 are used only to pass water along to the next downstream segment, but interact fully with the groundwater system and atmospheric fluxes.								
30	4	-1	29	-2	24	0	3.9E-03	5.56E-04
31	4	33	0	--	50	calculated	3.9E-03	5.56E-04
32	4	-2	31	-2	24	0	3.9E-03	5.56E-04
33	4	35	0	--	50	calculated	3.9E-03	5.56E-04
34	N/A, required only to keep numbering consistent at main recharge trench bed slope break							
35	4	37	0	--	50	calculated	3.9E-03	5.56E-04
36	4	-3	35	-2	24	0.1667	3.9E-03	5.56E-04
37	4	39	0	--	50	calculated	3.9E-03	5.56E-04
38	4	-4	37	-2	24	0.2000	3.9E-03	5.56E-04
39	4	41	0	--	50	calculated	3.9E-03	5.56E-04
40	4	-5	39	-2	24	0.2500	3.9E-03	5.56E-04
41	4	43	0	--	50	calculated	3.9E-03	5.56E-04
42	4	-6	41	-2	24	0.3333	3.9E-03	5.56E-04
43	4	45	0	--	50	calculated	3.9E-03	5.56E-04
44	4	-7	43	-2	24	0.5000	3.9E-03	5.56E-04
45	4	47	0	--	50	calculated	3.9E-03	5.56E-04
46	4	-8	45	-2	24	0.9999	3.9E-03	5.56E-04
47	4	49	0	--	50	calculated	3.9E-03	5.56E-04
48	4	0	47	-2	24	0	3.9E-03	5.56E-04
49	4	0	0	--	50	calculated	3.9E-03	5.56E-04

NOTES:

ICALC = Method used for stream depth calculation for the segment. Type 4 = tabulated values of flow, stage, and width.
OUTSEG = Downstream tributary segment into which the upstream segment deposits its remaining flow from its last downstream reach. Negative numbers indicate outflow to lake cells representing recharge trenches.
IUPSEG = Integer value of upstream segment from which a diversionary segment obtains some portion of flow.
IPRIOR = Parameter corresponding to the type of diversion calculation to apportion flow into the diversionary segment. Type -2 = percentage of flow from last upstream reach.
NSTRPTS – Parameter used only when ICALC = 4, the value corresponds to the number of tabulated flow, stage and width relations.
FLOW = Specified flow in indicated segment, m^3/day = cu. meters per day. When IPRIOR = -2, the value shown s is the amount of flow as a fraction of the flow present in the last reach of the upstream segment specified by IUPSEG. Values shown are for reference only and change per the actual amount of flow allowed into the headwater segments. The values were usually calculated to specify equal amounts into each lateral segment.
ET = evapotranspiration, m/day = meters/day, directly from stream surface.
PRECIP = precipitation, m/day = meters/day, falling directly on stream channel.

Note that while the headwater flow rate is specified, the flow at any downstream reach is different based on the amount of groundwater interaction (in or out of the reach), which is head-dependent and controlled by the boundary conductance term. The flow rate at any downstream reach is also affected by the specified evaporation rate (removes water from a reach) and precipitation rate (adds water to a reach).

4.3.1 Discussion of Basin Edge Simulations

Initial simulations showed that extraction rates at or near the 0.09 gpm/lineal ft. value were not sustainable for the time frame simulated. At the end of one year of extraction heads in the upper fissured clay aquifer show values below the bottom of layer 2 with significant cell drying at the west end of the trenches where no recharge trench exists to buffer the drawdown. Cell desaturation in layer 3 occurred only at the west end of the extraction trenches where drawdown is not adequately buffered. Inspection of the results for layer 4 (aquitard) showed that hardly any cell desaturation had occurred anywhere, indicating that the bottom of the trenches (which occurs just into this layer) had largely not become dewatered.

Acceptable recharge trench recharge flow rates were somewhere between 7.5 and 10 cfs. However, because the previous simulations indicated that where extraction trenches were not buffered along their length with a sufficient length of recharge trench, the degree of cell desaturation was exacerbated. Thus, recharge trenches were extended so that the recharge trenches more or less paralleled the extraction trenches for almost their full length. In general, the results showed a greatly improved outcome with regard to both cell desaturation and mounding. Excessive mounding is only present in the northern-most recharge trench and the southern-most recharge trench, which is expected due to the fact that there is no extraction trench bordering one side of these two recharge trenches that would help balance requirement of recharge trench inflow. During actual mine operations this would be alleviated by tuning the inflow to any number of recharge trenches with the head gate controls.

Table 27 presents the final water balance for these simulations culminating in a sustainable 0.06 gpm/lineal ft. extraction rate with full length recharge trenches configured with 7.5 cfs inflow. Calculated cumulative volume of water extracted for one year is 5,776,402 m^3. The simulated volume was 5,776,402 m^3 for 0% difference. The water balance shows that cumulative volumes (in/out) differ by only 0.4 percent (132,884 m^3).

Table 27. Water Balance for 0.06 gpm/lineal ft. Extraction, Extended Length Recharge Trenches with 7.5 cfs Trench Inflow[1].

Contributing Parameter[2]	Into Groundwater (m^3)[3]	Out of Groundwater (m^3)	Difference (m^3)
Storage	23,547,914	13,861,258	9,686.656
Recharge (areal, RSF4)	361,735	0	--361,735
ET (areal, EVT1)	0	12,940,494	-12,940,494
Recharge Trench Seepage (SFR1)	851	104,150	-103,299
Recharge Trench Seepage (LAK3)	9,318,641	413,953	8,904,688
Extraction Trenches (WEL1)	0	5,776,402	-5,776,402
TOTALS:	33,229,141	33,096,257	132,884

NOTES:

1. The total recharge trench inflow is 15 cfs, equal to the sum of inflow (7.5 cfs) specified at the headwater segment for each side of the recharge network.
2. Parenthesized terms are the MODFLOW packages responsible for the indicated parameter.
3. m = meters.

With reference to Table 27, the value of lake package seepage (9,318,641 m^3) into the groundwater which represents recharge trench infiltration, compared to the volume of water removed from storage (23,547,914 m^3), which represents the amount of water being yielded by the aquifer by a combination of pore desaturation and pore water depressurization, shows that the contributions to available water are dominated by the storage term. Assuming that the values reported pertain principally to the area modeled and neglecting the small stream term and the areal recharge term (the assumption being that in comparison to the entire playa, the contribution from recharge for just the area modeled is nominal), recharge trench seepage about 28% of the total flows into groundwater.

This would suggest that the extraction trenches could be pumping water that may contain up to about 28% diluting flow. This is based on the assumption that water quality in the recharge system, which according to design, contains diverted Sevier River water, and therefore reflects a significantly lower solute concentration than the brine aquifer. Also, it is assumed that the recharge trench system picks up little to no brine on its path to the extraction trench area modeled and along its subsurface path from recharge trench to extraction trench. This is a conservative assumption as in all likelihood the recharge trench system will incorporate some quantity of brine either by overland flow or from groundwater.

Figure 25 shows head in the upper fissured clay (layer 2) at the end of extraction. Only the bottoms of the extraction trenches are dry in layer 2. Figure 26 shows head in the lower fissured clay (layer 3) at the end of extraction. Significantly, just a few cells in the western ends of two trenches appear to have desaturated. Figure 27 shows head in the aquitard (layer 4) which contains the bottom of the trenches (refer to Table 24 for penetration depths). The results for layer 4 as shown in this figure demonstrate that none of the trench bottoms dewatered during the one year of simulated extraction at the 0.06 gpm/lineal ft. rate with 7.5 cfs recharge trench inflow.

Figure 28 presents the hydrographs for analytical wells screened in layer 3 and located next to each extraction trench at about the center of each trench. The lower elevation shown on the ordinate (1371.68 m amsl) represents the average elevation of the bottom of the URZ in the area of the extraction trenches and therefore, heads immediately next to the trenches never fell below that level. The recovery period (stress period 4) begins where the plots begin to trend upwards (Day 363) and heads are observed to over-recover during this stress period. In practice, during mine operations, the recharge inflow would be shut off at the head gate when heads recover to an elevation at or near the ground surface (probably sometime between day 400 and day 450).

Overall, the extension of recharge trenches to parallel virtually the entire length of extraction trenches was a positive influence on performance. Review of the data obtained for the recovery period shows that the desaturated cells rewet in the lower fissured clay (layer 3) by day 5, and by the end of day 39 of recovery, desaturated cells rewet in the upper fissured clay (layer 2).

4.3.2 Conclusion of Basin Edge Simulations

Modeling of extraction trenches and extraction trenches with recharge trenches was carried out with varying rates of extraction, recharge canal/trench system inflow, and recharge trench length. Five extraction trenches were simulated with identical extraction rates tied to a volume per lineal ft. of extraction trench which varied from 0.09 gpm/lineal ft. to 0.06 gpm/lineal ft. A sustainable extraction rate at this location probably lies nearer the 0.06 gpm/lineal ft. rate with recharge inflow of approximately 5 to 7.5 cfs apportioned between each trench (0.8 to 1.25 cfs per lateral trench). However, this extraction rate could be extended upwards depending on actual thickness of the URZ and how much recharge flow is available and for what duration. For the cases considered here, the total thickness of the URZ is relatively thinner because the area modeled is near the eastern edge of the playa. Better performance (i.e. a higher sustainable extraction rate) is expected toward basin-center where fissured clay aquifer thicknesses are greater.

The data obtained during the recovery period indicates that flow and duration of flow should be tuned so as not to overflow recharge trenches. If recharge flow is kept constant through a one year extraction period and the following recovery period, full recovery at the trench could probably be accomplished in 50 to 100 days. Lower recharge trench inflow rates used during recovery periods may increase recovery time but may have an added benefit of retaining a greater proportion of brine-rich water in upper layers because a lower proportion of freshwater would be used to replace the extracted water, and over time also allow greater overall mixing of the two waters.

The simulation results also indicate that recharge trenches should be constructed so that their lengths more or less parallel the full length of the nearest extraction trenches to realize optimal drawdown buffering capacity.

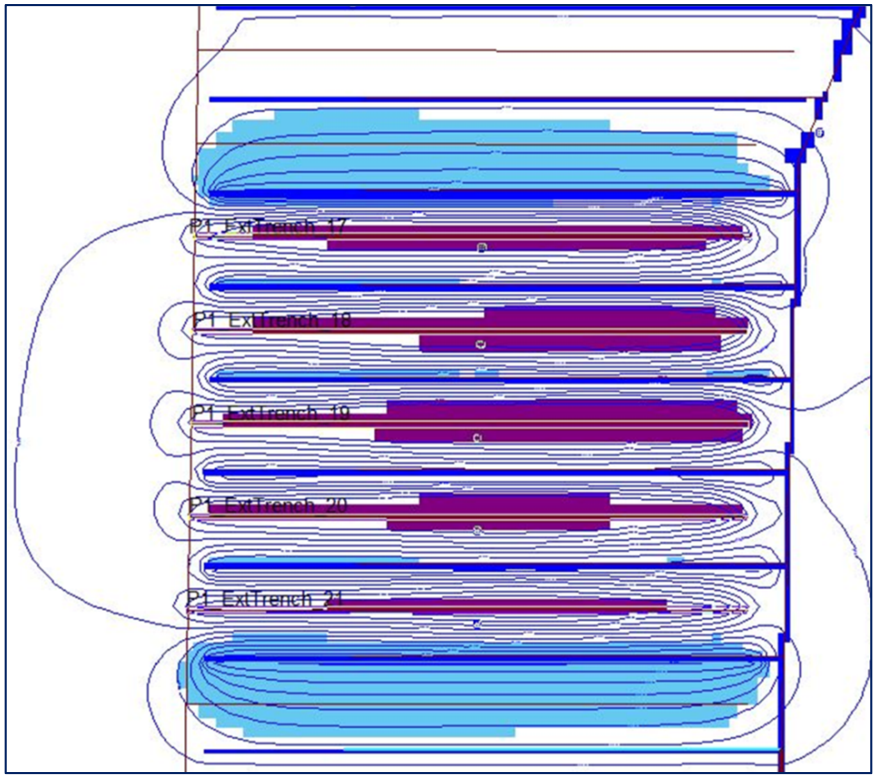

Figure 25. Head in Layer 2 at End of Extraction Period (0.06 gpm/lineal ft.) with Extended Recharge Trenches with 7.5 cfs inflow).

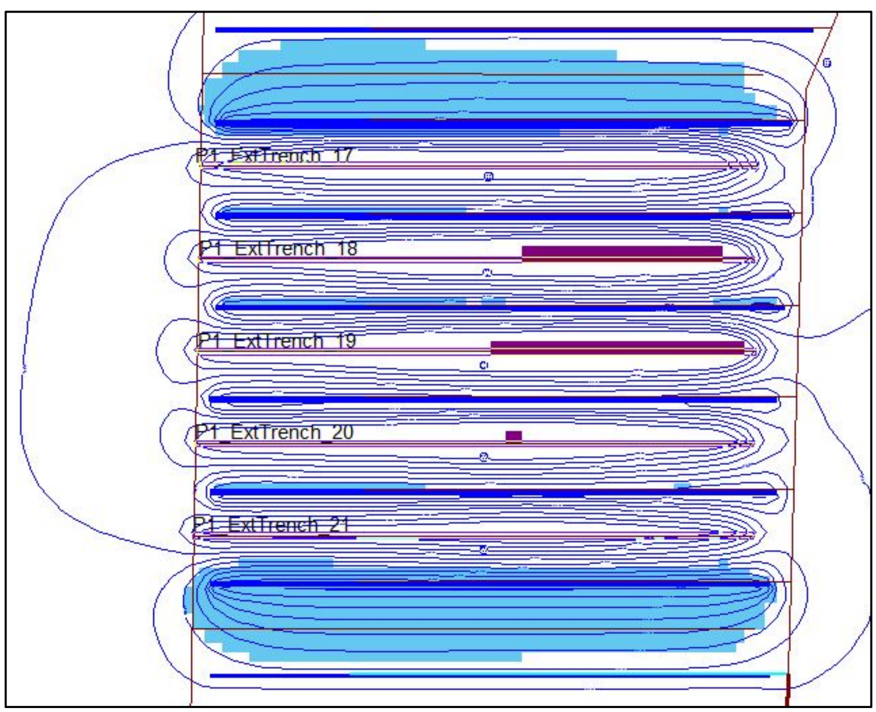

Figure 26. Head in Layer 3 at End of Extraction Period (0.06 gpm/lineal ft.) with Extended Recharge Trenches with 7.5 cfs inflow).

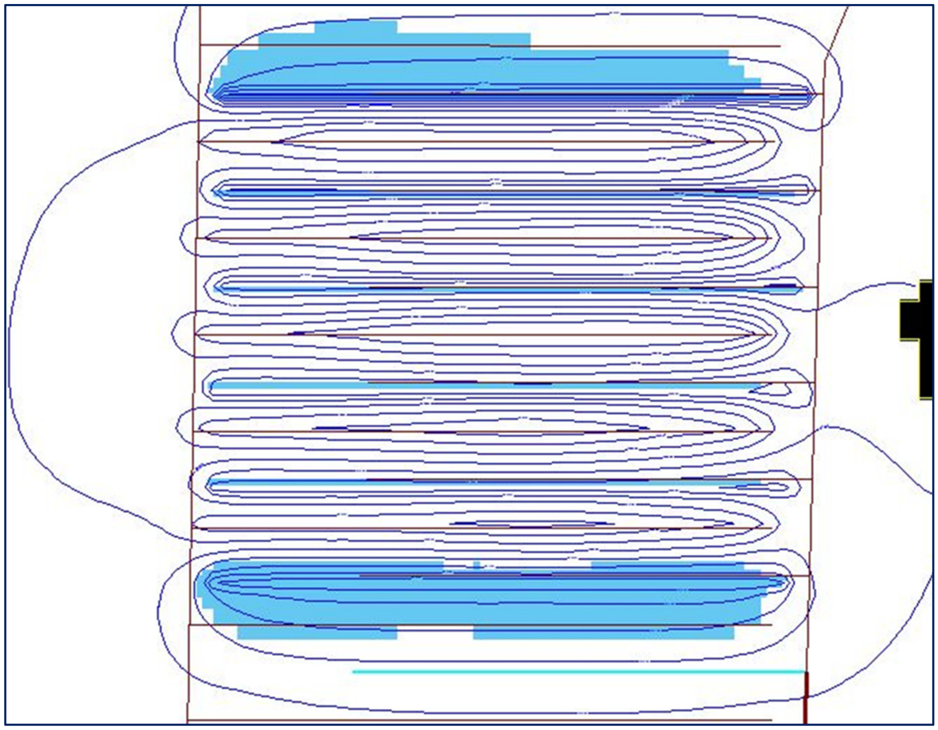

Figure 27. Head in Layer 4 at End of Extraction Period (0.06 gpm/lineal ft.) with Extended Recharge Trenches at 7.5 cfs inflow).

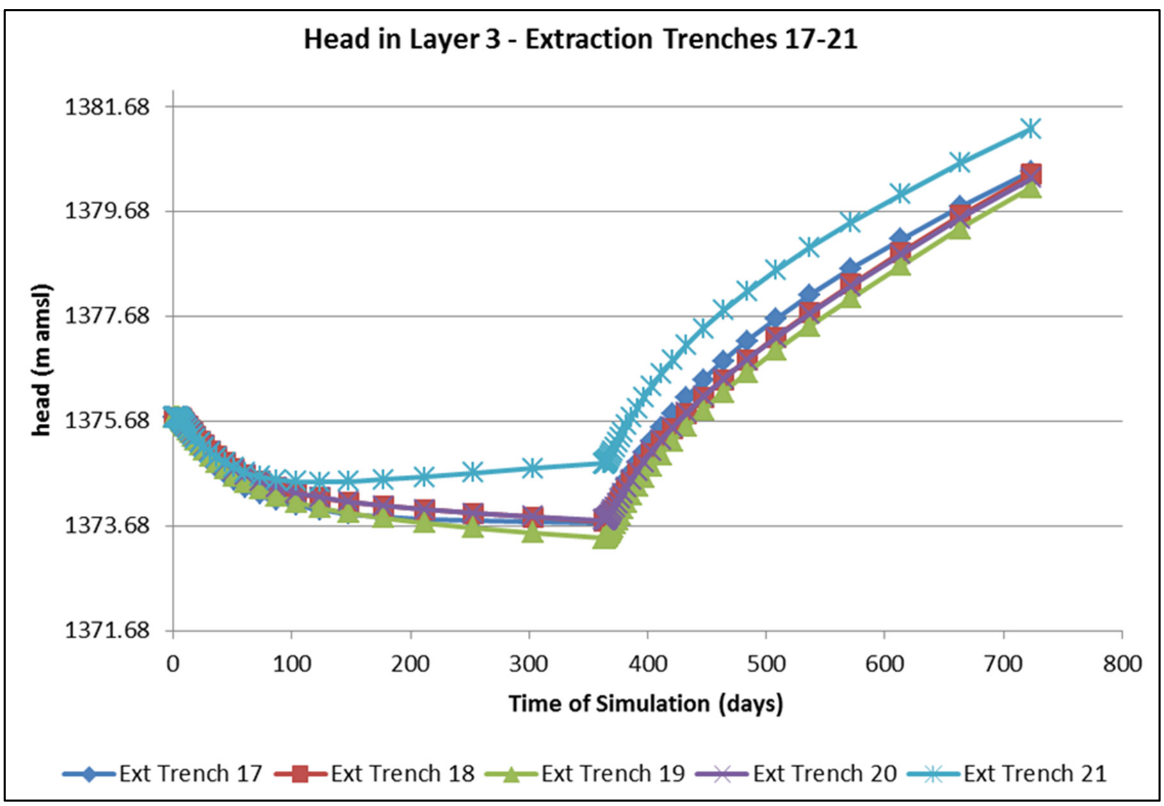

Figure 28. Hydrographs for Basin-Edge Layer 3 Analytical Wells Placed Next to Extraction Trenches.

4.4 Summary of Basin-Center Three Dimensional Scenarios

4.4.1 Introduction

Modeling described earlier evaluated the performance of a subset of the extraction and recharge canal/trench system located at the eastern edge of the basin in the upper lobe of the Sevier Lake Playa. The scenarios evaluated included a series of five 6.1 m (20-ft)-deep extraction trenches, spaced at 500 m center-to-center with six recharge trenches interspersed between extraction trenches at regular intervals, also spaced at 500 m intervals. The location selected for the previous simulations included the area occupied by Phase 1 Extraction Trenches 17 through 21 and recharge trenches 36 through 46 (even numbered).

In this area, the thickness of the upper resource zone, represented by the upper fissured clay and lower fissured clay aquifer underlain by the hypothesized middle aquitard is relatively smaller in comparison to areas closer to the center of the playa. Drawdown is proportional to the transmissivity (hydraulic conductivity multiplied by bed thickness). A relatively thinner upper resource zone will therefore present higher values of drawdown and lower sustainable extraction rates. As a result, the location previously modeled represents somewhat of a less-than-optimal scenario in terms of sustainable extraction rate.

To evaluate a more optimal scenario where the thickness of the URZ is greater, a location was selected in the southern lobe of the playa, south of Needle Point where the upper resource zone is relatively thicker. This area was suggested by Agapito Associates on July 30, 2013 and agreed to by Whetstone Associates. Because design documents that guided the earlier effort for the Phase 1 scenarios were then under revision due to a significant mine change involving relocation of pre-production ponds, there were no GIS shapefiles available at the time of the simulations to guide the placement of the main extraction canal, extraction trenches and recharge canal/trench system. As a result, a brief objective of the site location was communicated verbally to Whetstone with the direction that Whetstone create the layout with the same spacing as before, and place extraction trenches on either side of a central brine collection canal, using the Phase 1 South Brine Canal as a guide. The beginning of this central brine collection canal was placed south of Needle Point and preceding directly south, with lateral brine collection canals located to the west and east in alternating fashion.

4.4.2 Trench Layout

Because there was no design document to reference for the trench network design, the method used to design the trench network will be described here. With reference to Figure 29, a the north-south line representing the central brine collection canal was located by drawing a straight line with the northern end placed at the intersection of the original Phase 1 Extraction Trench No. 52 with the South Brine Canal as originally laid out in the Agapito Associates design document titled “Recharge and Extraction Trench Layout”, dated 6-21-2013. The southern end of this north-south line was placed at the intersection of the Phase 1 Extraction Trench No. 75 with the South Brine Canal as depicted in the aforementioned design document. This line more or less bisects the southern half of the playa east to west, and became the guide for laying out a representative extraction network as shown. The centrally located north-south line (green in Figure 29) was assumed to represent a main brine extraction canal and therefore it was assumed that all lateral extraction trenches would connect to it and extraction flow would be directed into it

GIS shapefiles containing the cell elevations for the top of layer 1 (representing the fat clay), and bottom elevations for the fat clay (layer 1), upper URZ (layer 2), lower URZ (layer 3) and the middle aquitard were exported from Groundwater Vistas and brought into GIS to provide data for further processing. A shapefile representing either a main recharge canal segment or a lateral recharge trench was constructed and assigned a boundary thickness and a hydraulic conductivity for the purpose of representing the conductance term. Stream bed elevations and initial stream stage were assigned to the first and last reaches for each shapefile.

Once the extent of the extraction and recharge network was constructed in GIS, a shapefile containing all the traces of entire network was imported back into Groundwater Vistas. Using this shapefile as a guide, the model grid was re-discretized to a finer cell size in the area of the new extraction and recharge, with the objective that cell width would not exceed the maximum width at land surface of the actual trapezoidal channels specified for each type of lateral trench or main canal.

