Final Great Salt Lake Comprehensive Management Plan and Record of Decision

UTAH DNR FORESTRY

Utah Department of Natural Resources Division of Forestry, Fire & State Lands

SWCA ENVIRONMENTAL CONSULTANTS

March 2013

RECORD OF DECISION

STATE OF UTAH DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY, FIRE AND STATE LANDS

RECORD OF DECISION
GREAT SALT LAKE COMPREHENSIVE MANAGEMENT PLAN
RECORD NUMBER: 13-0315-1

Date of Execution: MARCH 27, 2013

INTRODUCTION

Pursuant to UTAH CODE §§ 65A-2-2 and 65A-2-4 and the implementing regulations of Utah Administrative Code (UTAH ADMIN. CODE) R652-90, the Division of Forestry, Fire and State Lands (FFSL or the division) is empowered to prepare and adopt comprehensive management plans for sovereign lands and resources. Given this direction, FFSL initiated the Great Salt Lake (GSL) Comprehensive Management Plan (CMP) revision process with interagency cooperation and collaboration, and open public participation. For the duration of the planning process, a withdrawal was ordered on the lakebed from new leasing and permitting until the completion of the CMP. The withdrawal did not apply to uses associated with boundary settlements, trails or lake access improvement, or activities associated with the protection and enhancement of endangered species. Existing leases and permits were allowed to be renewed or extended in accordance with UTAH ADMIN. CODE R652-90-700.

The primary purpose of the GSL CMP is to guide FFSL, along with other local, state, and federal partners, in managing, allocating, and appropriately using GSL's sovereign land resources. The GSL CMP clearly sets forth defined management goals, objectives, and implementation strategies for guiding and directing future resource management actions, activities, and recreation uses on GSL.

In compliance with policy, procedures, rules, and statutes for comprehensive management planning, FFSL has completed the comprehensive management plan for the subject site. Therefore, FFSL issues this Record of Decision for the GSL CMP.

DESCRIPTION OF LANDS DIRECTLY AFFECTED

The planning unit area encompasses those sovereign lands below the surveyed meander line of GSL (an elevation range of 4,202–4,212 feet above sea level), located in Box Elder, Weber County, Davis, Salt Lake, and Tooele counties. The lands below the meander line are represented as owned by the State of Utah. Some of the sovereign land boundaries have not been settled, but the visions, goals, policies, and objectives in the GSL CMP will apply to those lands that are judged to be sovereign lands.

PROPOSED ACTION

The Proposed Action associated with this Record of Decision is the adoption and implementation of the 2013 GSL CMP.

RELEVANT FACTUAL BACKGROUND

The GSL CMP revision process began in March 2010. FFSL initiated the revision to update the decade-old management plan, to assess the current conditions of GSL at low levels (4,193.6 feet in the fall of 2010), and to incorporate research on the lake that had been completed in the last 10 years. FFSL was also interested in improving management, planning, and research activities of the Utah Department of Natural Resources (UDNR) and Utah Department of Environmental Quality (UDEQ) divisions on GSL. In addition to the GSL CMP revision, FFSL concurrently updated the GSL Mineral Leasing Plan (MLP). Through a rigorous competitive process, SWCA Environmental Consultants (SWCA) was hired to facilitate the development of the 2013 GSL CMP and MLP.

As part of the GSL CMP revision, FFSL convened the GSL Planning Team comprising UDNR and UDEQ representatives to provide input and support throughout the revision process. Throughout the process, the GSL Planning Team represented the long-term collaborative approach necessary to holistically manage the complex GSL ecosystem. The purposes of the GSL Planning Team were to

- provide resource-specific guidance throughout the planning process;
- provide the most recent, relevant research and data pertaining to GSL;
- provide timely review and comment on the document throughout the revision process; and
- offer project updates, milestones, and opportunities for comment to State of Utah agencies and the general public.

The GSL CMP planning process was designed to achieve a cumulative and linear development of visions, goals, and management objectives and to encourage public participation throughout the process. The planning process is illustrated in Figure 1.