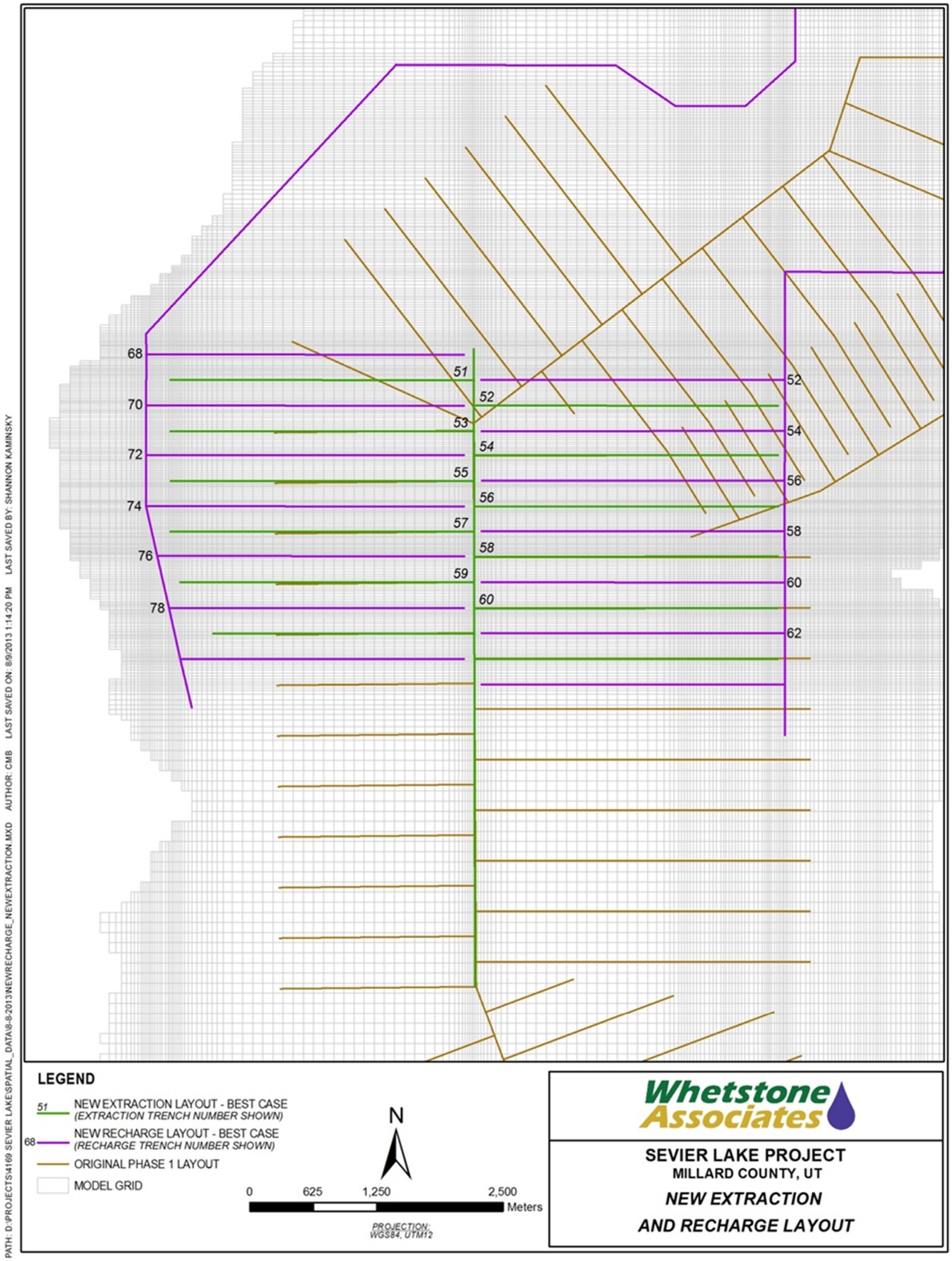

Figure 29. New Extraction-Recharge System Layout for Basin-Center Scenarios.

After the grid was re-discretized, each segment of the recharge network was imported back into Groundwater Vistas to assign stream boundary conditions to the cells covered by each respective shapefile. Values for these bed elevation and initial stream stage were calculated by Groundwater Vistas for intermediate reaches by linear interpolation.

As before, each recharge trench stream boundary condition was then removed up to the third reach, leaving a stub consisting of reaches 1 through 3. A lake boundary condition was then assigned to the cells formerly containing the stream boundary condition and copied down through the third layer. The target for the total length of each recharge trench (SFR stub plus LAK boundary conditions cells was approximately 3,000 m, and ranged between a value of approximately 2,920 m at recharge Segment 78 to approximately 3,150 m at segments 68-74 due to actual cell size. The ends of each recharge trench were terminated no closer than approximately 100 m from the central brine collection canal to maximize the buffering of drawdown in extraction trenches paralleling the recharge trenches.

Following the construction of the recharge network, extraction trenches were laid out on 500 m centers using analytical well line boundaries. The design of the extraction trenches was left as before: side-slope of 1V:1H, 13 m wide at ground surface and 6.5 m wide at mid-depth, with a flat bottom 1.5 m wide. This translated to an analytical element 6.5 meters wide and 6 meters deep, communicating to the top three layers. All analytical elements representing trenches except for one were 3,000 m in length. The remaining trench (trench No. 59) was specified as 2,900 m due to the geometry of the playa edge at this location. In addition, the center extraction canal (2,600 m length) was included in the simulation.

Table 28 presents parameters used in the construction of the SFR network representing the recharge canal/trench network prepared for the simulation area and used to generate the SFR package input files for use by MODFLOW-SURFACT. As indicated in Table 28, recharge flow was directly specified at two headwater segments represented by Segment 51 (east side) and Segment 67 (west side). Headwater recharge trench inflow was variable per simulation. The initial value of recharge inflow was specified as 18,350 m^3/day (7.5 cfs) for each individual side of the recharge network for a total flow of 36,700 m^3/day (15 cfs) for the entire recharge trench network. The headwater flow was then apportioned for each downstream lateral recharge trench segment on each side of the recharge network per the FLOW parameter specified.

Table 29 presents the elevation and thickness data calculated for each segment representing the recharge network.

Table 30 presents a tabulation of trench length, and layer elevation and thickness data for each simulated extraction trench.

4.4.3 Discussion of Basin-Center Simulations

As before, the model was configured to allow communication to three layers, the fat clay, the upper fissured clay (upper URZ) and the lower fissured clay (lower URZ). The design extraction rate of 0.09 gpm/lineal ft. was selected as the base case for the purpose of comparison to earlier simulations. The configuration required recalculation of the line boundary flux in order to function at the 0.09 gpm extraction rate for the initial simulation. Discharge from extraction trenches for one meter length of trench into each layer was calculated as 0.534 m^3/day, for a total extraction rate equal to 1.6 m^3/day per lineal m of trench. Therefore, for the example of a 3000 m extraction trench,

- 1.6 m^3/day/m * 3000 m = 4,800 m^3/day/trench
- 4,800 m^3/day/trench * 264.17 m^3/g = 1,268,016 gpd/trench
- 1,268,016 gpd/trench /1440 min. = 880.6 gpm/trench
- 880.6 gpm/trench / 9,843 ft. = 0.09 gpm/lineal ft. of extraction trench

Recharge trench inflow for each side of the recharge trench system (east and west) ranged from 7.5 cfs (18,350 m^3/day) to 9.0 cfs (22,022 m^3/day), equally feeding each side of the extraction trench network for total recharge inflow rate of 15 cfs (36,700 m^3/day) to 19 cfs (44,044 m^3/day).

Table 28. Initial SFR Parameters for Basin-Center Simulation of Recharge Network.

(NSEG) Segment	ICALC[1]	OUTSEG[2]	IUPSEG[3]	IPRIOR[4]	NSTRPTS[5]	Flow (m^3/day)[6]	ET (m/day)[7]	PRECIP (m/day)[8]
1-50	Not simulated							
51	4	53	0	--	50	18,350	3.9E-03	5.56E-04
52	4	-11	51	-2	24	0.17	3.9E-03	5.56E-04
53	4	55	0	--	50	calculated	3.9E-03	5.56E-04
54	4	-12	53	-2	24	0.20	3.9E-03	5.56E-04
55	4	57	0	--	50	calculated	3.9E-03	5.56E-04
56	4	-13	55	-2	24	0.25	3.9E-03	5.56E-04
57	4	59	0	--	50	calculated	3.9E-03	5.56E-04
58	4	-14	57	-2	24	0.33	3.9E-03	5.56E-04
59	4	61	0	--	50	calculated	3.9E-03	5.56E-04
60	4	-15	59	-2	24	0.5	3.9E-03	5.56E-04
61	4	63	0	--	50	calculated	3.9E-03	5.56E-04
62	4	-16	61	-2	24	0.99	3.9E-03	5.56E-04
63	4	0	0	--	50	calculated	3.9E-03	5.56E-04
64-66	Not Simulated							
67	4	69	0	--	50	18,350	3.9E-03	5.56E-04
68	4	-19	67	-2	24	0.17	3.9E-03	5.56E-04
69	4	71	0	--	50	calculated	3.9E-03	5.56E-04
70	4	-20	69	-2	24	0.20	3.9E-03	5.56E-04
71	4	73	0	--	50	calculated	3.9E-03	5.56E-04
72	4	-21	71	-2	24	0.25	3.9E-03	5.56E-04
73	4	75	0	--	50	calculated	3.9E-03	5.56E-04
74	4	-22	73	-2	24	0.33	3.9E-03	5.56E-04
75	4	77	0	--	50	calculated	3.9E-03	5.56E-04
76	4	-23	75	-2	24	0.50	3.9E-03	5.56E-04
77	4	79	0	--	50	calculated	3.9E-03	5.56E-04
78	4	-24	77	-2	24	0.99	3.9E-03	5.56E-04
79	4	0	0	--	50	calculated	3.9E-03	5.56E-04
80-81	Not Simulated							

NOTES:

1. ICALC = Method used for stream depth calculation for the segment. Type 4 = tabulated values of flow, stage, and width.
2. OUTSEG = Downstream tributary segment into which the upstream segment deposits its remaining flow from its last downstream reach. Negative numbers indicate outflow to lake cells representing recharge trenches.
3. IUPSEG = Integer value of upstream segment from which a diversionary segment obtains some portion of flow.
4. IPRIOR = Parameter corresponding to the type of diversion calculation to apportion flow into the diversionary segment. Type -2 = percentage of flow from last upstream reach.
5. NSTRPTS – Parameter used only when ICALC = 4, the value corresponds to the number of tabulated flow, stage and width relations.
6. FLOW = amount of flow specified directly for the segment, m^3 = cubic meters per day. When IPRIOR = -2, the value of flow for the segment is calculated by specifying FLOW as a value between 0 and 1, which represents a fraction of the flow present in the last reach of the upstream segment specified by the value of IUPSEG.. Values shown are for reference only and change per the actual amount of flow allowed into the headwater segments. The values were usually calculated to specify equal amounts into each lateral segment.
7. ET = evapotranspiration, m/day = meters/day, directly from stream channel.
8. PRECIP = precipitation, m/day = meters/day, falling directly on stream channel.

Table 29. Elevation and Thickness Data for Basin Center Recharge Network.

Segment No.[1]	Type	Layer 1 btm elev. (m amsl)[2]	Layer 2 btm elev. (m amsl)[2]	Layer 3 btm elev. (m amsl)[2]	URZ Thickness (m)[3]	URZ Thickness (ft.)[4]	Hydraulic Conductivity (m/day)	Boundary Thickness (m)
East Side								
1-50	Unused							
51	Main	1374.54	1372.91	1369.24	5.30	17.39	1.8E-05	0.5
52	Lateral	1374.44	1372.14	1368.71	5.73	18.80	0.06	1.0
53	Main	1374.34	1372.01	1368.53	5.80	19.05	1.8E-05	0.5
54	Lateral	1374.60	1372.39	1369.08	5.52	18.09	0.06	1.0
55	Main	1374.54	1372.33	1369.01	5.53	18.14	1.8E-05	0.5
56	Lateral	1374.64	1372.41	1369.09	5.54	18.19	0.06	1.0
57	Main	1374.72	1372.62	1369.46	5.26	17.26	1.8E-05	0.5
58	Lateral	1374.74	1372.59	1369.35	5.39	17.68	0.06	1.0
59	Main	1374.92	1372.93	1369.96	4.96	16.27	1.8E-05	0.5
60	Lateral	1374.84	1372.74	1369.59	5.26	17.24	0.06	1.0
61	Main	1374.96	1372.93	1369.89	5.08	16.65	1.8E-05	0.5
62	Lateral	1374.82	1372.63	1369.36	5.46	17.91	0.06	1.0
63	Main	1374.97	1372.81	1369.59	5.38	17.67	1.8E-05	0.5
64	Unused							
West Side								
66	Unused							
67	Main	1376.84	1375.54	1373.60	3.24	10.63	1.8E-05	0.5
68	Lateral	1375.86	1373.83	1370.78	5.08	16.67	0.06	1.0
69	Main	1376.63	1374.96	1372.45	4.18	13.71	1.8E-05	0.5
70	Lateral	1375.43	1373.55	1370.73	4.70	15.40	0.06	1.0
71	Main	1375.85	1374.16	1371.64	4.21	13.81	1.8E-05	0.5
72	Lateral	1375.10	1373.08	1370.06	5.05	16.55	0.06	1.0
73	Main	1375.62	1373.88	1371.28	4.34	14.24	1.8E-05	0.5
74	Lateral	1375.15	1373.14	1370.15	5.00	16.40	0.06	1.0
75	Main	1375.96	1374.47	1372.23	3.74	12.25	1.8E-05	0.5
76	Lateral	1375.40	1373.56	1370.81	4.60	15.08	0.06	1.0
77	Main	1376.59	1374.91	1372.40	4.19	13.75	1.8E-05	0.5
78	Lateral	1375.81	1373.64	1370.40	5.40	17.73	0.06	1.0
79	Main	1376.88	1374.80	1371.70	5.18	16.99	1.8E-05	0.5
80-81	Unused							

NOTES:

1. East side starts with No.51; west side starts with No. 67. Odd-numbered segments are main recharge canal segments, even-numbered segments are lateral recharge trenches
2. m amsl = meters above mean sea level, btm = bottom. Elevations are the average of elevation at beginning and end of each segment.
3. m = meters, thickness of layers 2 and 3 summed.
4. ft. = feet. Thicknesses in feet are included for the purpose of convenient comparison to conceptual model thicknesses.

Table 30. Layer Elevations, Depths and Thickness at Basin Center Extraction Trenches 51 through 62.

Trench	Surface Elevation (m amsl)[1]	Flat Clay Bottom (m amsl)	Upper-URZ Bottom (m amsl)	Lower-URZ bottom (m amsl)	Depth bgs to bottom of URZ (m)	Penetration into middle aquitard (m)[2]
West Side						
ExtTrench51	1377.41	1375.09	1373.14	1370.24	7.17	-1.17
ExtTrench53	1377.45	1374.66	1372.33	1368.85	8.6	-2.6
ExtTrench55	1377.47	1374.88	1372.72	1369.48	7.99	-1.99
ExtTrench57	1377.48	1375.19	1373.27	1370.4	7.08	-1.08
ExtTrench59	1377.50	1375.05	1372.99	1369.92	7.58	-1.58
East Side						
ExtTrench52	1377.25	1374.9	1372.94	1370.01	7.24	-1.24
ExtTrench54	1377.30	1374.97	1373.03	1370.12	7.18	-1.18
ExtTrench56	1377.30	1375.06	1373.18	1370.37	6.93	-0.93
ExtTrench58	1377.30	1375.28	1373.58	1371.05	6.25	-0.25
ExtTrench60	1377.34	1374.77	1372.61	1369.4	7.94	-1.94
Main Brine Collection Canal						
Main Brine Canal	1377.37	1374.65	1372.37	1368.96	8.41	-2.41
Trench	**Trench Length[3] (m)**	**Fat Clay Thickness (m)[4]**	**Upper URZ thickness (m)[4]**	**Lower URZ Thickness (m)[4]**	**URZ Thickness (m)[4]**	**URZ Thickness (ft.)[4]**
West Side						
ExtTrench51	3000	2.32	1.95	2.90	4.85	15.91
ExtTrench53	3000	2.79	2.33	3.48	5.81	19.06
ExtTrench55	3000	2.59	2.16	3.24	5.40	17.72
ExtTrench57	3000	2.29	1.92	2.87	4.79	15.72
ExtTrench59	2900	2.45	2.06	3.07	5.13	16.83
East Side						
ExtTrench52	3000	2.35	1.96	2.93	4.89	16.04
ExtTrench54	3000	2.33	1.94	2.91	4.85	15.91
ExtTrench56	3000	2.24	1.88	2.81	4.69	15.39
ExtTrench58	3000	2.02	1.70	2.53	4.23	13.88
ExtTrench60	3000	2.57	2.16	3.21	5.37	17.62
Main Brine Collection Canal						
Main Brine Canal	2600	2.72	2.28	3.41	5.69	18.67

NOTES:

1. m = meters, amsl = above mean sea level, ft. = feet.
2. Positive values indicate meters of penetration into layer 4 measured from below bottom of lower URZ. Negative values indicate meters above the top of layer 4 (no penetration).
3. Trench length as calculated by GIS. Actual modeled length is slightly greater in all cases because wherever the boundary condition touches a cell, the entire cell is included in the lineal extent of the boundary condition.
4. Thicknesses are calculated by differencing bottom elevations at the mid-point of the extraction trench. Thicknesses in feet are included for the purpose of convenient comparison to conceptual model.

To speed simulation time and to avoid the model the halting upon encountering non-converging solutions, the adaptive time-stepping package contained in MODFLOW-SURFACT was implemented. The adaptive time-stepping scheme selects a time-step size depending on the anticipated non-linearity of the system for a given calculation. If the anticipated non-linearity is not significant, a larger time-step size is selected to aggressively move forward with the simulation. If anticipated non-linearity is severe, a smaller time-step size is selected to ensure convergence for that time step. In the event that the solution fails to converge for a given time step, the time-step size is further reduced, and the solution is repeated. All stress periods were simulated as transient. Table 31 presents the stress period and time step data selected for the basin-center scenarios.

Table 31. ATO Time Discretization for Initial Basin-Center Extraction With Recharge Trenches.

Stress Period	Length (days)	Initial Time Step (days)	Minimum Time Step (days)[1]	Maximum Time Step (days)[2]	Time Step Multiplier[3]	Reduction (days)[5]	Purpose
1	7200	2.E-03	1.0E-04	200	1.2	50	Equilibration of constructed trenches with ambient aquifer heads.
2	variable	2.E-02	1.0E-02	2	1.2	2	Flow in recharge system with no extraction
3	360	2.E-02	1.0E-04	10	1.2	2	Flow in recharge system with extraction
4	variable	2.E-02	1.0E-04	10	1.2	2	Recovery, recharge trench flow only

NOTES:

1. Minimum time-step refers to the smallest time-step allowed before further reductions result in the program halting.
2. Maximum time step refers to the maximum size of a time step regardless of solution efficiency.
3. Time-step multiplier controls size of the jump to the next highest or lowest time step when the code detects changes in solution efficiency.
4. Reduction refers to the minimum size that a time-step would be cut by when solution inefficiencies are detected. In essence, this controls high quickly the ATO package can reach the minimum time-step allowed before the program halts.

Initial modeling showed that gains could be realized by tuning the amount of recharge allowed into each lateral trench segments. The principal cause of observed imbalance was the fact that the northern-most and southern-most recharge trench required comparatively less water than interior trenches because they laterally communicated with only one extraction trench. Each successive simulation therefore varied these amounts to optimize the drawdown buffering capacity of each recharger trench while at the same time not incur excessive flooding at ground surface. Table 32 presents the final inflow values for these simulations. This adjustment directs more flow to the center trenches and reduces flow to the first and last lateral trenches.

The final length of stress period 2 was adjusted to a length of 21 days to increase starting water levels in trenches while stress period 4 was shortened to 90 days to minimize the recovery time to target recovery water levels at approximately 1377.5 m amsl.

Also, after considering that ambient water levels in every test trench excavated during 2012 and 2013 were within 1 m of land surface within 24 hours of excavation, it was determined that initial water levels assigned to LAK1 boundary conditions representing recharge trenches were set several meters too low. As a result, all initial water levels for recharge trenches were set to 1 meter below land surface.

Table 33 presents the water balance for the 0.09 gpm/lineal ft. simulations with tuned dual 9 cfs recharge trench inflow. The water balance shows that cumulative volumes (in/out) differ by only 811 m^3, an error of virtually zero percent.

Table 32. Basin-Center Target Recharge Inflow Values for Individual Lateral Trenches, Dual Tuned 9 cfs.

Diversion Number	Recharge Inflow During Stress period 2 & 3 for Final scenario (cfs)[1]	Required FLOW Multiplier
52 & 68	1.0	0.1111
54 & 70	1.7	0.2125
56 & 72	1.8	0.2857
58 & 74	1.8	0.4000
60 & 76	1.7	0.6296
62 & 78	1.0	0.9999
TOTALS:	9.0 (per side)	--

NOTES:

1. cfs = cubic meters per second.

The calculated cumulative water volume extracted (including the main brine collection canal running between the lateral extraction trenches) was 18,743,400 m^3 for the one-year simulation period. The simulated extraction volume for the same time period was 18,743,630 m^3 for difference of virtually 0%.

Table 33. Water Balance for 0.09 gpm/lineal ft. Extraction with Tuned Dual 9 cfs Recharge Trench Inflow[1]

Contributing Parameter[2]	Into Groundwater (m^3)[3]	Out of Groundwater (m^3)	Difference (m^3)
Storage	25,740,986	14,572,366	11,468,620
Recharge (areal, RSF4)	235,677	0	235,677
ET (areal, EVT1)	0	10,607,358	-10,607,358
Recharge Trench Seepage (SFR1)	0.7	53,333	-53,332
Recharge Trench Seepage (LAK3)	18,172,950	172,116	18,000,834
Extraction Trenches (WEL1)	0	18,743,630	-18,743,630
TOTALS:	44,149,613	44,148,802	811

NOTES:

1. The total recharge trench inflow is 15 cfs, equal to the sum of inflows (7.5 cfs) specified at the headwater segment for each side of the recharge network.
2. Parenthesized terms are the MODFLOW packages responsible for the indicated parameter.
3. m = meters.

4.4.4 Conclusion of Basin Center Simulations

The results of the simulations at basin center utilizing extraction from the upper three-layer showed that the 0.09 gpm/lineal ft. extraction rate is sustainable with a recharge trench inflow rate of approximately 9 cfs per side.

To provide a rough estimate of the source of water extracted during the entire simulation, the volume obtained from storage could be considered to contain brine at the prevailing brine concentration. This volume can be compared to the volumes of water contributed as groundwater domain inflow by the other sources:

- Volume of water removed from storage - 25,740,986 m^3
- Volume of recharge trench seepage into the groundwater - 18,172,950 m^3
- Areal recharge (estimated for the modeled area only)[2] - 14,657 m^3

This tabulation shows that the contributions to water simulated as inflow to the groundwater domain continue to be dominated by the storage term, and though the recharge inflow rate was increased by 1 cfs per side, the actual fraction coming from non-brine sources stayed about the same compared to the earlier simulation with 8 cfs recharge inflow per side. Non-brine contributions totaled about 71 percent of the storage term, and about 41 percent of the total of all inflow contributions to the groundwater domain. The storage term remained about 1.42 times the volume of non-brine contributions.

Therefore, these calculations suggest that the extraction trenches could potentially be extracting water that may contain about 41% diluting flows with the assumption that water quality in the recharge system reflects a significantly lower solute concentration.

This potential outcome requires that the water contributed by recharge trench system represents ambient Sevier River water quality and picks up little to no brine on its path to the extraction trench area modeled and also along its path in the subsurface as it is drawn into extraction trenches. In all likelihood, however, water in the recharge trench system as it is being transmitted from the entry point at the northeast corner of the playa will increase in salinity due to either seepage into the trenches from the groundwater system or from overland run-off carrying salts and entering the trench system. Note that the water balance reflected in Table 33 shows smaller, but relevant recharge trench seepage terms (out of groundwater into recharge trench) of 53,333 m^3 (SFR1) and 172,116 m^3 (LAK3).

A more accurate depiction of the findings detailed above, which illustrates how the ratio of brine and freshwater contributions changes over time is presented in Figure 30. Stress period 1 was reset to 1 day to generate these data. The data were manually collected from the MODFLOW-SURFACT output file. The data indicate that the ratio of brine to freshwater inputs to groundwater (and therefore presumably available for extraction) declines over time. The purple line (lowest in the figure) represents the volume contribution to groundwater from freshwater sources (trench recharge and areal recharge). The red line (second from the bottom) represents the contribution to groundwater from aquifer storage (assumed to contain brine at the prevailing concentration). The blue line is the sum of these two aforementioned volumes. The green line represents the fraction of brine (from storage) when compared to the total volume of water contributed to groundwater from all sources.

As a percentage of the total volume input to groundwater, the brine ratio eventually reaches a percentage of approximately 63% at the end of extraction and 58% at the end of the complete simulation. In other words, as the duration of extraction and/or recharge increases, the fraction of water derived from storage in the aquifer (containing brine) which contributes to the groundwater available for extraction decreases as more and more water is derived from sources which do not contain brine.

If fresh recharge water was not required in order to replace water removed from the aquifer by the extraction trenches, the only dilution would result from the areal recharge water, which is a very small percentage of the water required for replacement (about 1-2%), but trenches would quickly dewater due to no sources of sufficient recharge.

[2] The recharge term reflected in Table 33 is the value for areal recharge (playa-wide). The estimated recharge term (14,657 m^3) for just the area modeled was calculated by assuming an area of 3.05E7 sq. meters for the area modeled and multiplying the areal recharge term in Table 33 by the fraction of the total playa area (0.06) that the assumed modeled area represents. Similarly, the estimated evapotranspiration term in Table 33 is calculated for the entire playa. A more representative value for the focus area could be calculated by multiplying 10,607,358 m^3 by 0.06.

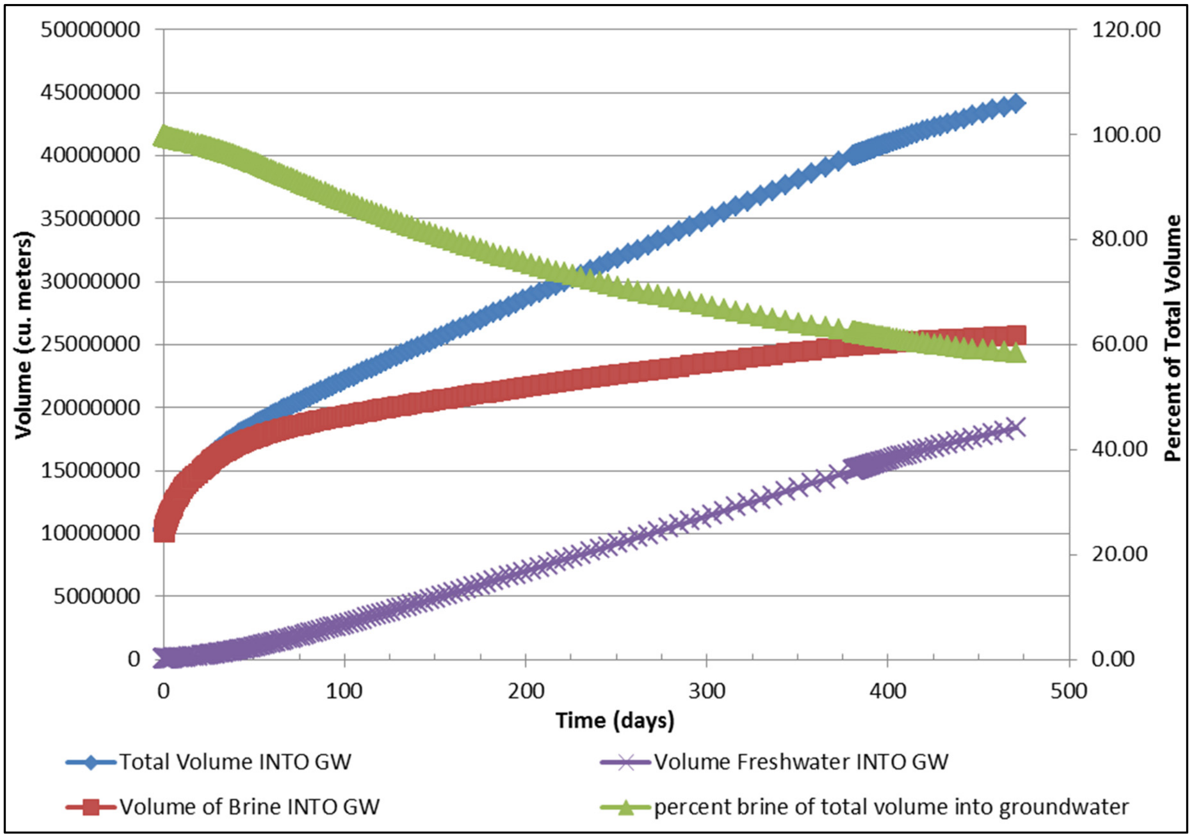

Figure 30. Ratio of Brine and Freshwater Volumetric Inputs into Groundwater for Basin-Center Shallow Extraction.

4.5 Five Layer (12.2 m Deep) Extraction with Recharge Trenches (Basin Center)

Earlier modeling described in the previous sections evaluated the performance of 6.1m (20-ft)-deep extraction trenches spaced at 500 m center-to-center with recharge trenches interspersed about extraction trenches at regular intervals, and also spaced at 500 m intervals. These simulations were located at two different areas of the Sevier Lake Playa.

The purpose of the present configuration to be further described below is to evaluate the characteristics of 12.2 m (40 ft.) deep extraction trenches. These trenches were laid out identically as described earlier (see Figure 29). However, in the earlier cases, it was assumed that the 6.1 deep extraction trenches were only open to layers 1 through 3. Calculations presented earlier in Table 30 showed that a 6.1 m deep trench configured to communicate only with the fat clay and the upper and lower URZ would underestimate the available flow because some portion of the trench would be in communication with the hypothetical aquitard. Because the aquitard would be considered a low producer due to its assumed low hydraulic conductivity, no effort was made to account for this in the earlier cases.

However, for the present case, 12.2 m (40-ft.)-deep trenches penetrate through the aquitard and into the LRZ. So to properly account for flow into 12.2 m deep trenches from the LRZ, the extraction trenches had to be opened to the aquitard and some portion of the LRZ. It is not possible to model partial penetration in MODFLOW, and if the entire LRZ was opened to communicate with the extraction trench, the opposite case would result: an overestimation of the flow available to the extraction trenches. Therefore, the layer representing the LRZ had to be split into two so the bottom of a 12.2 m trench would land at a layer bottom boundary. This has no impact on the conceptual model as the exact same hydraulic properties are assigned to the inserted layer. To accomplish this, the following procedure was followed using functionality provided by Groundwater Vistas.

1. A layer was inserted into the current layer 5 (LRZ) with the bottom elevation corresponding to the upper 10% of the LRZ just for initial placement purposes. This became new layer 5; the remaining (lower) portion of the LRZ became new layer 6.
2. Using grid mathematics, 12.2 meters were subtracted from every grid node corresponding to the original gridded surface of the playa surface. This new surface was then brought into Groundwater Vistas to set the elevation of the newly inserted layer for what became the upper part of the LRZ.
3. Next, layer penetrations were checked and it was determined that the bottom of this new layer either represented a zero thickness or penetrated the overlying aquitard bottom in several hundred locations by less than 0.1 meter. It was determined that the best course of action was to pull up the aquitard (layer 4) by that amount at all cells where this condition existed. Again using grid mathematics, an IF/THEN statement was formulated to subtract 0.1 meters from all cells in the aquitard layer that were penetrated by the bottom of the newly inserted layer. In any case, because the thickness of the aquitard is conceptual and was assigned an arbitrary thickness, this small adjustment at only those touch points will neither violate the conceptual model nor have any significant effect on the overall outcome.
4. After the above adjustments were made, 49 locations were identified where the bottom of the lower LRZ penetrated the new upper LRZ. These locations were adjusted by pulling up the bottom of the upper LRZ by 0.1 m using a similar procedure as in step 3. These left four cells in the upper LRZ were the penetration from below exceeded 0.1 m. These cells were manually adjusted up to extinguish the penetration.
5. At this point, Groundwater Vistas did not identify any other problem cells. Model input files were generated and input into MODFLOW-SURFACT for additional error checking. Additional cells were identified that represented zero thickness in new layer 5 and layer 6. The layer bottoms corresponding to just these cells in layers 4 and 5 were pulled up manually by 0.1 m. Input files were regenerated and no additional errors were detected.

As mentioned above, the model was now configured to allow communication to five layers, the fat clay, the upper fissured clay (upper URZ), the lower fissured clay (lower URZ), the aquitard, and a portion of the LRZ where the bottom of which corresponded to an elevation equal to 12.2 meters bgs (40 ft.) in depth. The design extraction rate of 0.09 gpm/lineal ft. was selected as the base case for the purpose of comparison to earlier simulations. The five-layer extraction required recalculation of the line boundary flux in order to function at the 0.09 gpm extraction rate for the initial simulation. Discharge from extraction trenches for one meter length of trench into each layer was calculated as 0.322 m^3/day, for a total extraction rate equal to 1.6 m^3/day per lineal m of trench. Therefore, for the example of a 3000 m extraction trench,

- 1.6 m^3/day/m * 3000 m = 4,800 m^3/day/trench
- 4,800 m^3/day/trench * 264.17 m^3/g = 1,268,016 gpd/trench
- 1,268,016 gpd/trench /1440 min. = 880.6 gpm/trench
- 880.6 gpm/trench / 9,843 ft. = 0.09 gpm/lineal ft. of extraction trench

The simulated extraction trench network was configured as described earlier for the basin center simulations with the exception of depth of extraction. Table 34 presents a tabulation of trench length, and layer elevation and thickness data for each modeled extraction trench, with depths now extended to 12.2 m (40 ft.) in depth.

One deep extraction scenario was simulated at the 0.09 gpm/lineal ft. extraction rate with 7.5 cfs recharge trench inflow. Some adjustments were made to the recharge trench flow specifications as shown in Table 35. During stress period 1, incipient flow was allowed into upper SFR segments of the recharge trench system (one flowing to the west and one flowing to the south) to simulate Sevier River water flowing onto the playa nears its natural channels. This flow was only allowed in two segments traversing the northern portion of the playa at a rate 3 cfs respectively in order to help establish a groundwater gradient during the initial stress period.

During stress period 2, the incipient flow was shut off in the aforementioned segments to simulate the diversion of all Sevier River water into the canal system. The flow diverted into the recharge trench network was specified as 7.5 cfs into each side of the recharge trench system, for a period of seven days during which no extraction was allowed.

Table 34. Layer Elevations, Depths and Thickness at Deep Basin Center Extraction Trenches 51 - 62.

Trench	Surface Elevation (m amsl)[1]	Flat Clay Bottom (m amsl)	Upper URZ Bottom (m amsl)	Lower URZ Bottom (m amsl)	Hypothetical Aquitard Bottom (m amsl)	Penetration Into LRZ (m)[2]
West Side						
ExtTrench51	1377.41	1375.09	1373.14	1370.24	1367.74	3.71
ExtTrench53	1377.45	1374.66	1372.33	1368.85	1367.80	2.54
ExtTrench55	1377.47	1374.88	1372.72	1369.48	1368.19	2.91
ExtTrench57	1377.48	1375.19	1373.27	1370.4	1368.96	3.67
ExtTrench59	1377.50	1375.05	1372.99	1369.92	1368.68	3.37
East Side						
ExtTrench52	1377.25	1374.9	1372.94	1370.01	1368.71	3.65
ExtTrench54	1377.30	1374.97	1373.03	1370.12	1368.87	3.76
ExtTrench56	1377.30	1375.06	1373.18	1370.37	1369.28	4.17
ExtTrench58	1377.30	1375.28	1373.58	1371.05	1369.59	4.48
ExtTrench60	1377.34	1374.77	1372.61	1369.4	1369.10	2.95
Main Brine Collection Canal						
Main Brine Canal	1377.37	1374.65	1372.37	1368.96	1367.74	2.56
Trench	**Trench Length[3] (m)**	**Fat Clay Thickness (m)[4]**	**Upper URZ Thickness (m)[4]**	**Lower URZ Thickness (m)[4]**	**Hypothetical Aquitard Thickness (m)[4]**	**LRZ Thickness (m)[4]**
West Side						
ExtTrench51	3000	2.32	1.95	2.90	1.31	10.56
ExtTrench53	3000	2.79	2.33	3.48	1.05	10.46
ExtTrench55	3000	2.59	2.16	3.24	1.29	9.77
ExtTrench57	3000	2.29	1.92	2.87	1.44	9.23
ExtTrench59	2900	2.45	2.06	3.07	1.24	9.84
East Side						
ExtTrench52	3000	2.35	1.96	2.93	1.3	13.02
ExtTrench54	3000	2.33	1.94	2.91	1.25	12.88
ExtTrench56	3000	2.24	1.88	2.81	1.09	12.96
ExtTrench58	3000	2.02	1.70	2.53	1.46	12.49
ExtTrench60	3000	2.57	2.16	3.21	1.30	12.39
Main Brine Collection Canal						
Main Brine Canal	2600	2.72	2.28	3.41	1.22	11.72

NOTES:

1. m amsl = meters above mean sea level
2. Positive values indicate meters of penetration into LRZ (layer 5) measured as meters below bottom of the middle aquitard.
3. Trench length as calculated by GIS. Actual modeled length is slightly greater in all cases because wherever the boundary condition touches a cell, the entire cell is included in the lineal extent of the boundary condition.
4. Thicknesses are calculated by differencing bottom elevations measured at the mid-point of the extraction trench.
5. See Table 30 for additional data.

Table 35. Target Recharge Inflow Values for Initial Deep Extraction Simulation.

Diversion Segment Number	Stress Period 1 Recharge Inflow (cfs)	Stress Period 2 and 3 Recharge Inflow (cfs)	Required Multiplier	Stress Period 4 Recharge Inflow (cfs)	Required Multiplier
2 & 3	3	--	N/A	--	N/A
52 & 68	--	0.750	0.1000	0.5	0.1000
54 & 70	--	1.5	0.2222	1.0	0.2222
56 & 72	--	1.5	0.2857	1.0	0.2857
58 & 74	--	1.5	0.4000	1.0	0.4000
60 & 76	--	1.5	0.6667	1.0	0.6667
62 & 78	--	0.750	0.9999	0.5	0.9999
TOTALS:	3 (per side)	7.5 (per side)	--	5.0 (per side)	--

NOTES:

1. cfs = cubic meters per second, values are per side of recharge trench system. Total inflow to the recharge trench network is therefore twice the rates shown in TOTALS.

During stress period 3, extraction was turned on and recharge trench inflow continued at the 7.5 cfs (18,350 m^3/day) rate for each side of the recharge trench system, variably feeding each lateral on each side of the recharge trench network for a total recharge inflow rate of 15 cfs (36,700 m^3/day) for a period of one year. During stress period 4, the recovery portion of the simulation (no extraction), the recharge trench inflow for was specified at a rate of 5 cfs (12,234 m^3/day) for each side of the recharge trench system, variably feeding each segment of each side of the recharge trench network for total recharge inflow rate of 10 cfs (24,468 m^3/day), for a period of 180 days.

4.5.1 Discussion of Basin Edge Deep Extraction Simulations

The results of this simulation showed that from a flow perspective, this may not be a sustainable scenario. In this scenario, extraction is opened to the fat clay (layer 1) through the upper LRZ (layer 5). (Significant cell drying was observed in layers 5 and 6 (LRZ) which is no surprise considering the lower hydraulic conductivity assigned to that layer. Drawdown is proportional to transmissivity, so where greater thicknesses of permeable intervals in the LRZ are present or where such layers exhibit higher hydraulic conductivities, dewatering would be less. Figure 31 shows head in the lower fissured clay while Figure 32 shows head in the upper LRZ. Heads in the lower part of the LRZ (not shown) are comparatively less impacted. Undoubtedly some of this cell drying was the result of the layer insertion because even through the layer did not violate the conceptual model, there were areas where its thickness would be small and therefore present difficulties in the numerical solution.

This phenomenon can be illustrated by cross-section. Figure 33 presents a south-north cross-section through the west side of the trench area at the end of stress period 2. Comparison of this figure to Figure 34, obtained at the end of extraction, shows that cell drying is focused in that relatively thinner portion of the upper LRZ where lower transmissivity prevails.

In both of the aforementioned figures, the vertical blue lines represent the traces of extraction trenches while the green cells depict (poorly) the trace of recharge trenches. As illustrated, inserting a layer into the top of the LRZ with a bottom based on subtracting 40 feet from ground surface results in an artificially thin layer in the area of the trench system because the layers above this layer still vary in depth based upon the surfaces imported into the model which are based on drill hole data.

Table 36 presents the water balance for the 0.09 gpm/lineal ft. deep extraction simulations with dual 7.5 cfs recharge trench inflow. The water balance shows that cumulative volumes (in/out) differ by -0.75 percent (329,671 m^3). The calculated cumulative water volume extracted (including the main brine collection canal) was 18,829,630 m^3 for the one-year simulation period. The simulated extraction volume for the same time period was 18,837,228 m^3 for difference of functionally 0%.

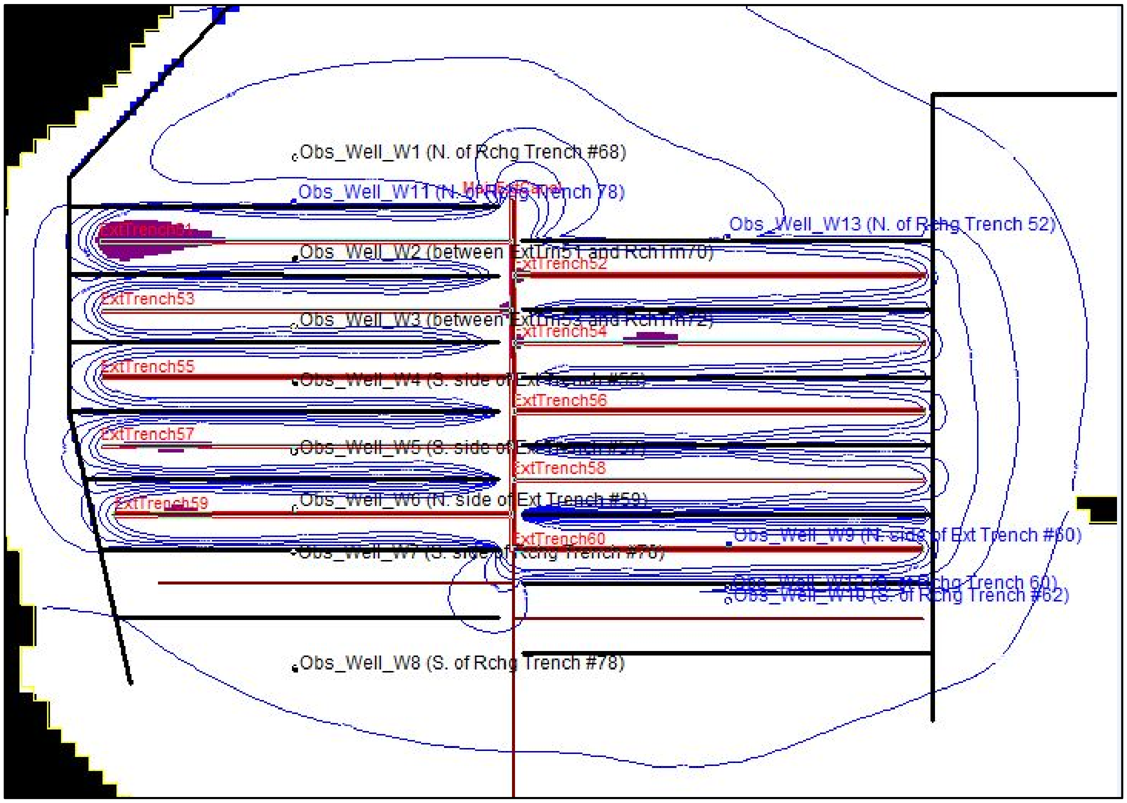

Figure 31. Heads Contours in Upper Fissured Clay (Layer 3) at the End of Extraction (Stress Period 3).

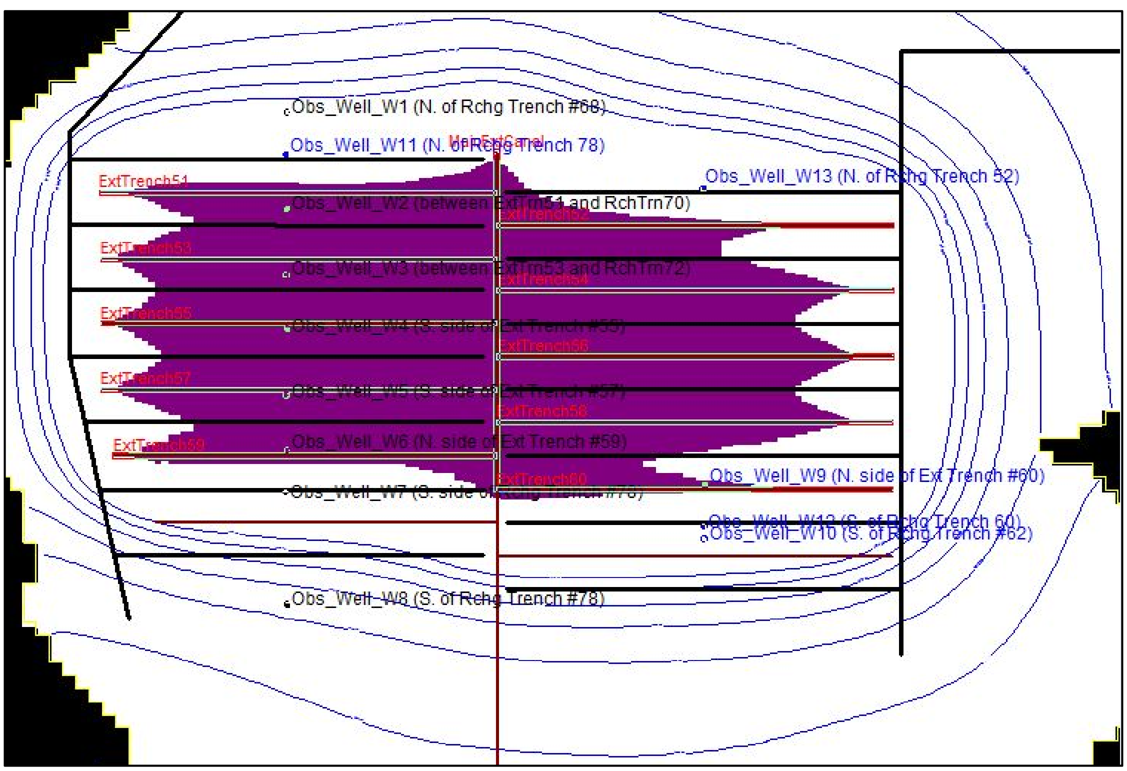

Figure 32. Heads Contours in Upper LRZ (Layer 5) at the End of Extraction (Stress Period 3).