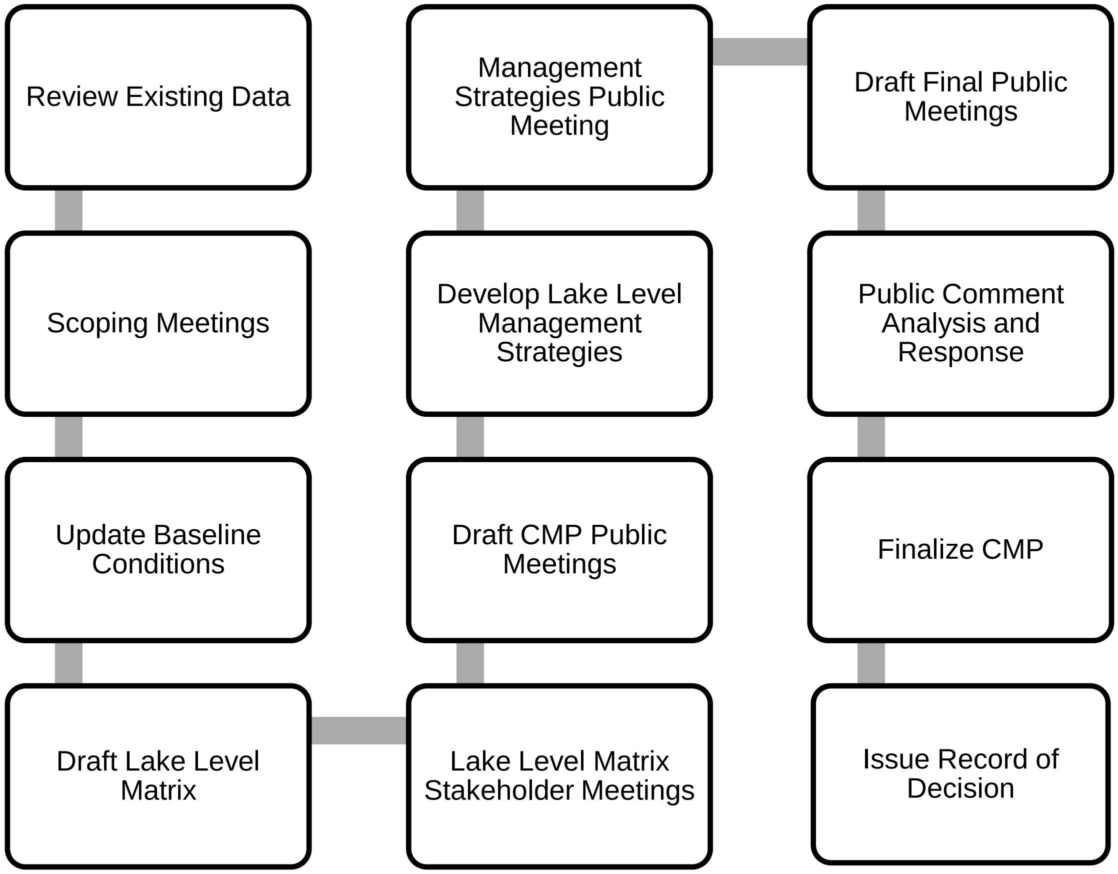

Figure 1. Great Salt Lake Comprehensive Management Plan planning process.

Public Involvement

The GSL CMP revision comprised a two-year public involvement process. FFSL submitted a notice of intent to initiate the GSL CMP revision process to the Resource Development Coordinating Committee (RDCC) in March 2010. Following that submittal, FFSL and SWCA conducted three rounds of public involvement meetings: 1) at scoping, 2) at the release of the draft GSL CMP, and 3) at the release of the final GSL CMP. During the development of the GSL Lake Level Matrix and Lake Level–Specific Management Strategies, FFSL held two rounds of stakeholder meetings to get feedback on a range of resource-specific lake level impacts. A summary of the GSL CMP public involvement opportunities is provided below.

1. In August 2010, FFSL and SWCA conducted one scoping meeting in each of the five affected counties to solicit public and agency concerns and comments (Table 1).