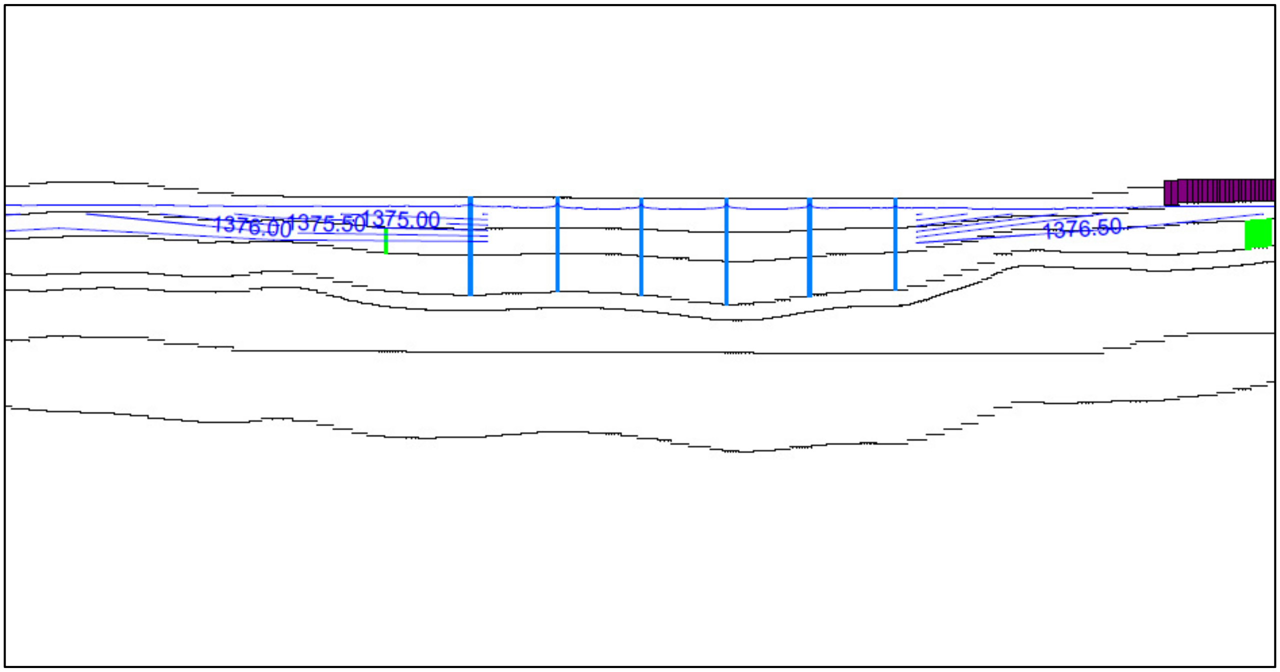

Figure 33. South-North Cross-Section Through the West Side of the Trench Network at the End of Stress Period 2.

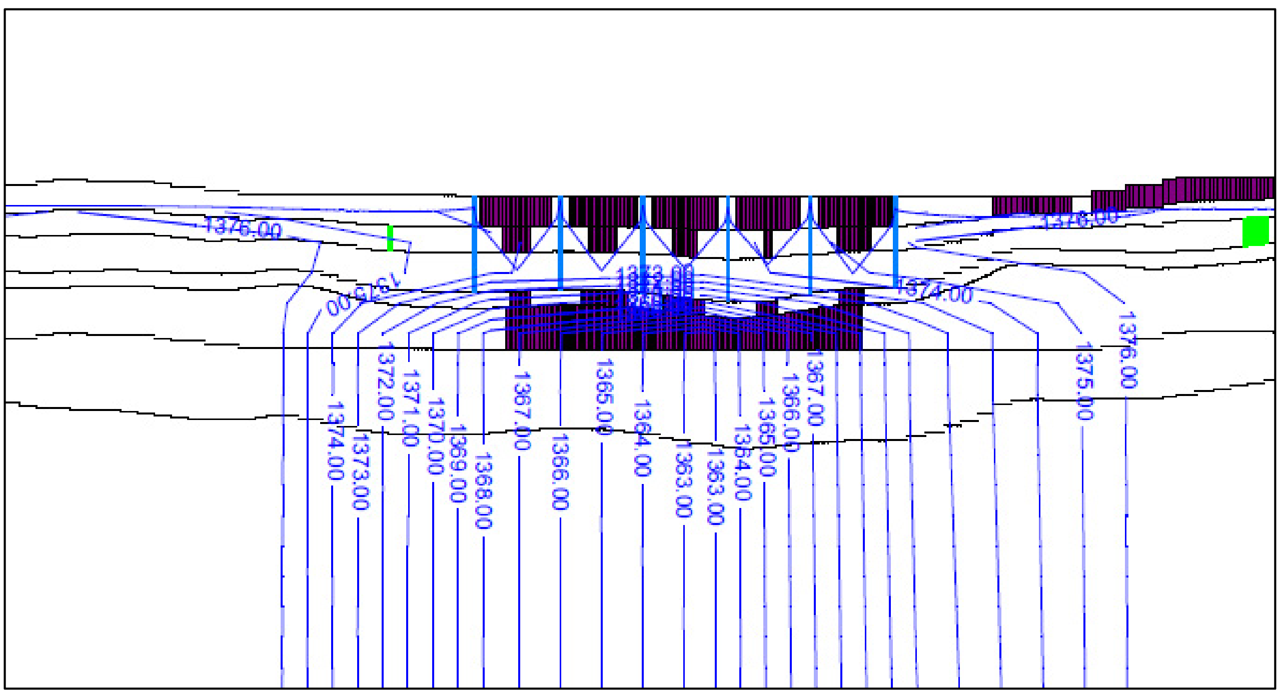

Figure 34. South-North Cross-Section Through the West Side of the Trench Network at the End of Stress Period 3.

Table 36. Water Balance for 0.09 gpm/lineal ft. Deep Basin Center Extraction with Dual 7.5 cfs Recharge Inflow[1].

Contributing Parameter[2]	Into Groundwater (m^3)[3]	Out of Groundwater (m^3)	Difference (m^3)
Storage	26,284,754	4,919,275	21,365,479
Recharge (areal, RSF4)	452,876	0	452,876
ET (areal, EVT1)	0	19,073,750	-19,073,750
Recharge Trench Seepage (SFR1)	118,657	88,514	30,143
Recharge Trench Seepage (LAK3)	16,730,312	997,503	15,732,809
Extraction Trenches (WEL1)	0	18,837,228	-18,837,228
TOTALS:	43,586,599	43,916,270	-329,671

NOTES:

1. The total recharge trench inflow is 15 cfs, equal to the sum of inflows (7.5 cfs) specified at the headwater segment for each side of the recharge network.
2. Parenthesized terms are the MODFLOW packages responsible for the indicated parameter.
3. m = meters.

To provide a rough estimate of the source of water extracted during the entire simulation, the volume obtained from storage could be considered to contain brine at the prevailing brine concentration. This volume can be compared to the volumes of water contributed as groundwater domain inflow by other sources:

- Volume of water removed from storage – 26,284,754m^3
- Volume of recharge trench seepage into the groundwater – 16,848,969 m^3
- Areal recharge (estimated for the modeled area only)[3] - 28,165 m^3

This tabulation shows that the contributions to water computed as volumetric inflows to the groundwater domain are somewhat dominated by the storage term. Non-brine contributions (16,877,134 m^3) total about 64 percent of the storage term, and about 39 percent of the total of all inflow contributions (43,586,599 m^3) to the groundwater domain. Stated another way, the storage term is about 1.56 times the volume of non-brine contributions. This represents somewhat of a worst scenario, because it requires the assumption that water quality in the recharge system reflects a significantly lower solute concentration (i.e., no mixing and no infiltration of groundwater into trenches).

Compared to the previous simulation with shallow trenches, where non-brine contributions totaled about 71 percent of the storage term, and about 41 percent of the total of all inflow contributions to the groundwater domain, the smaller percentages realized for the present simulation may reflect less recharge trench inflow, and a greater thickness of aquifer yielding brine from storage. This is not a large difference. However, noting that on the basis of hydraulics, water will be derived from the easiest pathways, and considering the difference in hydraulic conductivity between the fissured clay and the LRZ, water is preferentially obtained from lateral flow in the fissured clay.

A clearer depiction of the above which shows how the ratio of brine and freshwater contributions changes over time for the deep trench scenario is presented in Figure 35.

[3] The recharge term reflected in Table 36 is the value for areal recharge (playa-wide). The estimated recharge term (28,165 m^3) for just the area modeled was calculated by assuming an area of 3.05E7 sq. meters for the area modeled and multiplying the areal recharge term in Table 36 by the fraction of the total playa area (0.06) that the assumed modeled area represents. Similarly, the estimated evapotranspiration term in Table 36 is calculated for the entire playa. A more representative value for the focus area could be calculated by multiplying 10,607,358 m^3 by 0.06.

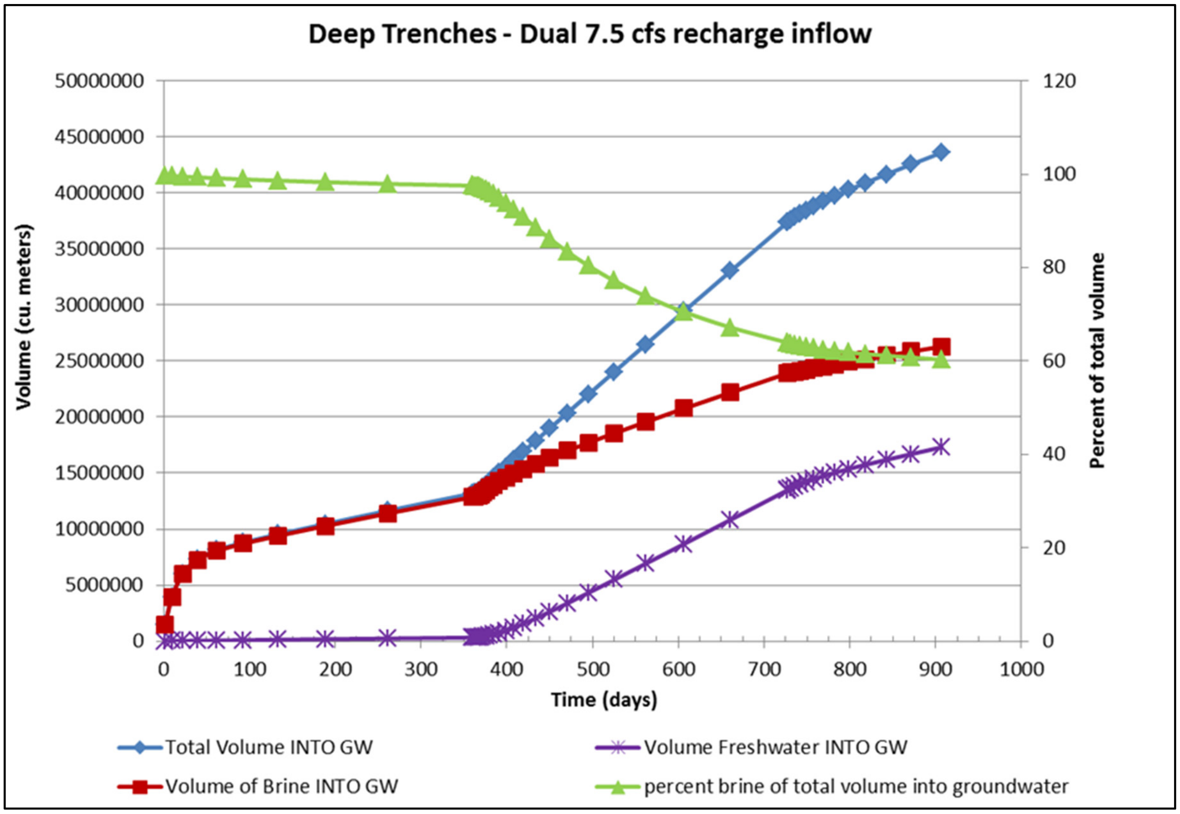

Figure 35. Ratio of Brine and Freshwater Inputs into Groundwater for Deep Trenches.

Similar to the case earlier presented in Figure 30, the fraction that brine makes of the total volumetric inputs to groundwater (and thus could then be extracted), decreases with time to about 0.64 at the end of extraction, and about 0.6 at the end of recovery.

In comparing the two figures, note that there is a time difference. This resulted from a difference in stress period 1 length (1 day versus 360), stress period 2 length, (7 days versus 21), and the length of stress period 4 (180 days versus 90). The resetting of stress period 1 to one day was overlooked for the present simulation, but only impacts the results from visual standpoint.

A comparison of Figure 35 to the earlier Figure 30 is easily drawn by starting at 360 days in Figure 35. Again, the slightly higher values in the current simulation probably reflects the slightly greater amount of water that is derived from storage in the aquifer due to the greater thickness of aquifer that the extraction can access.

5. PREDICTIVE TRANSPORT SIMULATIONS

5.1 Conceptual Model

The conceptual model for simulating transport in the Sevier Lake Playa aquifers is one based on an advective-diffusive system. Here, some layers or intervals within a layer, exhibit high permeability and are juxtaposed with porous materials of low permeability. Solute transport takes place within high permeability zones primarily by advection, and chiefly by diffusion in the low permeability areas.

Such is the case hypothesized for the fissured clay aquifer and the aquifer that comprises the lower resource zone, where flow is largely restricted to clayey silts, sands, and to a lesser degree, gravels. Figure 36 presents these concepts diagrammatically for both the fissured clay aquifer and the lower resource zone. The upper part of the figure indicates that advective flow (black arrows) takes places through the fissures developed in the clay matrix. Diffusion (red arrows) is likely the dominant process for solute transport in and out of the clay matrix blocks between fissures. This concept is supported by field-measured hydraulic conductivities in the range of up to 7 m/day for the fissured clay while field (SDRI) infiltration data (vertical saturated hydraulic conductivity) and laboratory saturated hydraulic conductivities for the clay matrix have been measured as low as 5E-05 m/day.

The lower part of Figure 36 depicts the lower resource zone where advective flow is hypothesized to take place within clayey silt, sand, and gravelly intervals of variable thickness and lateral extent. As in the case for the fissured clay, velocities may be so low in the clay matrix bounding permeable intervals that diffusion dominates transport in these zones (red arrows), while transport takes place by advection (black arrows) in the clayey silts, sands, and gravels. Correspondingly, hydrophysical data collected in the lower resource zone indicate interval specific hydraulic conductivities as high as 4 to 7 m/day, while again laboratory hydraulic conductivity data for the clay matrix indicate values as low as 5E-05 m/day

Diffusion of solute into the low-permeability zones can reduce the mass of solute moving adjectively in the higher permeability zones (Zheng and Bennett, 2002), and the opposite would be expected to be true where mass stored in the lower permeability clay matrix diffuses into the more permeable zones (when the concentration gradient dictates) and is then subjected to advection-dominated transport at that point.

As suggested by Zheng and Bennett (2002), for the case of the Sevier Lake Playa where fresher water injected through infiltration trenches to provide recharge to the brine aquifer during mine operations, mass transfer of solute from the clay matrix into fissures of the upper clay aquifer or permeable zones in the LRZ would reduce the tendency for dilute water to “finger” preferentially for long distances along those permeable zones. The result, especially where fissuring is well developed, or where greater numbers and/or thicknesses of clayey silts/sands/gravel intervals are present in the LRZ, is that a more uniform solute distribution develops and the advance of a dilution front would be slowed in comparison to the case where only advection through the higher permeability zones is considered.

If the Sevier Playa aquifer system was characterized to the point where exact bed thicknesses, fissure apertures and fissure densities were everywhere known, and depths and thicknesses of every permeable zone in the LRZ were known, it would be possible to construct a model wherein the number of layers and cell sizes would honor such a distribution. Appropriate aquifer properties could then be assigned on a layer by layer basis with appropriate parameters to account for advective-diffusive transport within and between layers. This approach is neither possible from a field data collection perspective nor practical from a modeling standpoint.

As an alternative, such an advective-diffusive system can be simulated through the use of a dual-domain model, which divides the aquifer into two distinct transport regimes, termed the mobile and immobile domains (e.g., van Genuchten and Wierenga, 1976; Gerke and van Genuchten, 1993).

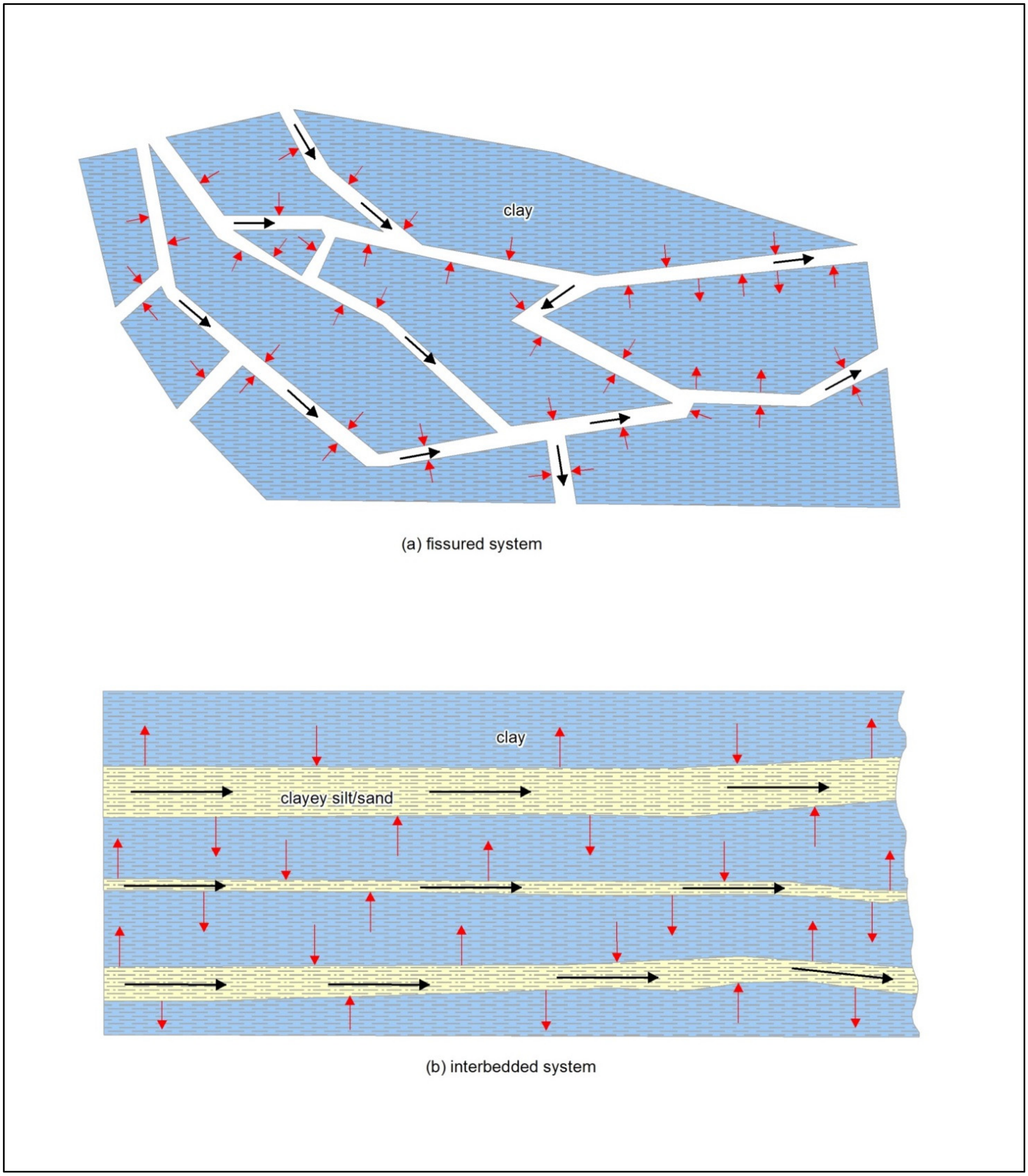

Figure 36. Diagrammatic Representation of Dual-Domain Porous Media Suggested for the Fissured Clay Aquifer (a) and the Lower Resource Zone (b) (modified after Zheng and Bennett, 2002).

Zheng and Bennett (2002) present a transport equation that relates the rate of solute accumulation in both domains to the net solute inflow in the mobile domain, while a second equation defines the rate of mass transfer between the two domains:

$$\theta_m \frac{\partial C_m}{\partial t} + \theta_{im} \frac{\partial C_{im}}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta_m D_{ij} \frac{\partial C_m}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(q_i C_m) + q_s C_s \qquad \text{[Eq. 2]}$$

And for the mass transfer,

$$\theta_m \frac{\partial C_{im}}{\partial t} = \zeta(C_m - C_{im}) \qquad \text{[Eq. 3]}$$

Where,

C_m = solute concentration in the mobile domain (mass/L^3
C_{im} = solute concentration in the immobile domain (mass/L^3)
θ_m = porosity of the mobile domain (L^3/L^3)
θ_{im} = porosity of the immobile domain (L^3/L^3)
D_{ij} = dispersion coefficient in the mobile domain, calculated using the seepage velocity in the mobile domain, q/θ_m (L^2/t)
ζ = first-order kinetic rate coefficient of reversible mass transfer between the mobile and immobile domain (t^{-1})

For a given porosity ratio expressed by the fraction of mobile porosity over total porosity, θ_m/θ, (i.e., the mobile fraction), as the mass transfer rate coefficient increases, the exchange between the immobile and mobile domains becomes increasingly fast (Zheng and Bennett, 2002) and if large enough, eventually leads to equilibrium conditions between the two domains where $C_m = C_{im}$ at any time; thus the dual domain functions more and more like a single domain model with a porosity approaching that of the total porosity of the porous medium (Hydrogeologic, 1996b; Zheng and Bennett, 2002).

On the other hand, for a given mass transfer coefficient, when the mobile fraction increases, the arrival time of peak concentrations (or minimum concentrations in the case of a dilution front), is delayed because when θ_m/θ increases, a greater portion of the total pore space is utilized for advective movement, thereby requiring lower groundwater velocities to transmit the same volume of water.

Zheng and Bennett (2002) also point out that the role of physical dispersion is reduced under the dual domain concept because much of the macroscopic dispersion is represented by the mass transfer between domains, therefore the dispersion coefficient may be set to small values to essentially account only for molecular diffusion and microscopic dispersion.

Using the model presented by van Genuchten and Wierenga (1976) parameters can be estimated for use in the MODFLOW-SURFACT model. Noting that the fraction of porous media filled with mobile and immobile water, θ, is given by:

$$\theta = \theta_m + \theta_{im} \qquad \text{[Eq. 4]}$$

(i.e. total porosity when saturated), van Genuchten and Wierenga (1976) define the fraction of the total water that is mobile by the parameter Φ:

$$\Phi = \frac{\theta_m}{\theta} \qquad \text{[Eq. 5]}$$

They then define an additional parameter *f* (fraction of the total domain that lies within the dynamic region, i.e., in contact with mobile water). The immobile fraction of the total domain (1-*f*) is therefore given by the ratio of the immobile domain to the total domain volume. Therefore, by rearrangement of terms,

$$\theta_m = \Phi\theta \qquad \text{[Eq. 6]}$$

and,

$$\theta_{im} = \frac{\theta_m}{\Phi} - \theta_m = \theta - \Phi\theta. \qquad \text{[Eq. 7]}$$

By definition, and assuming saturated conditions, it can be stated that

$$f\varphi_m = \theta_m \qquad \text{[Eq. 8]}$$

and,

$$(1-f)\varphi_{im} = \theta_{im} \qquad \text{[Eq. 9]}$$

where,

φ_m = porosity of the mobile domain
φ_{im} = porosity of the immobile domain.

By substitution, equations are given (Hydrogeologic, 1996b) which may be used to provide the parameters used in MODFLOW-SURFACT by those presented by van Genuchten and Wierenga (1976):

$$\varphi_m = \frac{\Phi\theta}{f} \qquad \text{[Eq. 10]}$$

$$\varphi_{im} = \frac{(\theta - \Phi\theta)}{(1-f)} \qquad \text{[Eq. 11]}$$

Table 37 presents the dual domain parameters estimated for the simulation efforts utilizing this approach.

Table 37. MODFLOW-SURFACT Dual Domain Parameters Compared to Dual Domain Model of van Genuchten and Wierenga (1976)

	MODFLOW-SURFACT (Hydrogeologic, 1996b)				van Genuchten and Wierenga (1976)			
LAYER	φ_{im}[1]	φ_m[2]	f[3]	$(1-f)$[4]	θ_m	θ_{im}	θ	Φ
Fat Clay	0.514	0.52	0.03	0.97	0.02	0.499	0.514	0.03
U URZ	0.55	0.63	0.13	0.873	0.080	0.481	0.561	0.14
L URZ	0.53	0.59	0.12	0.883	0.069	0.467	0.537	0.13
LRZ	0.50	0.61	0.31	0.69	0.190	0.345	0.535	0.36
Layer 5	0.51	0.51	0.01	0.99	0.01	0.505	0.510	0.01

NOTES:
1. MODFLOW-SURFACT parameter PHIIM
2. MODFLOW-SURFACT parameter PHI
3. MODFLOW-SURFACT parameter PHIF, mobile fraction
4. Immobile fraction

5.2 Discretization

Due to the size of the model, subareas had to be identified in order to reduce computation time, memory requirements for processing output files, artificial oscillation and numeric dispersion. The first two items are mostly due to convenience, as obtaining results from scenarios in a timely manner was important to meet schedule, and binary head, cell-by-cell flow, and concentration output files became unwieldy to process when sizes exceed 8-10 GB or so.

The initial discretization of the playa was specified with 435 rows, and 259 columns with 100 m cell dimensions, which for a 7 layer model, resulted in 761,250 cells. Modifications to cell sizes in the vicinity of trenches were made before transport simulations so that no cells would exceed the dimensions of a trench footprint at land surface. This resulted in 825 rows by 476 columns, which for a 6 layer model resulted in 2,356,200, with a minimum cell width of 14.5 m and a minimum cell height of 9.6 m.

Artificial oscillation and numerical dispersion are challenges to successfully modeling transport, especially in advective dominated conditions (Zheng and Bennett, 2002). Numeric dispersion and use of appropriate grid resolution and transport schemes are among the most difficult challenges when modeling a salt water intrusion problem (Langevin and Zygnerski, 2013). Sanford and Pope (2010) encountered the same problem for a large 2000 km^2 salt-water intrusion problem and questioned whether concentrations at an individual well could be accurately simulated by a numerical model of that scale.

The following discussion is taken largely from by Zheng and Bennett (2002) and offers a succinct description of the difficulties involved in both time and spatial discretization.

The method of spatial discretization often leads to artificial oscillation (often referred to as overshoot or undershoot), and a model is especially susceptible to this when sharp concentration fronts are present. In the case of the Sevier Lake Playa, recharging a brine aquifer with relatively fresh water infiltrated through trenches would seem to apply. The sharpness of the concentration front (in this case, perhaps the dilution front might be the more appropriate term), or the degree to which the transport problem is dominated by advection, can be measured by the Peclet number (*Pe*), which in a one-dimensional flow field is given by

$$Pe = \frac{v\Delta x}{D} = \frac{\Delta x}{\alpha L} \qquad \text{[Eq. 12]}$$

Where,

v = uniform seepage velocity
D = uniform dispersion coefficient (v, multiplied by longitudinal dispersivity, αL)
Δx = cell width.

For purely advective groundwater flow, $Pe \rightarrow \infty$. As physical dispersion becomes significant, *Pe* becomes smaller. Inspection of the above equation shows that *Pe* is also dependent on cell size, becoming smaller as grid size decreases. The smaller *Pe* numbers associated with smaller grid sizes implies that artificial oscillation can be reduced or eliminated with a finer model mesh, and also has been shown that when Δx is such that $Pe \leq 2$, oscillatory behavior is eliminated (Huyakorn and Pinder, 1983).

However, to keep Pe within a small value the grid spacing may have to be kept so small as to lead to an extremely large number of cells, resulting in an impractical problem in terms of computational memory demands and simulation time. Further, for problems dominated by advection ($\alpha L \rightarrow 0$), oscillation cannot be avoided no matter how small the spatial discretization is.

The problem can be addressed to some degree by the use of an upstream weighting numerical scheme. However, upstream weighting tends to increase numerical dispersion. Further, where natural dispersion is small, numerical dispersion can cause changes in concentration to be much more gradual in the simulation results than they are in reality.

A further source of numeric dispersion is related to the approximation of the time derivative. Peaceman (1977) shoes that a formula can be constructed for the apparent dispersion coefficient D_{num} associated with numerical dispersion:

$$D_{num} = v\Delta x\left[\left(\frac{1}{2} - \alpha\right) + C_r\left(\omega - \frac{1}{2}\right)\right] \qquad \text{[Eq. 13]}$$

Where,

α = spatial weighting factor
ω = temporal weighting factor
C_r = Courant number, defined as:

$$C_r = \frac{v\Delta t}{\Delta x} \qquad \text{[Eq. 14]}$$

The Courant number can be interpreted as the number of cells (or fraction of a cell) that a solute particle is advected in one time step. To obtain sufficiently accurate solutions, it is generally required that the Courant number be less or equal to one. The immediate implication here when comparing this equation to the equation for the Peclet number, is that attempts to decrease the Peclet number by reducing cell size to address artificial oscillation, impacts the degree to which numerical dispersion affects the solution as Δx appears in the denominator in the Courant equation.

5.3 Numerical Scheme and Transport Parameters

In general, numerical schemes used in the transport modeling included implicit upstream weighting IACLVL=0 with Crank-Nicolson time-weighting approximation THETRD=0.5 (α=0, ω=1) for rapid prototyping, and adaptive TVD with the van Leer flux limiter IACLVL=-2 with Crank-Nicolson time-weighting approximation THETRD=0.5 (α=0, ω=1/2,) for final simulations.

The TVD (total-variation-diminishing) numerical scheme is characterized by the property that the sum of concentration differences between adjacent nodes diminishes over successive transport steps, a necessary condition if the transport solution is to remain largely free of artificial oscillation (Harten, 1983; Cox and Nishikawa, 1991). Because the TVD scheme is essentially a higher-order method, and as such, usually reduces numerical dispersion at the expense of introducing artificial oscillation, a TVD method is typically implemented with a so-called flux limiter to suppress or eliminate artificial oscillation.

In the case of the MODFLOW-SURFACT implementation, the van Leer flux limiter (van Leer, 1977) is utilized. TVD methods are computationally more demanding than conventional finite difference methods; hence the use of the TVD numerical scheme only for final simulations after prototyping using faster methods, as a four-fold increase in time to solution could often be realized.

The following tables (Table 38 through Table 40) present the options that were selected for all the MODFLOW-SURFACT transport simulations.

Table 38. Transport Parameters Selected for All Simulations (BAS Package).

Parameter	Value	Definition
ITRAN	1	ITRAN =1 indicated simulation is flow and transport.
IDUAL	1	IDUAL =1 indicated transport includes a dual domain representation with no equilibrium adsorption in the immobile domain.

Table 39. Transport Parameters Selected for All Simulations (BCF4 Package).

Parameter	Value	Definition
ISS	0	ISS =0 indicates that simulation is transient. Sometimes stress period 1 was simulated as steady-state.
HDRY	-1.0E+30	Head assigned to cells converted to dry during a simulation.
IWDFLAG	0	IWDFLAG = 0 indicated wetting Capability is not active.
IREALSL	1	IREALSL =1 indicates Van Genuchten functions used to define flow in the unsaturated zone above water table.
ICNTRL	0	ICNTRL = 0 indicates upstream weighting is used for relative permeability term.
IVHYC	1	IVHYC =1 indicates vertical hydraulic conductivities are read and used to compute leakances.
IANIXY	0	IANIXY = 0 indicates that horizontal anisotropy is uniform within each layer.
VANAL	0.5	Value of Van Genuchten (1980) parameter alpha for unsaturated media when LAYCON value is = 43.
VANBT	1.59	Value of Van Genuchten (1980) parameter beta for unsaturated media when LAYCON value is = 43. Actually refers to parameter n where m = 1 -1/n

VANSR	0.32	Value of van Genuchten (1980) parameter residual saturation for unsaturated media when LAYCON value is = 43.

Table 40. Transport Parameters Selected for All Simulations (BTN1 package).

Parameter	Value	Definition
LINR	0	Retardation is not applied.
IDCYTP	1	Degradation is only species dependent.
ILAMWS	1	Rate of degradation is same in all phases including soil.
NSPECI	1	Total number of species to be considered in the transport simulation.
ICHAIN	0	Transformation one species to another is not allowed.
IDISP	2	Longitudinal, transverse and vertical dispersivity data are read from LDISP, TDISP, VTDISP.
IEQPART	0	Transport occurs in active phase only.
NDENS	1	Flag for use with density-dependent module. Integer for number of species whose density effects are to be included for flow.
IUNCAD	0	When IUNCAD = 0, adsorbed mass on solid phase is calculated according to traditional approach Cs = Kd * Cw
IMOVEON	0	Time-step is cut for non-converged flow/transport iterations to attempt solution for the smaller time step.
DCLOSE	0.001	Convergence criterion for closure on concentrations for density-dependent flow.
NOBOY	1	Environmental heads are printed/saved.
KEFFECT	0	Hydraulic conductivity is not affected by density or viscosity
CNOFLOW	-9.99E+02	Concentration assigned to no-flow boundaries
CCLOSE	0.001	Concentration change criterion in the case of non-linear iterations..
NNOTCV	15	Maximum number of time-step cuts allowed in solving transport equation before aborting simulation. Value from 3 to 15 is suggested.
IBCFCC	52	Unit number to save storage and decay terms for all phases. Need to find open number.
ICROSS	0	Cross dispersion terms are neglected, NOT included for the non-TVD schemes
NOMATRIX	1	Coefficient matrix is NOT written and is computed whenever it is required.
IPHSFLAG	0	Index for the phase that occupies space between porosity and specific yield, active phase fully occupies space.

5.4 Initial Prototype Transport Simulations

Initially, five species were selected for simulation, Na^{+} Cl^{-}, K^{+}, Mg^{2+} and $S0_4^{2-}$. Initial concentrations were based upon the site-wide averages calculated from all analytical results (Table 41). Due to the size of the model, and the number of species simulated, transport model runs were taking several weeks to complete. This was not an acceptable situation. It was determined from the analytical data that the five species of interest composed 95% of the TDS term by mass. Therefore for the purposes of density dependent flow computations, TDS would represent an acceptable surrogate.

It was also determined that because the transport characteristics for all solutes were assumed to be similar (e.g., no retardation, adsorption, degradation), they would be assumed to travel conservatively and relative concentrations of each species would stay more or less constant regardless of the TDS concentration.

Table 41. Species-Dependent Parameters Used for Transport Simulations.

Parameter	Na^+ (kg/m^3)	K^+ (kg/m^3)	Mg^{2+} (kg/m^3)	Cl^- (kg/m^3)	$SO4^{2-}$ (kg/m^3)	TDS (kg/m^3)	Sevier River[1] (kg/m^3)	Fresh water[2] (kg/m^3)
Component Number	1	2	3	4	5	--	--	--
SCONC[1]	73.86	3.08	3.79	92.16	24.35	207.64	0.884	--
SIMCONC[2]	73.86	3.08	3.79	92.16	24.35	207.64	--	
CDENS[3]	73.86	3.08	3.79	92.16	24.35	207.64	--	--
RHODENS[4]	1100.76	1098.21	1114.71	1102.37	1096.67	1159.32	--	--
RFRESH[5]	--	--	--	--	--	--	--	1000
DIFF[6]	1.149E-04	1.693E-04	6.091E-05	1.75E-04	9.245E-05	1.045E-05	--	--

NOTES:
1. Initial concentrations, mobile domain.
2. Initial concentrations, immobile domain. Assumed equal to mobile domain.
3. Maximum solution concentration. Probably higher.
4. Reference fluid density at maximum concentration.
5. Assumed.
6. Free Water Molecular Diffusion (Li and Gregory, 1974). Value for TDS calculated from weighted geomean of all five species.
7. Sevier River provided for reference only. Not used in model.

Therefore TDS was used as a concentration surrogate for all five species. This drastically reduced simulation time to a more manageable timeframe of between several hours to one day or so.

The mass transfer coefficient was estimated by use of the Damköhler number. The Damköhler number may be taken as a measure for the tendency for reaction to the tendency for transport (Domenico and Schwartz, 1998). In this case, to see the conceptual maximum effect of mass transfer of solute from the "immobile" porosity domain into the mobile porosity domain (back diffusion), a mass transfer coefficient that results in a Damköhler Number (DAI) of 1 can be computed by:

$$DAI = \alpha L / v \qquad \text{[Eq. 14]}$$

Where,

α = mass transfer coefficient (per time, T)
L = characteristic length (e.g., 250 m between injection and extraction trench)
v = average linear constituent velocity over L (length per time).

Various estimates of v were made based on observed gradients and hydraulic conductivity values obtained from the trench-based aquifer test site. Velocities were calculated using the following formula (Fetter, 1989):

$$v = \frac{Kdh}{n_{ed}dl} \qquad \text{[Eq. 15]}$$

Where,

v = average linear solute front velocity
K = hydraulic conductivity
n_{ed} = effective Darcian porosity, equal to the Darcian pore factor (0.97) times effective porosity
dh/dl = gradient (dimensionless).

Once velocities were estimated, and the characteristic length, L, was estimated as 250 m, mass transfer coefficient alpha was calculated by solving for alpha by dividing the DAI (set to unity) by the quotient *L/v*. Table 42 presents the parameter values used for the estimation of mass transfer coefficients.

Table 42. Parameters used for Estimating Mass Transfer Coefficients.

Layer	Darcian Pore Factor	Effective Porosity	Effective DPF	Hydraulic Conductivity (m/day)	Gradient Estimates	Velocity (m/day)	alpha (1/T)
1 – Fat Clay	0.97	0.03	0.0294	7	0.50	0.003	1.2E-05
2 – Upper Fissured Clay	0.97	0.09	0.0873	6.3	0.010	0.82	3.3E-03
3 – Lower fissured Clay	0.97	0.08	0.0776	2	0.010	0.83	3.3E-03
4 – Upper LRZ	0.97	0.06	0.0582	2	0.036	1.23	4.9E-03
5 Lower LRZ	0.97	0.06	0.0582	0.01	0.036	1.23	4.9E-03
6 – Deep Lacustrine	0.97	0.02	0.0194	7	0.10	0.052	2.1E-04

NOTES:

1. Darcian Pore Factor from Fetter (1989)
2. Effective DPF = effective Darcian pore factor, DPF x estimated effective porosity.

5.4.1 Changes Made For Transport Simulations

A significant change was also made for the transport simulations. Earlier flow-only simulations included a low permeability layer (referred to as the middle aquitard) in all configurations. This was hypothetical as explained in earlier sections of this report.

The presence of the aquitard was always considered tenuous at best and there was little evidence for its existence as a model layer with assigned properties that in any case were guesses at best. Because including this layer in the model added several hundred thousand cells to the grid that seemed to serve little purpose other than to add significant additional time to each transport simulation, size the cell-by-cell, head, and concentration files that were already approaching 10 15 Gb in size, a decision was made to delete the layer. Until further field work produces evidence of a playa-wide aquitard that divides flow between the upper fissured clay and the so-called lower resource zone, it is recommended that this layer be left out of subsequent simulations.

Layer-specific parameterization for the remainder of this report reflects the removal of the aquitard. Table 43 presents the layer dependent parameters used for all subsequent transport simulations. Also, after review of the complete data set from hydrophysical test results obtained from first half of 2013, the value of LRZ hydraulic conductivity was raised from 1 to 2 m/day.

To provide due-diligence, the original model used for transient calibration to the trench-based aquifer stress test described in Section 3.5, was rerun with the aquitard removed. Fortunately, the results indicated improvement in residual heads, which provided further basis that perhaps the aquitard layer was more misleading to the interpretation of modeling results than it was insightful. The sum of squares of residuals for the end of pumping improved from 942 to 846. Figure 37 presents head contours plotted with residuals. Comparison to Figure 20 shows noticeable improvement. Similar improvement was observed for the end of recovery (Figure 38) which can be compared to Figure 21 to gauge the level of improvement due to this change. Unfortunately, while performing this check, an error was discovered that had carried through all of the previous modeling from the point of calibration to the trench-based aquifer stress test. During sensitivity analysis, the value of hydraulic conductivity for the upper fissured clay was varied. A value of 7 m/day was left by accident in the zone table for this layer and was not noticed until this point. The value should have been 7.9 m/day as originally computed from the trench test calibration statistics. Based on the sum of squares of residuals, there is not a huge impact, and because this value was used for all the preceding simulations for flow, it was decided to just make note of this error and keep the value as is.

Finally, an additional error in value for the van Genuchten (1980) beta parameter was discovered and corrected from units of centimeters to meters and used for all the transport simulations.

Table 43. Layer-Dependent Parameters Used for Transport Simulations..

Parameter	Layer 1 – Fat Clay	Layer 2 – Upper Fissured Clay	Layer 3 – Lower Fissured Clay	Layer 4 – Upper LRZ	Layer 5 – Lower LRZ	Layer 6 – Deep Lacustrine
Horizontal K (m/day)	0.00018	7	6.3	2	2	0.01
Vertical K (m/day)	1.8e-005	7	6.3	0.2	0.2	0.001
Specific Storage[1]	0.0015	0.013	0.011	2.7E-06	2.7E-06	1.E-06
Specific Yield[1]	0.02	0.08	0.08	0.06	0.06	0.02
PHI[2]	0.52	0.63	0.59	0.61	0.61	0.51
PHIIM[3]	0.514	0.55	0.53	0.50	0.50	0.51
PHIF[4]	0.03	0.13	0.12	0.31	0.31	0.01
SF1[5]	0.05	0.10	0.094	8.7E-06	8.7E-06	1.0E-04
SF2[6]	0.67	0.63	0.68	0.19	0.19	2
LDISP[7]	0.1	3.13	2.13	1.13	1.13	0.9
TDISP[8]	0.03	0.939	0.639	0.339	0.339	0.27
VTDISP[9]	0.005	0.157	0.107	0.057	0.057	0.045
LAYCON	43	43	43	40/43	40	40
SCONC	207.64	207.64	207.64	207.64	207.64	207.64
SIMCONC	207.64	207.64	207.64	207.64	207.64	207.64
DUALRATE[10]	1.2Ee-05	3.3E-03	3.3E-03	4.9E-03	4.9E-03	2.1E-04

NOTES:

1. Non-Transport values of storage parameters provided for comparison purposes.
2. Effective porosity, for dual domain simulations, this is void space in mobile domain per unit volume of mobile domain, as calculated by Equation 10.
3. Porosity of immobile domain, this is the void space of the immobile domain per unit volume of immobile domain as calculated by Equation 11.
4. PHIF is also known as the parameter *f*, the mobile fraction.
5. Mobile domain version of specific storage. Obtained by dividing the non-transport storage value by the value of PHIF.
6. Mobile domain version of specific yield. Obtained by dividing the non-transport storage value by the value of PHIF.
7. Longitudinal dispersivity, estimated from case studies presented in Gelhar (1993).
8. Transverse horizontal dispersivity, estimated at 30% of LDISP.
9. Transverse vertical dispersivity, estimated at 5% of LDISP.
10. First order mass transfer coefficient (1/T), estimated from Dahmköhler number (Domenico and Schwartz, 1998). See Table 42 and accompanying discussion for further details on estimation of this parameter.

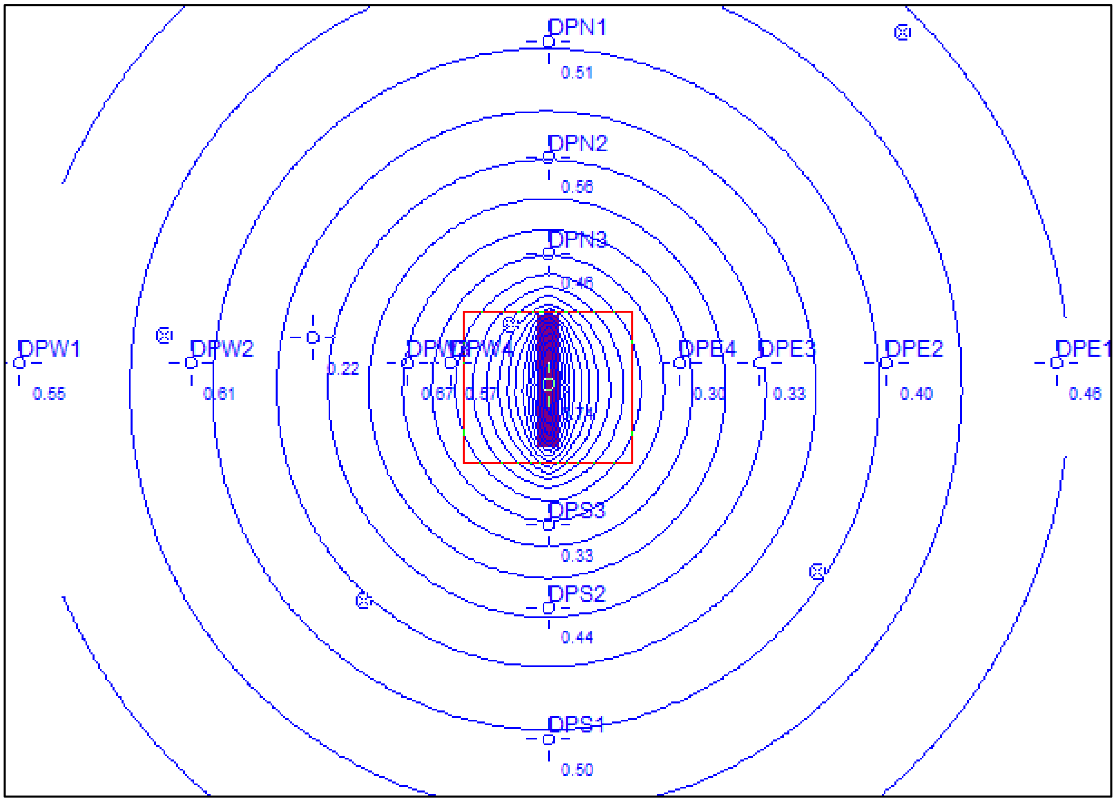

Figure 37. Plot of Head Contours with Residuals at End of Pumping, After Removal of Aquitard Layer.

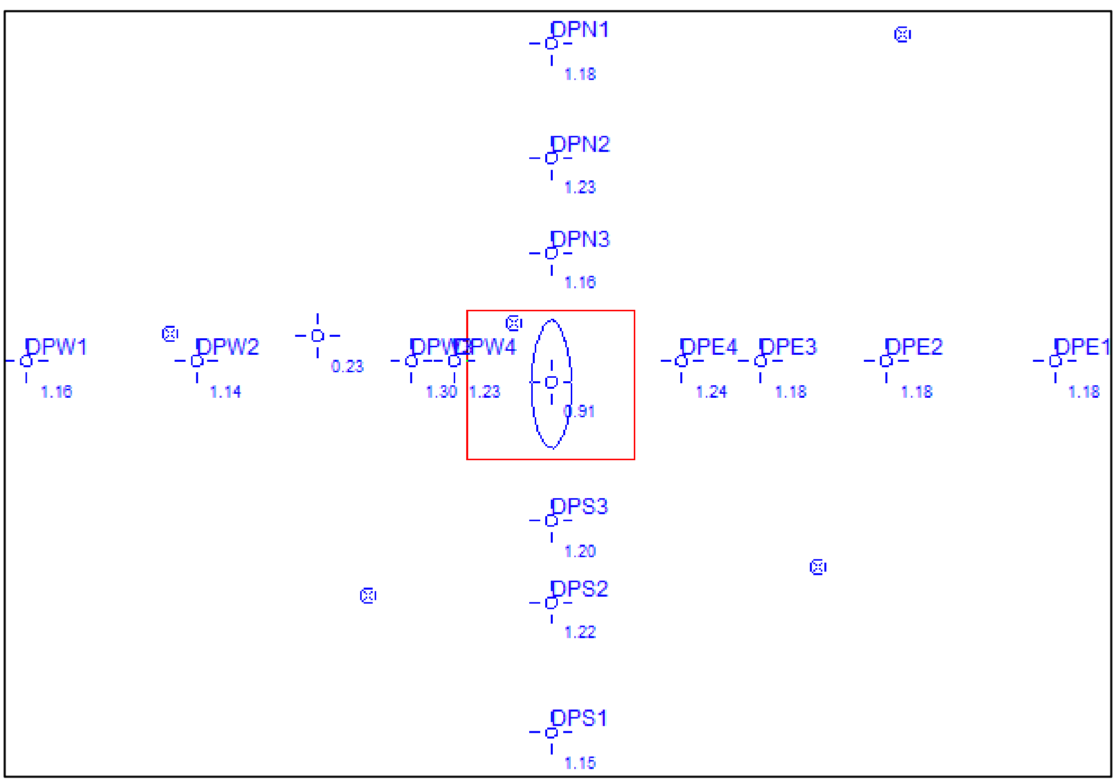

Figure 38. Plot of Head Contours with Residuals at End of Recovery, After Removal of Aquitard Layer.