Table 1. *Scoping Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
August 10, 2010	10:00 a.m.–1:00 p.m.	Ogden, Utah	2380 Washington Blvd
August 17, 2010	10:00 a.m.–1:00 p.m.	Farmington, Utah	28 East State Street
August 17, 2010	4:00–7:00 p.m.	Salt Lake City, Utah	2001 South State Street
August 24, 2010	3:00–6:00 p.m.	Tooele, Utah	47 South Main Street
August 31, 2010	9:00 a.m.–Noon	Brigham City, Utah	01 South Main Street

2. In May 2011, FFSL and SWCA conducted one public meeting in each of the five counties that surround GSL to solicit public and agency feedback on the draft GSL CMP (Table 2).

Table 2. *Draft Great Salt Lake Comprehensive Management Plan Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
May 12, 2011	6:00–8:00 p.m.	Brigham City, Utah	01 South Main Street
May 17, 2011	6:00–8:00 p.m.	Ogden, Utah	2380 Washington Blvd.
May 18, 2011	6:00–8:00 p.m.	Farmington, Utah	28 East State Street
May 19, 2011	6:00–8:00 p.m.	Tooele, Utah	47 South Main Street
May 24, 2011	6:00–8:00 p.m.	Salt Lake City, Utah	1594 West North Temple

3. In March 2012, FFSL and SWCA conducted one public meeting in each of the five counties that surround the GSL to solicit public and agency feedback on the draft final GSL CMP (Table 3).

Table 3. *Draft Final Great Salt Lake Comprehensive Management Plan Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
March 20, 2012	6:00–8:00 p.m.	Clearfield, Utah	562 South 1000 East
March 21, 2012	6:00–8:00 p.m.	Tooele, Utah	47 South Main Street
March 22, 2012	6:00–8:00 p.m.	Salt Lake City, Utah	1575 West 1000 North
March 27, 2012	6:00–8:00 p.m.	Brigham City, Utah	26 East Forest Street
March 28, 2012	6:00–8:00 p.m.	Ogden, Utah	2464 Jefferson Avenue

Meeting Design

The public involvement meetings combined formal presentation and open house formats. At each meeting, SWCA's project manager provided a brief project overview or presentation. Following this informational session, an open house meeting was conducted in a meeting space within the same building. Attendees were greeted and asked to sign in, as well as informed about the meeting format and given the option of taking a business card with the project website and contact information and/or a scoping comment form. Attendees were informed about ways to submit comments and encouraged to ask questions of SWCA's public involvement staff and resource specialists from the GSL Planning Team.

Informational display boards were also arranged around the meeting room to provide the following background information:

- Explanation of the plan revision process and the general timeline and sequence of events
- Description of the general need for a plan revision and responsible entities
- Definition of sovereign lands, public trust, and multiple-use/sustainable yield
- Map and list of potential resource issues
- Opportunities for public comment and a description of available comment methods
- Description of the mineral leasing process
- Lake Level Matrix

Meeting Advertising

Pursuant to FFSL requirements, public involvement meetings were advertised in a variety of formats (Table 4) prior to their scheduled dates. In each format, the advertisements provided logistics, explained the purpose of the scoping meetings, gave the schedule for the public and agency comment period, outlined additional ways to comment, and provided methods of obtaining additional information.

Table 4. *Advertising of Public Meetings*

Media Notices and Other Forms of Advertising
Media notice releases for the scoping period were emailed on July 30, 2010, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader* Media notice releases for the draft GSL CMP were emailed on April 19, 2011, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader* Media notice releases for the draft final GSL CMP were emailed on March 7, 2012, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader*
Meeting information was posted on the project website, www.gslplanning.utah.gov on July 30, 2010.
The draft GSL CMP was posted on the project website, www.gslplanning.utah.gov on May 2, 2011.
The final GSL CMP was posted on the project website, www.gslplanning.utah.gov on March 7, 2012.