5.5 2-D Transport Simulations

5.5.1 Introduction

Initial prototype runs were difficult to interpret due to artificial oscillation and to some degree, numerical dispersion. This was the likely result of the grid cell size in the playa-wide model, and also due to effects of increased groundwater velocities near extraction trenches. Efficiently arriving at solutions was also complicated by the general non-linearity of the problem and cell drying near extraction trenches which caused implausibly high concentrations in the uppermost layers.

To address the impact on schedule from the problematic 3D model simulations and still provide needed data for design decisions with respect to trench spacing, it was decided to model a series of 2D slices through the playa-wide 3D model in the basin-center area previously modeled for flow only. The area for the 2D section was selected from a north-south cut at the trench centerline from the west side of the trench network. This allowed the 2D slice to honor the layer elevations and thicknesses at that specific point on the playa.

The length of the section was approximately 1000 meters long in a north-south direction, to accommodate two extraction trenches and three recharge trenches at 500 m spacing, one extraction trench and two recharge trenches at 750 m spacing, and one extraction trench and two recharge trenches at 1000 meter spacing.

Because the strip was one cell wide, there was no longer any facility to route water using SFR into the LAK cells representing recharge trenches. Therefore, the withdrawal parameter of the LAK package was used to simulate flow into recharge trenches. The withdrawal parameter is simple, and represents a volumetric flux that is added or subtracted to a lake during a stress period. As in previous simulations, the flow rate used was determined by trial and error with the goal that the head (stage) of the lake would remain as close to land surface as possible throughout each stress period of a simulation.

Because the 2D model was sufficiently small in scale, the recharge trench boundary condition could be built in trapezoidal shape to better simulate the geometry of a recharge trench. Each lake boundary condition was built with 16 model cells at ground surface (layer 1), 10 model cells in layer 2, and 4 model cells in layer 3. In cross-section, the boundary condition is represented by the blue cells as shown in Figure 39 (enlarged to show detail). Two analytical observation wells are also shown in Figure 39. In this particular case (500 m spacing), the extraction trench would be located 250 meters to the south (left in figure) and the other recharge trench would be located 500 m to the south (further to left in figure).

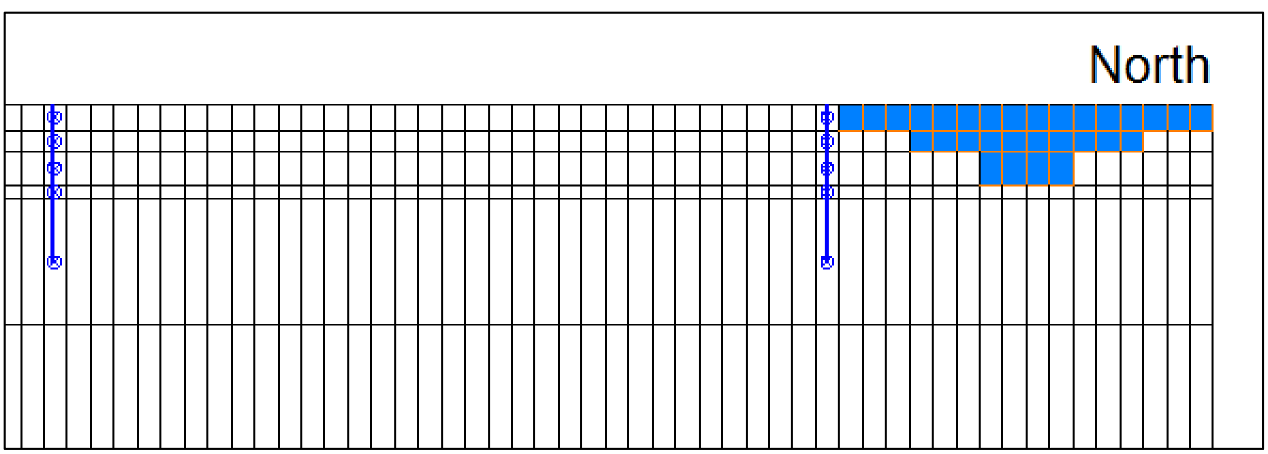

Figure 39. Cross-section of a Recharge Trench Represented by the LAK boundary Condition.

Because the 2D strip was one cell wide, line boundaries could no longer be used to simulate extraction trenches. Therefore a single well was placed in a cell used to represent the one meter wide section of extraction trench. The well was configured with the base extraction rate specified at 1.6m^3/day to simulate the target extraction rate of 0.09 gpm/lineal foot required by the mine project design.

During simulations, numerous parameters were often varied to achieve convergence, quicker times to solution, and reduction in artificial oscillation and numerical dispersion. Table 44 presents these parameters.

Table 44. Parameters Varied throughout Simulations.

Parameter[1]	Package[2]	Value	Definition
IACLVL	BTN1	0 or -2	Numerical scheme; 0 = fully upstream weighting. -2 = Adaptive TVD scheme with the van Leer flux limiter.
THETRD	BTN1	1.0 or 0.5	Control parameter for time-weighting scheme. 1.0 = fully implicit scheme (reduces oscillation). 0.5 = Crank Nicolson scheme is used.
MXITERC	BTN1	30-50	Max number of outer iterations (calls to solution routine) in the case of non-linear iterations
ISWAB	BTN1	1,2	1 = Transport boundary condition on a prescribed head node checks for inflow/outflow at every iteration. 2 = Check for inflow/outflow is time-lagged.
ILAG	BTN1	0, 1	0 = buoyancy terms are updated rigorously. 1 = Buoyancy term is time-lagged.
LAYCON	BCF4	40,43	Layer-type index array. First digit is always 4, Second digit is either 0, strictly confined, or 3, confined/unconfined. T and S depend on head. Harmonic mean inter-block hydraulic conductivity. Assignment sometimes varied due to trench depth.

NOTES:
1. Parameters pertain to MODFLOW-SURFACT.
2. Stated package contains the indicated parameter.

After each run was completed, the model output file was parsed at selected times for the volume pumped by the well package and the mass of solute (TDS) withdrawn by the well package at those times. Average concentrations of produced brine at various times were calculated by dividing the mass produced by the volume of water pumped. The average concentrations calculated was then divided by the initial concentration (207.64 kg/m^3) to produce a plot of relative concentration versus time, which would allow comparison between scenarios based on the degree of dilution over time.

5.5.2 500 m Trench Spacing

Several scenarios at different extraction rates were run at 500 m trench spacing. The objective of these runs was to determine a sustainable extraction rate, and determine the impacts to brine water quality from water derived from recharge trenches. The relative concentration of the volume of brine produced during the extraction period along with the recharge rate were compiled and compared to one another..

Review of the 500 m results shows that while the 0.09 gpm/lineal ft. extraction rate could be sustained, the relatively close distance to recharge trenches accelerated the time to where dilution negatively impacts relative concentrations. After three years of pumping at the base rate, relative concentrations had fallen to below 0.85. As a counter measure, a lower extraction rates was tested, and the time before reaching 0.85 relative concentrations was extended to 10 years. However, during this time only 8.3 tons of K^+ was produced, compared to 9.9 tons produced for the three year extraction period at the higher extraction rate.

The costs associated with trench construction at such small distances also played into the basis for selecting any particular trench spacing. For all of these reasons, brine extraction at 500 m spacing was deemed plausible, but further modeling was moved to scenarios with 750 m trench spacing.

5.5.3 750 m Trench Spacing

Numerous scenarios were run at 750 m trench spacing. The objective of these runs was to build upon the data collected from the 500 m spacing runs, determine a sustainable extraction rate, determine effective of dilution from recharge trenches, determine the effect of deepening trenches, and determining whether switching extraction from trenches to wells at some point was an effective strategy for extracting brine rather than deepening trenches. The relative concentration of the volume of brine produced during the extraction period along with the recharge rate used was compared between each scenario.

The results indicated that the base extraction rate (1.6 m^3/day) with shallow trenches (pumping from layers 1 through 2) could be supported with relative concentrations remaining above 0.96 for three years, and above 0.9 for as long as 7.5 years. In addition, it was determined that relative concentrations could be maintained above 0.99 for at least 10 years if the extraction rate was dropped to 0.4 m^3/day (1/4 base rate).

Building on this, several additional scenarios considered back-to-back 7.5 year extraction periods that began with shallow trench extraction as usual but then switched to deeper extraction for the second 7.5 year period. The scenarios differed by the following:

- Second phase of pumping included deep trenches that pumped from all layers 1 through 4 (upper LRZ).
- Second phase of pumping included deep trenches that pumped only from both LRZ layers 4 and 5.
- Both phases of pumping included only deep trenches pumping from layers 1 through 4.

All of the previously described scenarios were considered successful for the timeframes modeled, but a total of 14 years of extraction did not meet project requirements.

The next and final series of simulations focused on 1000 m trench spacing.

5.5.4 1000 m Trench Spacing

Numerous scenarios were run at 1000 m trench spacing. The objective of these runs was to build upon the data collected from the 500 m and 750 m spacing runs, determine a sustainable extraction rate, determine effective of dilution from recharge trenches, determine the effect of deepening trenches, and determining whether switching extraction from trenches to wells at some point was an effective strategy for extracting brine rather than deepening trenches. The relative concentration of the volume of brine produced during the extraction period along with the recharge rates used was compared between each scenario.

5.5.4.1 Initial 2D 1000 m Trench Scenarios

The following scenarios were investigated:

1. One shallow 20-ft deep extraction trench, pumping at 1.6 m^3/day from 3 layers for duration of one year. This simulation indicated that relative concentrations generally remained in the range of 0.9 to 0.93 for the year simulated.
2. One shallow 20-ft deep extraction trench, pumping at 1.6 m^3/day from 3 layers for duration of three years. Results showed that relative concentrations generally remained in the range of 0.92 to 0.95 for the three years simulated.
3. One shallow 20-ft deep extraction trench, pumping at 0.4 m^3/day from 3 layers for 10 years duration. Results showed that relative concentrations remained above approximately 0.98 for the 10 years simulated.
4. One shallow 20-ft deep extraction trench, pumping at 1.6 m^3/day from 3 layers for duration of 9.5 years. Results showed that relative concentrations remained between 0.9 and 0.93 for the 9.5 years simulated.
5. To characterize the contribution of lower layers, the preceding scenario was modified by setting initial brine concentrations in the layers 4 through 6 to zero and rerunning the simulation. The results were then compared to previous simulation No. 4 above which utilized only shallow extraction with initial concentrations in the lower layers set to normal values. . To calculate the contribution from the lower resource zone, the concentrations simulated for the two scenarios were

differenced at selected times, the assumption being that the difference in concentration would represent the amount of contribution from the LRZ. Figure 40 presents the data for just the first 9.5 year extraction period, pumping from layers 1 through 3 while Figure 41presents the results from the second scenario with modified concentrations in the lower layers. This simulation indicated that a little over one half of the mass produced was coming from the LRZ by the end of the 9.5 year extraction period (see green line in Figure 42).

6. One shallow 20-ft deep extraction trench, pumping at 1.6 m^3/day from 3 layers for duration of 9.5 years, but with initial concentrations in layers 4 through 6 set to zero and density-dependent flow turned off. This simulation was designed to investigate the influence of density-dependent flow had on simulation results. With initial concentrations modified to zero in the lower layers, the results indicated very little difference between simulating this scenario with density-dependent flow turned on and density-dependent flow turned off. Figure 43 presents the results of this simulation as compared to the 9.5 year base case with normal initial concentrations in all layers.

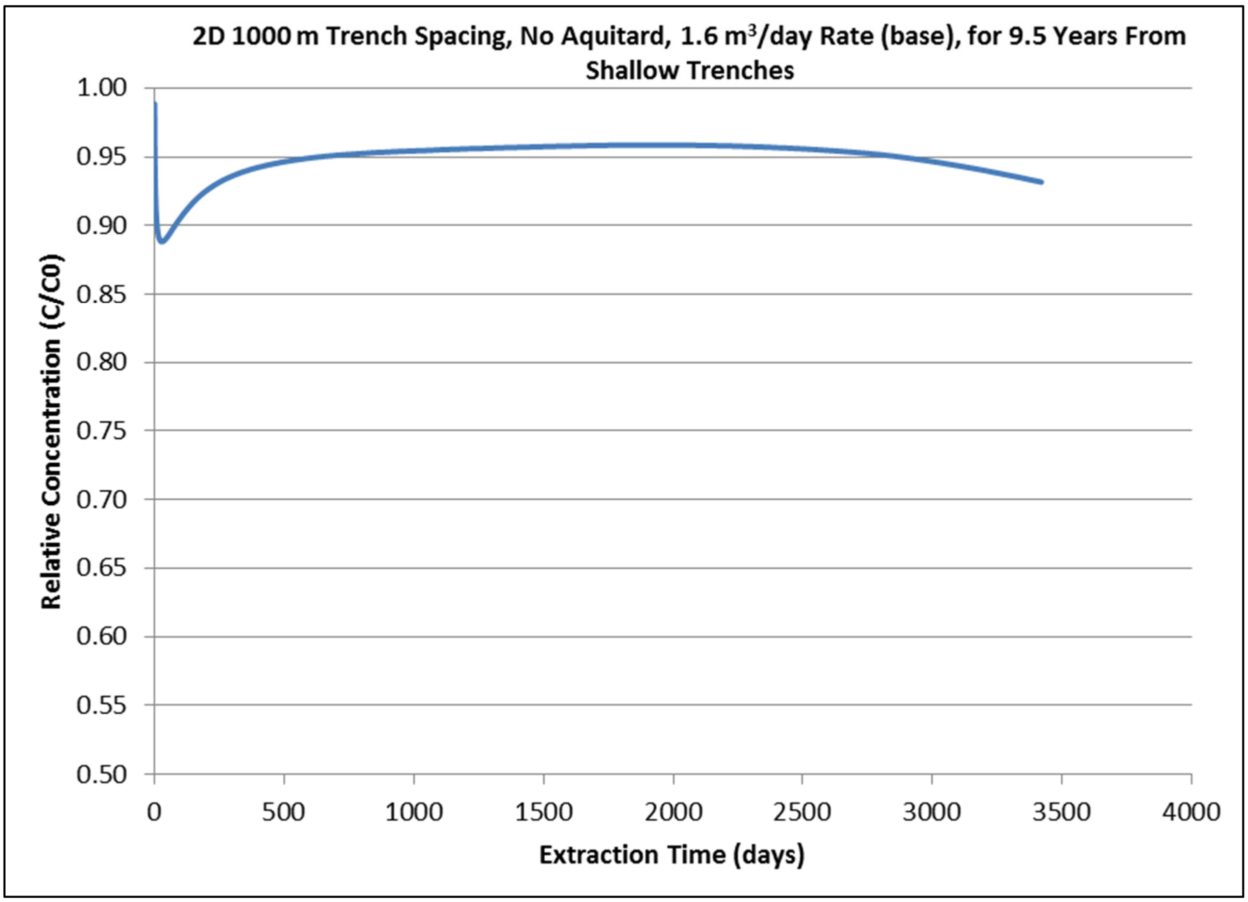

Figure 40. Relative Concentrations for 9.5 year-long Shallow Trench Extraction.

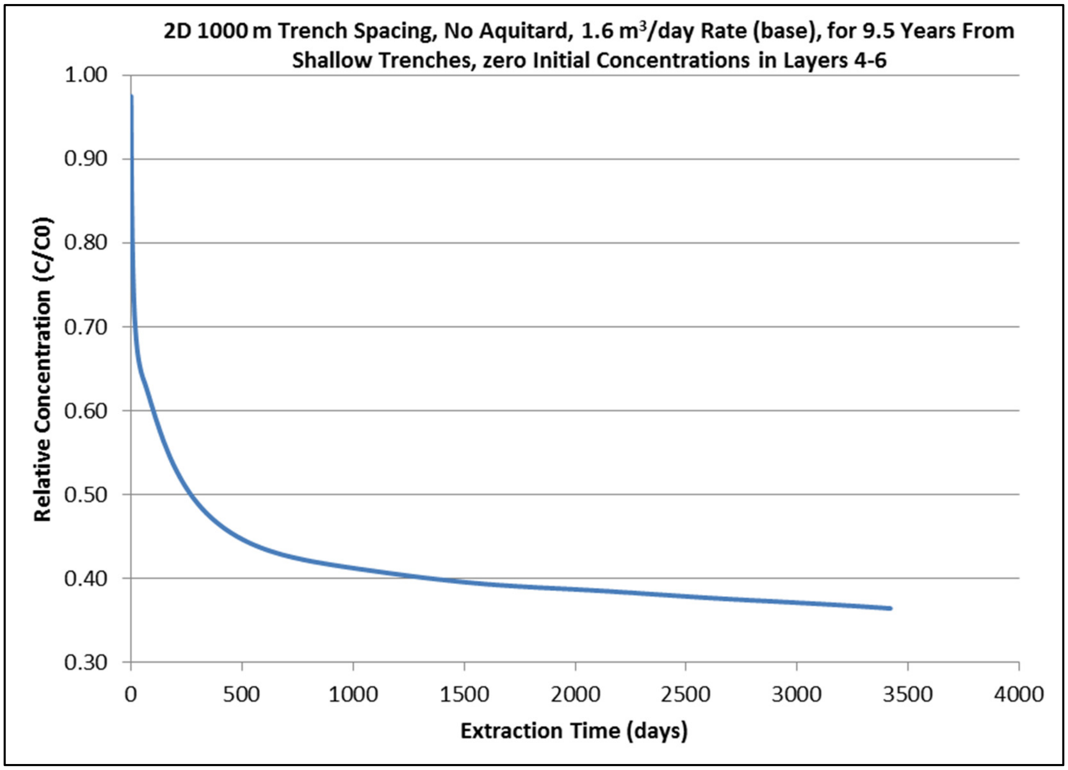

Figure 41. Relative Concentrations for 9.5 year-long Shallow Trench Extraction with Initial Concentrations Set to Zero in Layers 4-6.

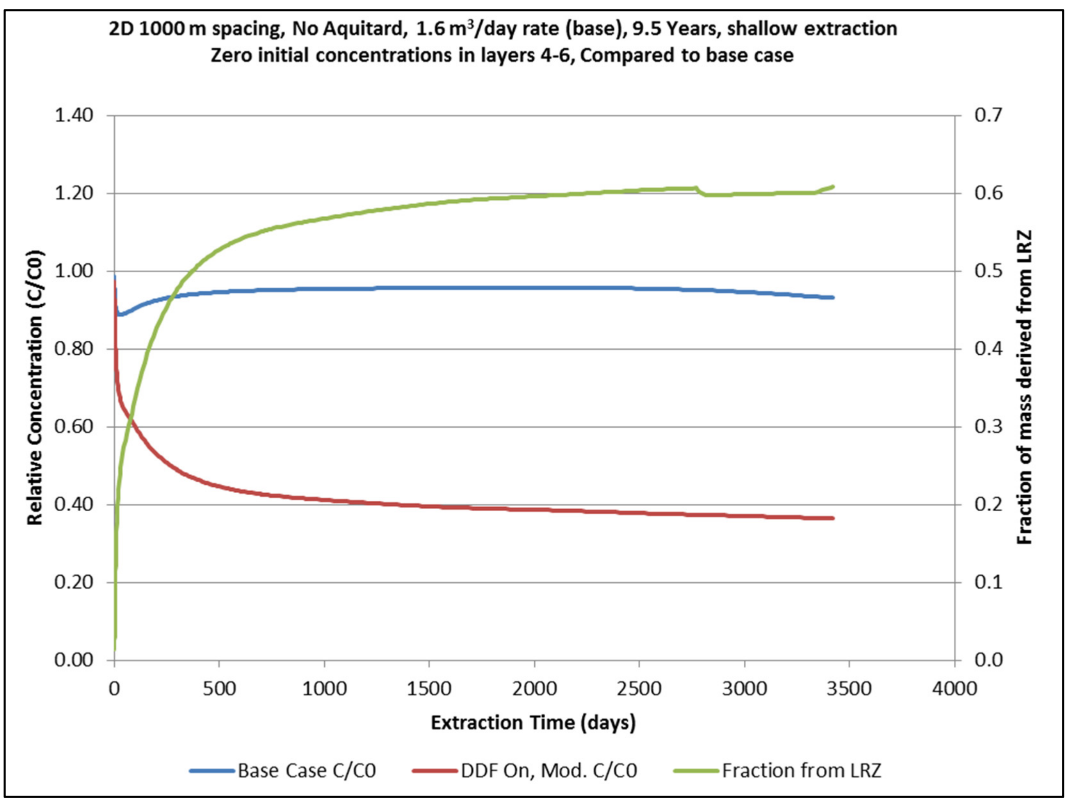

Figure 42. Comparison of Results With Modified Initial Concentrations in Layers 4 - 6.

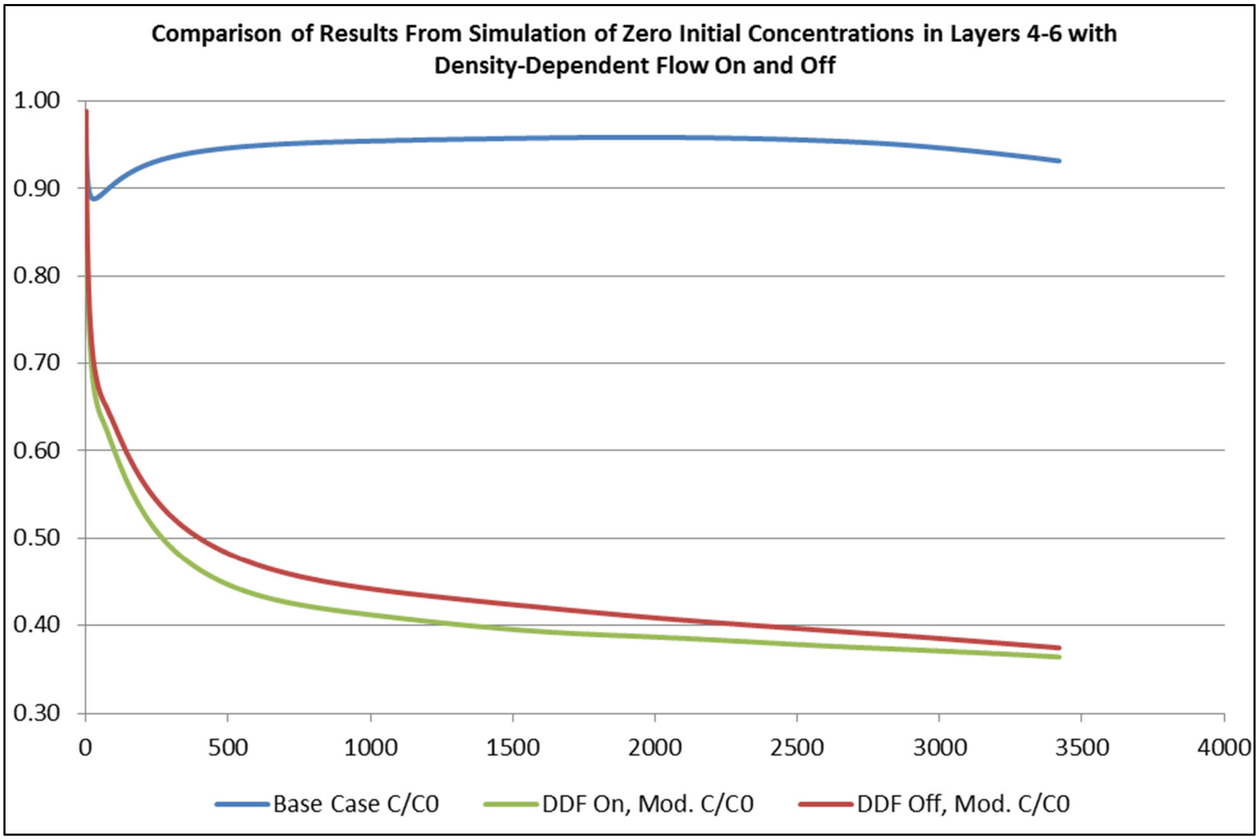

Figure 43. Comparison of Modified Concentration Results with Density-Dependent Flow Module Enabled and Disabled.

Table 45 summarizes the stress period lengths and the intent of each stress period used for the initial 1,000 m trench spacing simulations.

Table 45. Summary of Stress Periods and Recharge Rates used for Initial Simulations at 1,000 m Spacing.

Stress Period	Sim. 1 (days)	Sim. 2 (days)	Sim. 3 (days)	Sim. 4 (days)	Sim. 5 (days)	Sim. 6 (days)	Purpose
1	SS	SS	SS	SS	SS	SS	quiescence
2	7	7	7	7	7	7	Initiation of trench recharge flow
3	360	1080	1080	3420	3420	3420	Extraction with recharge
4	120	180	180	180	180	180	recovery with recharge
5	1080	1080	1080	3420	3420	3420	passive recovery

5.5.4.2 2D 1000 m Trench with Dual 9.5 year Extraction Periods

Based on the learning from these data, it was determined that the relative concentration of 0.9 was an acceptable cut-off grade for further investigation involving trench deepening. These next scenarios placed two 9.5-year extraction periods back-to-back, the first pumping from shallow trenches (layers 1 through 3), the second pumping from deepened trenches (layers 1 through 4). Table 46 summarizes the stress periods employed.

Table 46. Summary of Stress Periods and Recharge Rates Used for Two 9.5-Year Long Extraction Periods at 1000 m Spacing

Stress Period	Simulation 7 (days)	Simulation 8 (days)	Simulation 9 (days)	Purpose
1	SS	SS	SS	quiescence
2	7	7	7	initiation of trench recharge flow
3	3420	3420	3420	Extraction/Recharge
4	180	180	180	recovery with recharge
5	3420	3420	3420	passive recovery
6	3420	3420	3420	Extraction by trenches or well with recharge

The following scenarios were investigated:

7. As initially found in simulation no. 4 from the previous round, relative concentrations remained above 0.9 for the first extraction period, but fell to as low as approximately 0.74 by the end of the second extraction periods with the deepened trenches.
8. To again check the influence of density-dependent flow on simulation results, the preceding scenario was modified by turning off this module and rerunning the simulation. The results were similar to the earlier test (no. 6) where very little effect was noted. It is likely that the extraction exerts a higher level of control on the hydraulic of the aquifer and is able to exert enough control of water flow such that any segregating effects due to density-dependent flow are masked. Due to the contrast of water densities resulting from setting initial concentrations to zero in layers 4-6 to zero, this is close to a "best-case" scenario for identifying effects off density-dependent flow.
9. The final simulation focused on pumping shallow trenches for the first 9.5 year extraction period, and then following this with extraction from a well field completed in the LRZ. This is further discussed in the next section.

5.5.4.3 2D 1000 m Trenches and Wells Simulation

As additional data continued to indicate that the 1000 m trench spacing scenario with back-to-back 9.5 year extraction periods was appearing favorable from a mine design standpoint, several other avenues of experimentation were undertaken. For example:

- The ET extinction depth was varied for some simulations to follow stress periods when drawdown were not expected to be large In other words, when the water table was close to ground surface as in the first stress period before pumping began or during recovery periods, the ET extinction depth was decreased to 1 meter. When drawdown was expected to be large, such as during extraction, the ET extinction depth was left at the original value of 3.75 m below ground surface.
- Areal recharge was varied between the base value of 1E-06 m/day and 5.5E-05 m/day to see whether such a change over the long periods simulated made any difference.
- Deep trenches were replaced with wells for the second 9.5-year extraction period.

For the final scenario, instead of pumping from deeper trenches during the second 9.5-year extraction period, extraction was assumed to be restricted to wells. Various well spacing including 100, 200, 250, 300 and 400 meters were simulated to identify well extraction rates that could be sustained solely with recharge trench leakage. Though simulations showed that employing injection wells dispersed within an extraction well field, the added costs are significant (up to double). Results from 3D simulations of various well field configurations showed that extraction wells spaced on 400 meter centers could sustain 18.3 gpm pump rates. Wells at this spacing and with a discharge rate scaled to the 2D model space were added to the 2D model. The discharge rate was obtained from the following procedure:

- The 3D model space between two recharge trenches constructed on 1,000 m centers accommodates 16 wells if spaced on 400 m centers.
- The 3D simulation of the well field indicated that each well could be pumped at a rate of 100 cu. meters/day (18.3 gpm) for a total production rate of 1,600 cu. m./day.
- The 3,096 m long trench between the two recharge trenches produces 1.61 m^3/day per lineal meter for a total production of 4985 cu. m/day.
- The ratio of trench production to well production: 1600/4985 = 0.32 scaling factor for wells.
- If the 2D model considers a one-meter-wide section of extraction trench cut normal to trench length, the pump rate of one well should be scaled to 0.32 of the rate of the trench.
- Therefore, the scaled single well rate is calculated as: 1.61 * 0.32 = 0.5 m^3/day.

Figure 44 presents the results of a simulation where the initial 9.5-year extraction period obtains water from shallow trenches pumping from layers 1-3. The second extraction period utilizes the wells only, completed in layers 4-5, corresponding to the LRZ.

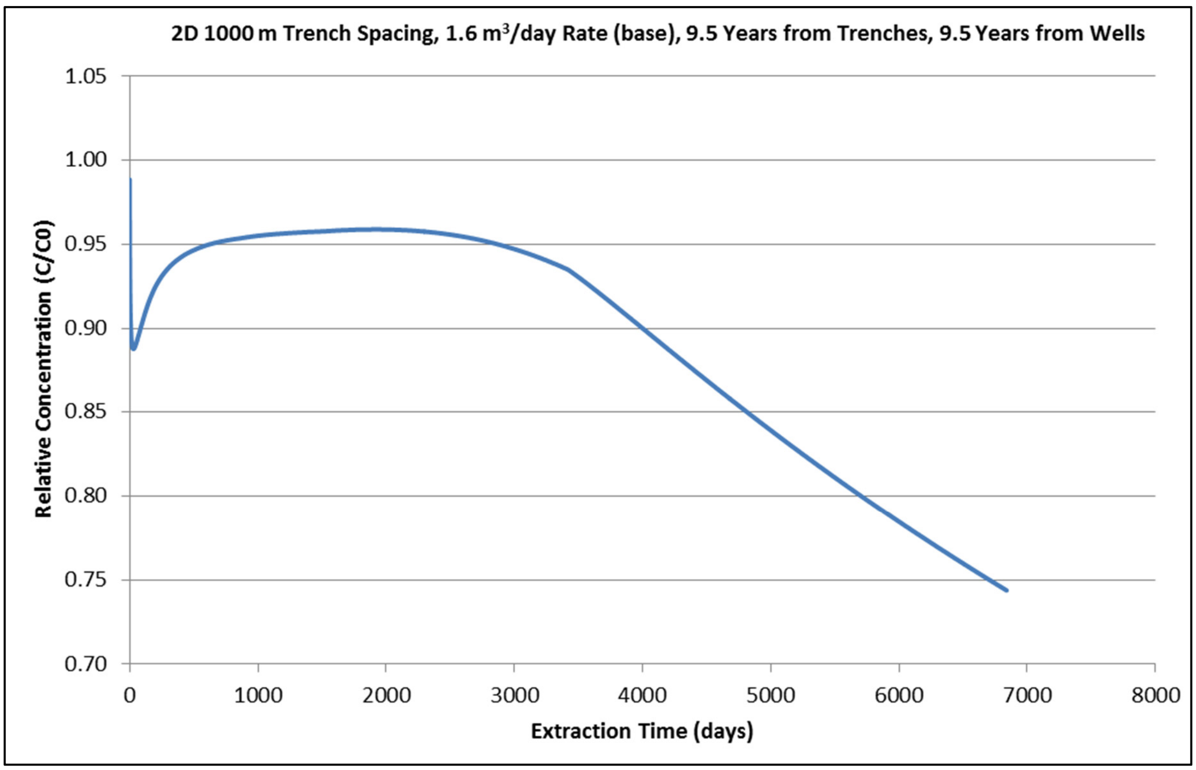

Figure 44. Simulation Results for Two 9.5 year Extraction Periods, First by Trenches, then followed by Wells.

The results demonstrated that acceptable brine concentrations can be extracted through a combination of trenches and wells for a period of at least 19 years based on the current understanding of transport properties. This is an improvement over results from deepened trenches for the second phase of extraction. The principle reason is that wells can be discreetly screened in the horizon of choice, minimizing extraction of lower quality water from other layers. The deepened trench scenario does not have that luxury because a trench will simply extract water through whatever intervals provide water in the most hydraulically efficient manner.

Break-through curves located at two locations along the 2D section were prepared to support the final simulation involving 1000 m spaced trenches and two 9.5 year-long extraction periods. These curves provide instantaneous estimates of brine concentration at the indicated locations as opposed to earlier presentations where average cumulative concentrations are calculated from the mass of TDS extracted divided by the volume of water pumped at some time.

Figure 45presents the break-through curve for a point located within 2.5 m of an extraction well, located 300 meters from the nearest recharge trench. The combination of properties including dispersivities, groundwater velocities, and grid cell size (along with the lack of cell desaturation which usually occurs in the vicinity of extraction trenches) results in a coherent distribution of concentrations with little to no artificial oscillation. Also, because this location is 300 m from the nearest recharge trench and 200 m from the nearest extraction trench, there is not a huge contrast in dilution in layers 2 through 4.

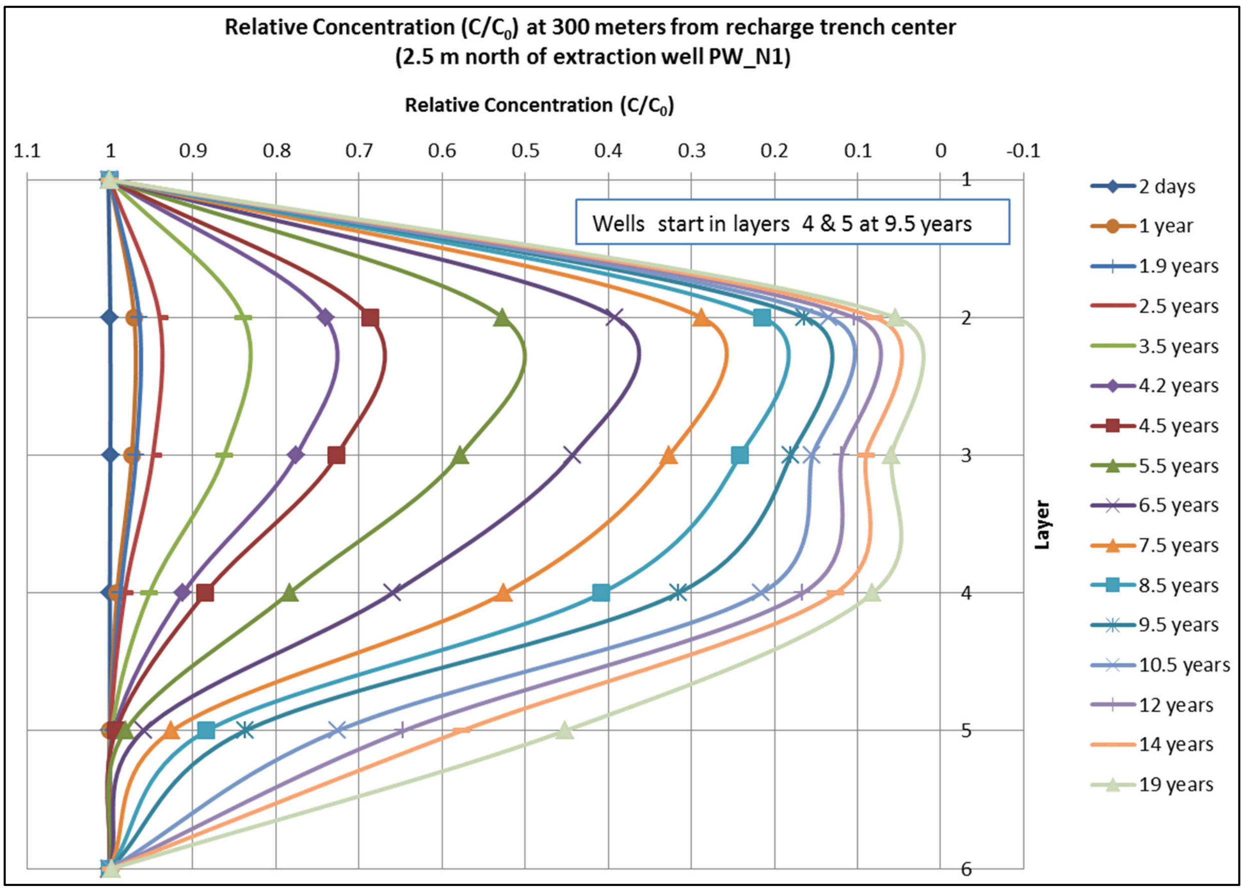

Figure 45. Break-through Curves for a Point 300 m from Nearest Recharge Trench and next to a LRZ Extraction Well.

Figure 46 presents the breakthrough curves for a point located within 2.5 m of an extraction trench, and therefore 500 m from the nearest recharge trench. Comparing the data shown in Figure 45 (above) to Figure 46 shows that near the extraction trench, where a wider range of groundwater velocities are expected along with cell desaturation, the results are less smooth. Putting aside the effects of cell desaturation on calculated concentrations, these observations are in line with the theory earlier discussed in Section 5.2, where cell size, groundwater velocity and dispersion all play a role in the degree to which artificial oscillation and numerical dispersion affects simulated results. In any case, by the end of well extraction, relative concentrations in layer 4 (upper LRZ) remain between 0.5 and 0.6 and relative concentrations in layer 5 (lower LRZ remain at approximately 0.8.

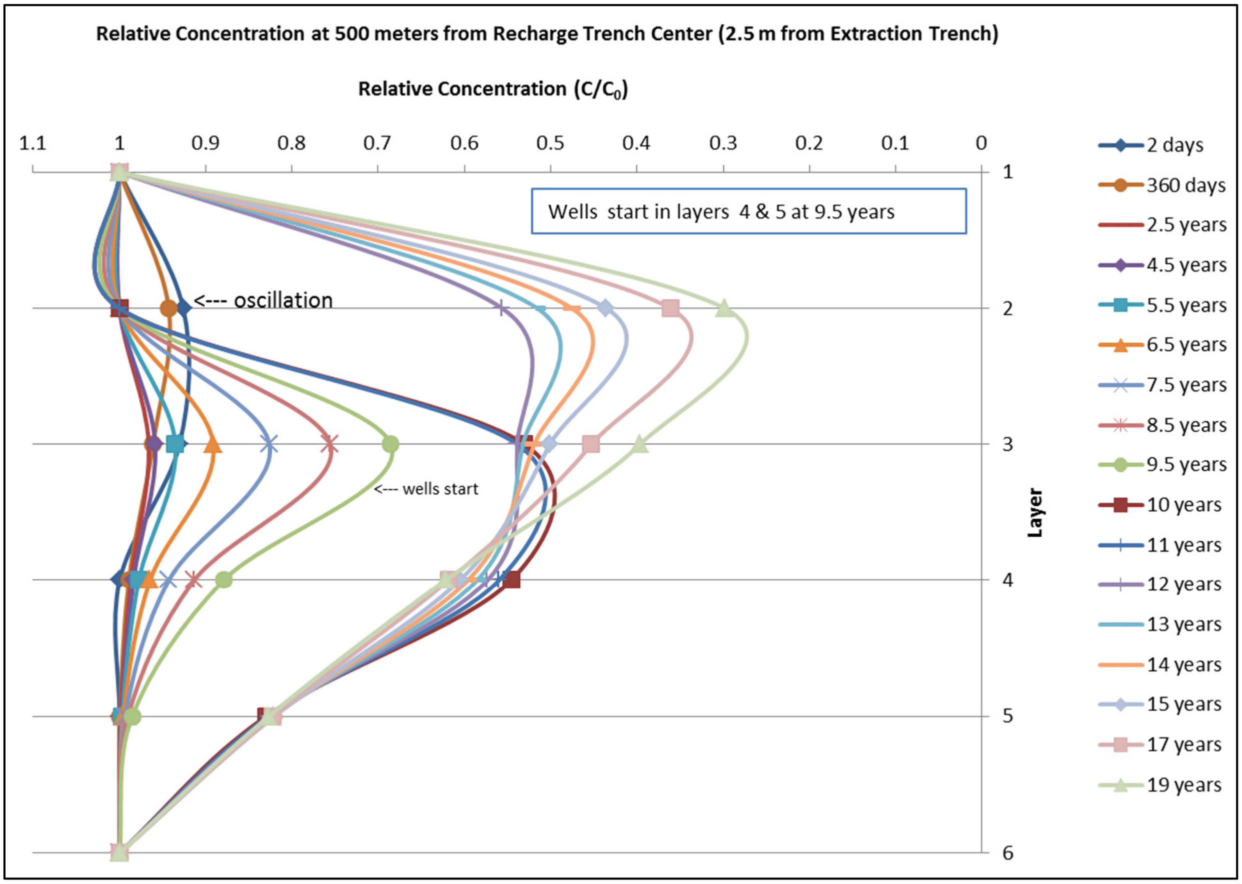

Figure 46. Break-through Curves for a Point 500 m from Nearest Recharge Trench and next to an Extraction Trench.

5.5.5 Sensitivity to Principal Mass Transfer Parameters

A basic sensitivity analysis was performed on three selected transport parameters that are expected to exert control over brine concentration changes over time. These three parameters included the mobile fraction (PHIF), the mass transfer coefficient (DUALRATE), and dispersion coefficients. The mobile fraction was varied between 25% and 50% of the base value in each layer. The mass transfer coefficient for each layer was directly varied two orders of magnitude upwards, and two orders of magnitude downwards. Further changes upwards to the mass transfer coefficient did not have any significant effect on relative concentrations. The dispersivities were varied one order of magnitude upward and one order of magnitude lower. Dispersivities were changed by varying the longitudinal dispersion coefficient as stated, while the transverse horizontal and vertical components were estimated as 0.3 and 0.05 percent of the longitudinal value, as currently calculated for the base case in all of the previous modeling.

By far, relative brine concentrations were most sensitive to the changes made to the mass transfer coefficient (Figure 47). This was followed by the dispersivities as shown in Figure 48. Relative concentrations showed minor sensitivity to the value of the mobile fraction when PHIF was varied over the stated range (Figure 49).

Both dispersivity and the mass transfer coefficient reflect elements of groundwater velocity and are scale dependent, such that varying their respective values incorporates any changes to both velocity and the distance over which transport occurs. Higher groundwater velocities must have quicker rates of mass transfer in order to produce significant amounts of solute by diffusion out of immobile pore space. Obviously longer travel distances puts water in contact with diffusing immobile porosity over longer periods of time when measured at some point down-flow (all other things equal).

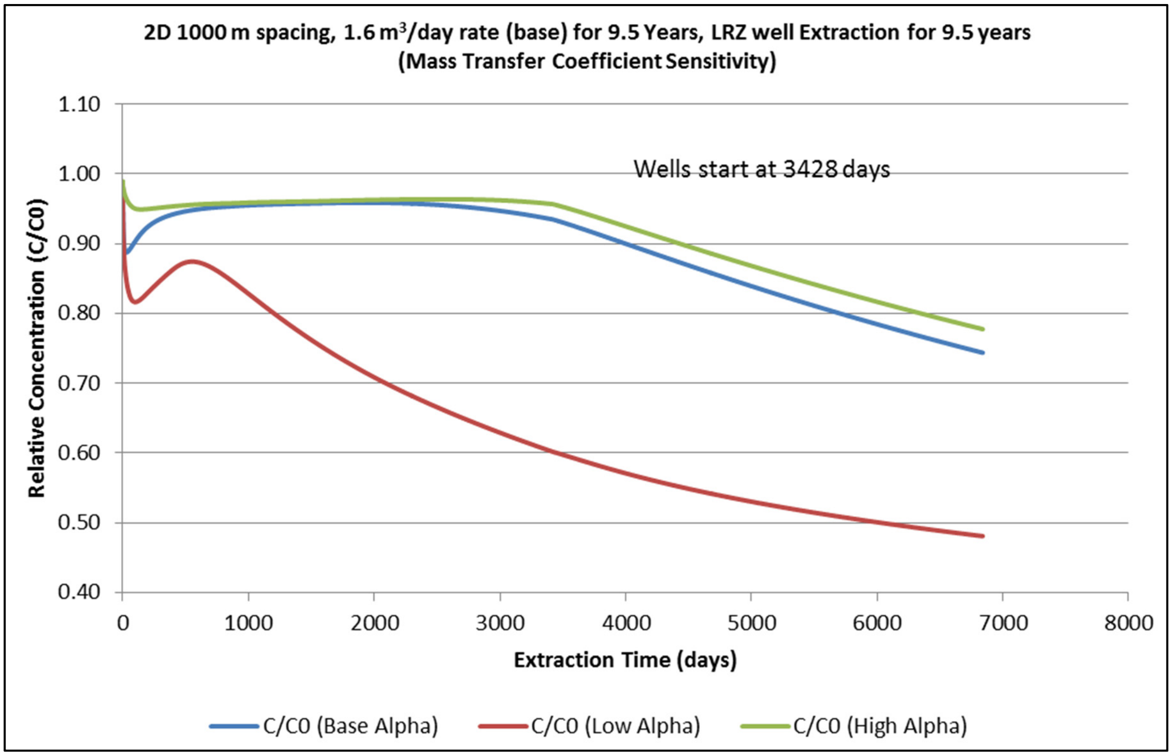

Figure 47. Sensitivity of Relative Concentration to Changes in Mass Transfer Coefficient.

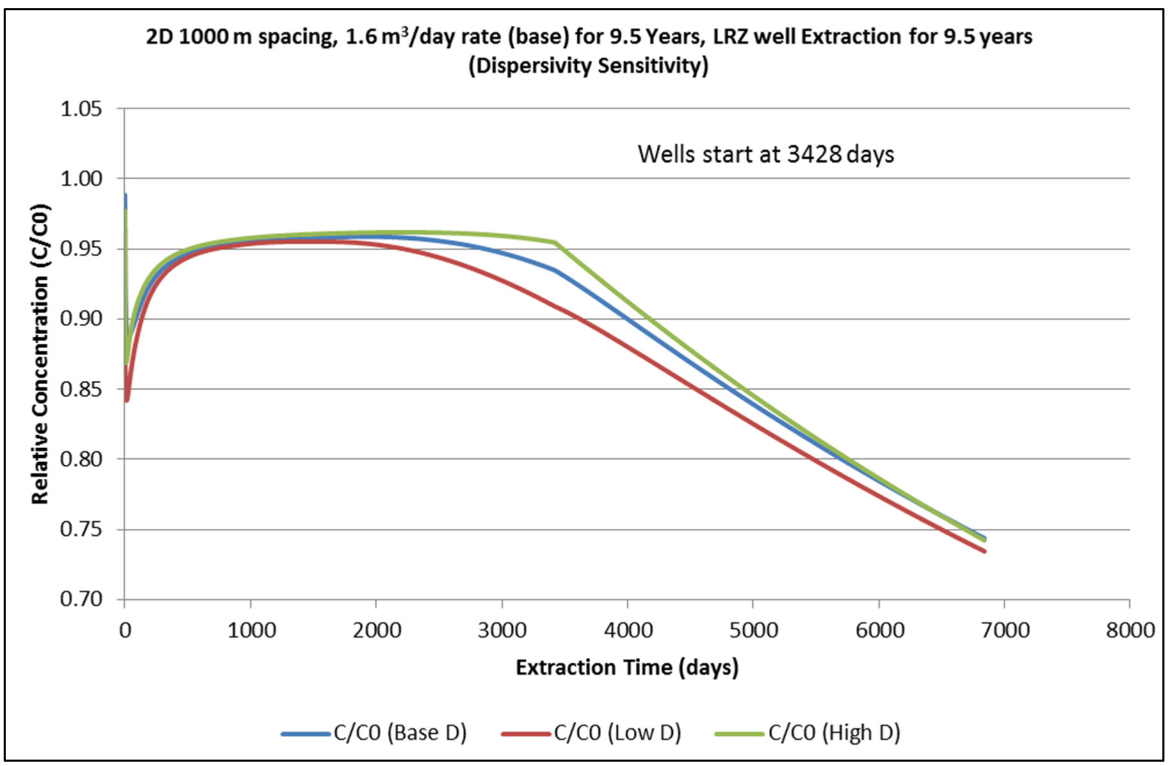

Figure 48. Sensitivity of Relative Concentration to Changes in Dispersivity.

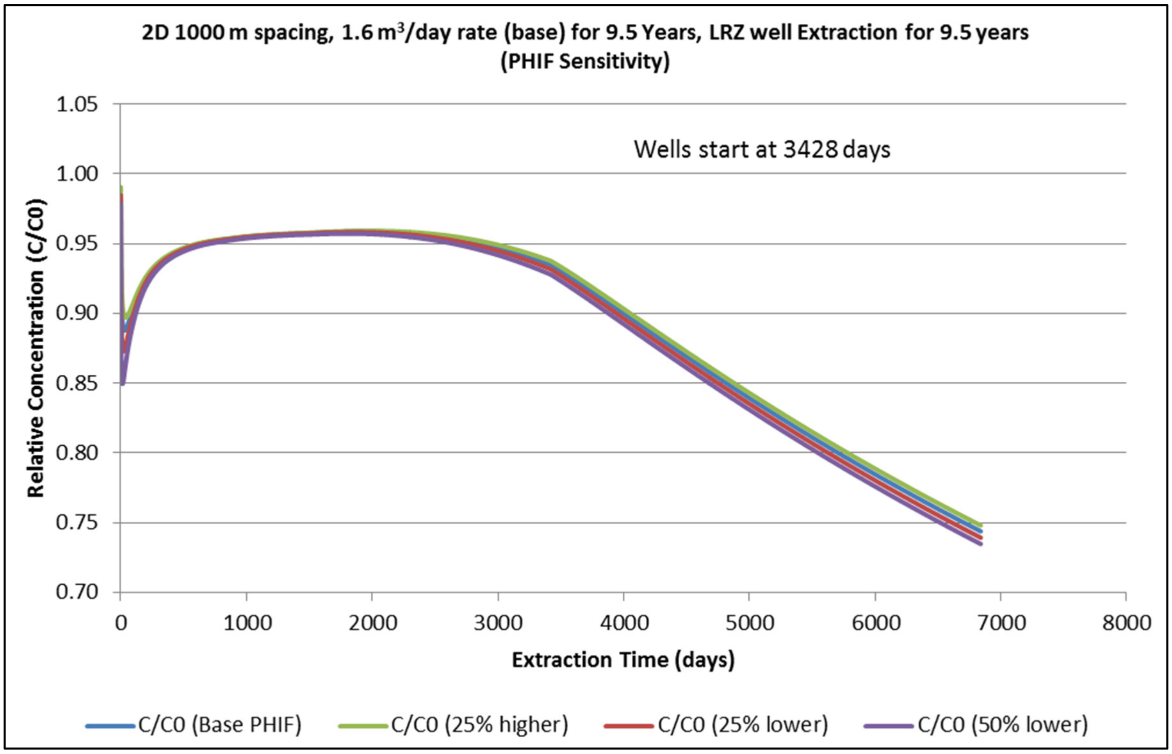

Figure 49. Sensitivity of Relative Concentration to Changes in Mobile Fraction.

Changes in velocity over a variety of distances traveled imply more dispersion over time, possibly resulting in more dilution or in greater mixing of low solute concentration water with highly concentrated brine. On the other hand, a resulting lower concentration at a lower groundwater velocity implies a high concentration gradient directing mass out of immobile pore space and increasing the residence time in which to do so.

5.5.6 2D Transport Simulations Conclusion

Numerous 2D simulations were conducted using an area located in the southern basin center of the Sevier Lake Playa. The results indicated that spacing extraction trenches at distances of up to 1,000 m would place the source of recharge far enough way so as not to dilute unacceptably the resource at the extraction trench, yet be close enough to provide a source for recharge to counter the effects of drawdown.

The results from 2D simulations showed that for the particular trench spacing, layer thicknesses, layer depths, and transport parameters specified, at least two 9.5-year extraction periods could be supported with relative concentrations staying above 0.75 throughout the 19-year period.

Best results were obtained when the LRZ resource could be exploited without also accessing water from the upper resource zone, which by the end of the first 9.5 year extraction period contained enough recharge trench-derived water to significantly dilute concentrations. Constructing deeper 40-ft trenches, or deepening the ones already in place would not be a recommended practice because simulations showed that even though a significant thickness of LRZ was in contact with a 40-ft deep trench, the trenches would preferentially accesses water laterally from the more permeable layers lying above in the fissured clay aquifer. Therefore, the only avenue to maintain high brine concentration would be to install wells in the LRZ which would maximize the fraction of water being obtained directly from the LRZ and restrict water derived from above to whatever amount was induced to leak vertically to wells screened in the LRZ.

Simulations also showed that locating wells closer to extraction trenches would optimize the extraction of higher concentrations of brine. However, the distance between wells must be maintained at some minimum value to counter well interference and resulting production rates.

As expected, brine concentrations over time are significantly sensitive to the value of the mass transfer coefficient. The values selected for the modeling described in this report represent mass transfer rates estimated at optimum efficiency (all other things equal).

Increasing the value of this parameter had very little effect on the resulting relative concentrations. This does not mean the values used represent the maximum mass transfer rates expected at the Sevier Lake Playa. Rather the values estimated for the modeling represent the most efficient mass transfer rates based on the other properties which affect travel times, groundwater velocities, or are otherwise dependent on scale of the transport simulation.

6. CONCLUSIONS, LIMITATIONS AND SOURCES OF UNCERTAINTY

The modeling conducted for the Project was comprehensive yet challenging due to the non-linearity of the simulation problem. The results demonstrate that a trench-based system can be used for extracting brine from the shallow fissured clay aquifer at acceptable brine concentrations for two extraction phases with estimated durations of up to ten years each. The results also indicated that following or supplementing trench extraction with a third phase involving extraction wells completed in the lower resource zone is an effective strategy to maintain brine flow to the pre-concentration ponds. However, up to two thousand wells may be required to match the discharge that trenches can provide.

Limitations

Several key parameters affecting the quantity and grade of brine are currently unconstrained and warrant further characterization for the next phase of this project. These include:

1. Mass Transfer Coefficient
2. Distribution/retardation coefficients for species of interest
3. Longitudinal and transverse dispersivities at multiple scales
4. Effective porosity/mobile fraction at field scale

Areal recharge is not completely understood, nor exactly has its role in impacting brine grade over long periods been characterized. The data available thus far indicate that recharge from meteoric sources is small, and the results from the modeling effort should be viewed in this light. It is also probable that recharge may vary spatially due to the degree of efflorescent salt crust present on the playa surface or the amount of playa that is covered by standing water.

Watershed run-off was not investigated to any large degree by the modeling presented here. Run-off terms were used in parameterizing the LAK package, and were briefly investigated using general head boundaries at the playa margins, but there are little to no direct data available to support any numbers at this time. There is visual and anecdotal evidence that watershed run-off does occur and such run-off does cross the playa boundary, but what occurs after such water enters the playa boundary is unknown.

Other Sources of Uncertainty

There is uncertainty resulting from the relatively small spatial distribution of measured hydraulic properties. While it is not expected that hydraulic properties vary markedly across the playa, this is a data gap that will need to be closed for the next phase of the project.

Water level measurements contained survey error that was impossible to correct. The field data already obtained would benefit from a more accurate survey and could be back-corrected. Also, the available data were too often not obtained at the same locations at regular (seasonal or quarterly intervals). Greater emphasis should be placed on obtaining spatially distributed water level measurements using a systematic procedure that focuses on obtaining water levels that are comparable temporally and spatially.

While the hydrophysical data obtained from the 2013 field efforts provided needed data to conceptualize the lower resource zone hydrologic characteristics, there is much more work to be done to arrive at a more reliable understanding of the nature and extent of the lower resource. Additional drilling and testing should focus on the transition between the upper resource zone and the lower resource zone. Short-screened well pairs may be an effective method to determine hydrologic communication across this zone.

There are undoubtedly sources of uncertainty resulting from errors incurred while building, parameterizing and parameterizing models for the multitude of different scenarios simulated for this effort. Great care was taken to minimize and disclose any errors discovered during the modeling process.

Recommendations

A pilot-scale test involving multiple recharge and extraction trenches is highly recommended as a next step. A pilot-scale test would provide critical evidence that the extraction and recharge scenarios are viable at or beyond the scales investigated here. At some point, the resources expended on additional characterization spent on attempting to characterize the spatial distribution of hydrologic properties would be better spent on a pilot study.

A large-scale tracer test would provide opportunities to constrain several transport parameters. Such a test could be accomplished within the realm of any pilot scale study. However, before any additional effort is expended on tracer testing, laboratory work must be conducted to identify the most appropriate solute for the Sevier Lake Playa subsurface environment. It is therefore recommended that geochemical laboratory work be pursued to estimate sorption coefficients in order to better understand the transport characteristics of individual solute species. It possible that certain species may advect at different rates, diffuse at different rates, or exhibit different behaviors under a range of geochemical conditions.

The question of a playa-wide hydrologic barrier to vertical flow between the so-called upper and lower resource zones could be further constrained by installing short-screen well pairs, spatially distributed across the playa. Such well pairs would also be useful in generating needed additional hydraulic properties data for the lower resource zone and could be used for well-to-well tracer testing to better constrain transport properties of the lower resource zone.

Estimated costs associated with recommendations of further work are compiled in Table 47.

Table 47. Estimated Costs of Recommended Future Work.

Task	Qty	Unit Cost	Total
Field			
Drill and construct shallow nest of 2 direct-push wells consisting of 2" dia PVC.	12	$6,000 ea.	$72,000
Drill and construct deep nest of 2 Sonic wells consisting of 4" dia PVC	12	$25,000 ea.	$300,000
Conduct well-to-well aquifer stress tests to determine hydraulic conductivity and communication between upper and lower zones using existing shallow sonic wells.	6	$7,375 ea.	$44,250
Data Interpretation and reporting for well aquifer properties testing	80	$100/hr.	$8,000
Trench-based test (assumed to be conducted during pilot-scale operational testing, or utilizing existing dual trench site with existing observation wells)	10	3,960/day	$39,600
Laboratory			
Geochemical testing to determine sorption coefficients/retardation	5	$1,200	$6,000
Geochemical testing to determine most appropriate solute for tracer studies	1	3,000	$3,000
Interpretation and reporting of Laboratory Testing	80	95	$7,600

Additional Ideas to Consider

To obtain additional data for the fat clay, simple tests such as measuring passive flow into a large cavity would provide some additional data to supplement any additional SDRI testing. Such testing could be inexpensively conducted with a pressure transducer and a backhoe. It is also possible that a tracer of some kind could be distributed to the playa surface in some manner. The fate of the tracer in the subsurface could be tracked over time and therefore offer some insight to how seasonal recharge occurs.

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Appendix B
Financial Model

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Table B.1: Initial Capital Cost Amortization ($ in millions, Uninflated)

Year	PP-3	PP-2	PP-1	1	TOTAL
Initial Capital Costs					
Utility/Common Infrastructure	$ -	$ 2.6	$ 32.8	$ 9.5	$ 44.9
Playa Infrastructure	6.7	32.5	9.6	0.0	$ 48.8
Stock Pile	0.0	0.1	0.4	5.9	$ 6.3
Process Building & Truck Loadout	0.0	23.3	123.0	9.5	$ 155.8
Truck Shop	0.0	1.5	0.9	0.1	$ 2.5
Administration Building	0.0	1.3	0.8	0.1	$ 2.2
Rail Loadout Site	0.0	0.3	2.4	28.5	$ 31.1
Total Direct Costs	**6.7**	**61.7**	**169.8**	**53.6**	**291.8**
GC Taxes, Bonds & Insurance	0.0	0.7	3.8	1.2	5.6
Contractor Overhead & Profit	0.0	1.3	7.0	2.2	10.5
Tax on Owner Purchased Equipment	0.0	0.0	2.8	0.0	2.8
Detailed Engineering & Commissioning	7.0	4.2	2.8	0.0	13.9
Owners' Costs	10.7	2.6	4.3	0.0	17.5
Total Indirect Costs	**17.7**	**8.7**	**20.6**	**3.3**	**50.3**
Contingency	0.8	7.7	21.1	6.7	36.3
Total Initial Capital Costs	**$ 25.2**	**$ 78.0**	**$ 211.6**	**$ 63.6**	**$ 378.4**

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Table B.2: Cash Flow Model Inflation Assumptions

Year	%/Yr	PP-3	PP-2	PP-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Revenue Inflation																																					
Sulfate of Potash	2.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	102.00%	104.04%	106.12%	108.24%	110.41%	112.62%	114.87%	117.17%	119.51%	121.90%	124.34%	126.82%	129.36%	131.95%	134.59%	137.28%	140.02%	142.82%	145.68%	148.59%	151.57%	154.60%	157.69%	160.84%	164.06%	167.34%	170.69%	174.10%	177.58%	181.14%
Expense Inflation																																					
Operating Expenses	2.00%	102.00%	104.04%	106.12%	108.24%	110.41%	112.62%	114.87%	117.17%	119.51%	121.90%	124.34%	126.82%	129.36%	131.95%	134.59%	137.28%	140.02%	142.82%	145.68%	148.59%	151.57%	154.60%	157.69%	160.84%	164.06%	167.34%	170.69%	174.10%	177.58%	181.14%	184.76%	188.45%	192.22%	196.07%	199.99%	203.99%
Capital Expenses	2.00%	102.00%	104.04%	106.12%	108.24%	110.41%	112.62%	114.87%	117.17%	119.51%	121.90%	124.34%	126.82%	129.36%	131.95%	134.59%	137.28%	140.02%	142.82%	145.68%	148.59%	151.57%	154.60%	157.69%	160.84%	164.06%	167.34%	170.69%	174.10%	177.58%	181.14%	184.76%	188.45%	192.22%	196.07%	199.99%	203.99%

Note: Revenues are not inflated between PP-3 and Year 3 since they are based on a third party forecast. Revenues are inflated at 2% per year beginning in Year 4.

Table B.3: Undiscounted Cash Flow Model (Inflated, $ in millions unless otherwise noted)

Year	PP-3	PP-2	PP-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	TOTAL
Product Pricing ($/t, Ex-works)																																					
Sulphate of Potash	$566	$566	$578	$597	$663	$721	$735	$750	$765	$780	$796	$812	$828	$845	$862	$879	$896	$914	$933	$951	$970	$990	$1,010	$1,030	$1,050	$1,071	$1,093	$1,115	$1,137	$1,160	$1,183	$1,207	$1,231	$1,255	$1,280	$1,306	
Production Schedule (Mtpy)																																					
Sulphate of Potash	-	-	-	0.05	0.10	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.15	-	9.0
Total Revenue	$ -	$ -	$ -	$ 29.9	$ 66.3	$ 216.3	$ 220.6	$ 225.0	$ 229.5	$ 234.1	$ 238.8	$ 243.6	$ 248.5	$ 253.4	$ 258.5	$ 263.7	$ 268.9	$ 274.3	$ 279.8	$ 285.4	$ 291.1	$ 296.9	$ 302.9	$ 308.9	$ 315.1	$ 321.4	$ 327.8	$ 334.4	$ 341.1	$ 347.9	$ 354.9	$ 362.0	$ 369.2	$ 376.6	$ 192.1	$ -	$8,679.0
Operating Costs																																					
Labor	-	-	-	8.8	11.5	11.7	12.0	12.2	12.5	12.7	13.0	13.2	13.5	13.8	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	16.8	17.1	17.5	17.8	18.2	18.5	18.9	19.3	19.7	20.0	20.4	10.4	-	486.3
Power	-	-	-	1.4	2.1	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.8	5.9	6.0	6.1	6.2	6.4	6.5	6.6	6.7	6.9	7.0	7.2	7.3	7.4	7.6	7.7	7.9	8.1	8.2	4.2	-	190.7
Natural Gas	-	-	-	3.5	5.5	12.7	12.9	13.2	13.5	13.7	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	16.7	17.1	17.4	17.8	18.1	18.5	18.9	19.2	19.6	20.0	20.4	20.8	21.2	21.7	22.1	11.3	-	512.7
Reagents, Consumables & Maintenance	-	-	-	2.5	5.0	13.6	13.9	14.2	14.5	14.8	15.0	15.3	15.7	16.0	16.3	16.6	16.9	17.3	17.6	18.0	18.3	18.7	19.1	19.5	19.9	20.3	20.7	21.1	21.5	21.9	22.4	22.8	23.3	23.7	12.1	-	548.3
Salt Harvest & Haul to Rail	-	-	-	2.0	4.1	12.7	12.9	13.2	13.5	13.7	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	16.7	17.1	17.4	17.8	18.1	18.5	18.9	19.2	19.6	20.0	20.4	20.8	21.2	21.7	22.1	11.3	-	509.8
General & Administrative	-	-	-	3.9	4.2	5.6	5.8	5.9	6.0	6.1	6.2	6.4	6.5	6.6	6.7	6.9	7.0	7.2	7.3	7.4	7.6	7.7	7.9	8.1	8.2	8.4	8.6	8.7	8.9	9.1	9.3	9.4	9.6	9.8	5.0	-	232.0
Total Operating Expenses	-	-	-	22.1	32.4	61.1	62.3	63.6	64.9	66.2	67.5	68.8	70.2	71.6	73.0	74.5	76.0	77.5	79.1	80.6	82.3	83.9	85.6	87.3	89.0	90.8	92.6	94.5	96.4	98.3	100.3	102.3	104.3	106.4	54.3	-	2,479.8
Production Royalties	-	-	-	1.7	3.7	12.1	12.4	12.6	12.9	13.1	13.4	13.7	13.9	14.2	14.5	14.8	15.1	15.4	15.7	16.0	16.3	16.7	17.0	17.3	17.7	18.0	18.4	18.8	19.1	19.5	19.9	20.3	20.7	21.1	10.8	-	486.8
Operating Profit Before Tax, Depreciation & Amortization (EBITDA)	-	-	-	6.0	30.2	143.0	145.9	148.8	151.8	154.8	157.9	161.1	164.3	167.6	171.0	174.4	177.9	181.4	185.0	188.7	192.5	196.4	200.3	204.3	208.4	212.6	216.8	221.2	225.6	230.1	234.7	239.4	244.2	249.1	127.0	-	5,712.4
Depreciation & Amortization	-	-	-	(15.2)	(15.5)	(16.3)	(16.6)	(17.3)	(17.6)	(19.2)	(21.6)	(22.0)	(21.4)	(21.4)	(21.1)	(21.8)	(21.1)	(26.7)	(33.1)	(33.2)	(33.5)	(33.4)	(32.7)	(32.6)	(25.6)	(18.9)	(19.4)	(19.1)	(19.2)	(19.9)	(18.7)	(15.5)	(8.4)	(4.3)	(23.0)	(61.6)	(747.0)
Operating Profit Before Tax (EBT)	-	-	-	(9.2)	14.7	126.7	129.3	131.5	134.2	135.6	136.3	139.1	142.9	146.2	149.9	152.6	156.8	154.7	151.9	155.6	159.0	163.0	167.6	171.7	182.8	193.7	197.4	202.0	206.4	210.2	216.0	223.9	235.8	244.7	104.0	(61.6)	4,965.5
Income Tax (Expense) Refund	-	0.0	0.1	0.2	0.3	(33.7)	(36.4)	(37.0)	(37.7)	(38.0)	(38.1)	(38.9)	(40.1)	(41.1)	(43.5)	(44.3)	(45.6)	(44.5)	(43.2)	(44.3)	(45.3)	(46.6)	(48.0)	(49.3)	(53.2)	(57.1)	(58.2)	(59.6)	(60.9)	(62.1)	(63.9)	(66.6)	(70.8)	(73.1)	(30.1)	23.6	(1,427.0)
Net Income	$ -	$ 0.0	$ 0.1	$ (8.9)	$ 15.0	$ 93.0	$ 92.9	$ 94.5	$ 96.4	$ 97.6	$ 98.2	$ 100.2	$ 102.8	$ 105.1	$ 106.4	$ 108.3	$ 111.2	$ 110.2	$ 108.7	$ 111.3	$ 113.7	$ 116.4	$ 119.6	$ 122.4	$ 129.6	$ 136.6	$ 139.2	$ 142.4	$ 145.4	$ 148.2	$ 152.1	$ 157.3	$ 165.0	$ 171.6	$ 73.9	$ (38.0)	$3,538.5
CASH FLOW (UNDISCOUNTED)																																					
Capital Expenditures																																					
Initial Capital Expenditures	$ (25.7)	$ (81.2)	$(224.6)	$ (68.8)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ (400.2)
Sustaining Capital Expenditures	-	-	-	-	(2.0)	(5.9)	(2.1)	(5.1)	(2.2)	(11.0)	(16.7)	(4.6)	(1.9)	(1.9)	(3.1)	(7.1)	(6.1)	(55.8)	(49.7)	(2.1)	(4.4)	(2.2)	(2.3)	(5.2)	(7.1)	(2.4)	(6.0)	(2.5)	(2.5)	(6.9)	(2.6)	(2.7)	(2.8)	(2.8)	(38.1)	(38.9)	(306.7)
Total Capital Expenditures	(25.7)	(81.2)	(224.6)	(68.8)	(2.0)	(5.9)	(2.1)	(5.1)	(2.2)	(11.0)	(16.7)	(4.6)	(1.9)	(1.9)	(3.1)	(7.1)	(6.1)	(55.8)	(49.7)	(2.1)	(4.4)	(2.2)	(2.3)	(5.2)	(7.1)	(2.4)	(6.0)	(2.5)	(2.5)	(6.9)	(2.6)	(2.7)	(2.8)	(2.8)	(38.1)	(38.9)	(707.0)
Operating Profit Before Tax (EBT)	-	-	-	(9.2)	14.7	126.7	129.3	131.5	134.2	135.6	136.3	139.1	142.9	146.2	149.9	152.6	156.8	154.7	151.9	155.6	159.0	163.0	167.6	171.7	182.8	193.7	197.4	202.0	206.4	210.2	216.0	223.9	235.8	244.7	104.0	(61.6)	4,965.5
Non-cash Adjustments: Depreciation & Amortization	-	-	-	15.2	15.5	16.3	16.6	17.3	17.6	19.2	21.6	22.0	21.4	21.4	21.1	21.8	21.1	26.7	33.1	33.2	33.5	33.4	32.7	32.6	25.6	18.9	19.4	19.1	19.2	19.9	18.7	15.5	8.4	4.3	23.0	61.6	747.0
Free Cash Flow (pretax)	(25.7)	(81.2)	(224.6)	(62.8)	28.2	137.2	143.8	143.8	149.6	143.8	141.3	156.5	162.5	165.7	167.8	167.2	171.8	125.6	135.3	186.6	188.1	194.2	198.0	199.1	201.3	210.2	210.8	218.7	223.0	223.1	232.0	236.7	241.4	246.2	88.9	(38.9)	5,005.5
Income Tax (Expense) Refund	-	0.0	0.1	0.2	0.3	(33.7)	(36.4)	(37.0)	(37.7)	(38.0)	(38.1)	(38.9)	(40.1)	(41.1)	(43.5)	(44.3)	(45.6)	(44.5)	(43.2)	(44.3)	(45.3)	(46.6)	(48.0)	(49.3)	(53.2)	(57.1)	(58.2)	(59.6)	(60.9)	(62.1)	(63.9)	(66.6)	(70.8)	(73.1)	(30.1)	23.6	(1,427.0)
Free Cash Flow (after tax)	$ (25.7)	$ (81.2)	$(224.5)	$ (62.6)	$ 28.5	$ 103.5	$ 107.5	$ 106.8	$ 111.9	$ 105.8	$ 103.2	$ 117.6	$ 122.3	$ 124.6	$ 124.3	$ 123.0	$ 126.2	$ 81.1	$ 92.1	$ 142.3	$ 142.8	$ 147.6	$ 150.0	$ 149.8	$ 148.1	$ 153.1	$ 152.6	$ 159.1	$ 162.1	$ 161.1	$ 168.1	$ 170.1	$ 170.7	$ 173.1	$ 58.8	$ (15.4)	$3,578.5