Table 4. *Advertising of Public Meetings*

Postcards and Other Invitations
Postcards announcing the scoping meetings were sent to those on the mailing list on August 2, 2010. These comprised the following: • UDNR staff identified as having an interest in the project • Prior and current GSL Planning Team members • Nongovernmental organizations identified as having a possible interest in the project • Local and state agencies identified as having jurisdictional authority in the project • Residents who had attended prior plan meetings • Members of the general public who signed up for updates via the project website • Members of the press • All landowners adjacent to the meander line within the affected counties
A meeting invitation for the scoping meetings was emailed to those on the project mailing list for whom email addresses were provided or were obtainable on August 2, 2010.
A scoping meeting announcement was posted on the following listserves: • GSL Technical Team • Jordan River Watershed Council • South Shore Cooperative Weed Management Area
A project poster was displayed at the FRIENDS of GSL Issues Forum April 28–30, 2010.
A meeting invitation for the draft GSL CMP was emailed to the 416 individuals on the project mailing list for whom email addresses were provided or were obtainable as of April 19, 2011. Postcards announcing the draft GSL CMP meetings were sent to the 567 individuals on the project mailing list for whom mailing addresses were provided or were obtainable as of April 19, 2011. These comprised the following: • UDNR staff identified as having an interest in the project • Prior and current GSL Planning Team members • Nongovernmental organizations identified as having a possible interest in the project • Local and state agencies identified as having jurisdictional authority in the project • Residents who had attended prior plan meetings • Members of the general public who signed up for updates via the project website • Members of the press • All landowners adjacent to the meander line within the affected counties
A meeting invitation for the draft final GSL CMP was emailed to the 416 individuals on the project mailing list for whom email addresses were provided or were obtainable as of March 7, 2012. Postcards announcing the draft final GSL CMP meetings were sent to the 638 individuals on the project mailing list for whom mailing addresses were provided or were obtainable as of March 7, 2012. These comprised the following: • UDNR staff identified as having an interest in the project • Prior and current GSL Planning Team members • Nongovernmental organizations identified as having a possible interest in the project • Local and state agencies identified as having jurisdictional authority in the project • Residents who had attended prior plan meetings • Members of the general public who signed up for updates via the project website • Members of the press • All landowners adjacent to the meander line within the affected counties

Stakeholder Meetings

During the revision process, two rounds of stakeholder meetings also took place (one in January 2011 and one in November 2011). The stakeholders invited to the meeting consisted of industry, recreation, and environmental advocacy groups. The GSL Planning Team members were also invited to the stakeholder meetings. The objective of the first stakeholder meeting was to preview and gather comment on the GSL Lake Level Matrix. The objective of the second meeting was to preview and comment on the draft management strategies. The comments gathered at the stakeholder meetings were incorporated into the document, as appropriate. A summary of the public meetings held to date is provided in Table 5.

Table 5. *Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
January 4, 2011	2:00–4:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South
January 6, 2011	2:00–4:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South
November 1, 2011	10:00 a.m.–Noon	Salt Lake City, Utah	SWCA, 257 East 200 South
November 3, 2011	1:00–3:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South

PUBLIC TRUST

FFSL acknowledges its responsibility to the Public Trust and obligation to multiple-use, sustained yield management. As stated in the GSL CMP, "the overarching management objectives of FFSL are to protect and sustain the trust resources and to provide for reasonable beneficial uses of those resources, consistent with their long-term protection and conservation. This means that FFSL will manage GSL and its resources under multiple-use, sustained yield principles (UTAH CODE § 65A-2-1) by implementing legislative policies (UTAH CODE § 65A-10-8) and accommodating public and private uses to the extent that those policies and uses do not substantially impair Public Trust resources and or the lake's sustainability. Any beneficial use of Public Trust resources is subsidiary to long-term conservation of resources."

The 2013 GSL CMP was designed to facilitate FFSL's management of GSL and its resources under multiple-use, sustained-yield principles, as stated in UTAH CODE § 65A-2-1. In particular, the management strategies highlight the range of multiple uses under FFSL's jurisdiction. Together with the Lake Level Matrix, the management strategies outline how FFSL will ensure the sustained yield of GSL resources.

Further, according to UTAH CODE § 65A-10-8, FFSL is required to "prepare and maintain a comprehensive plan for the lake that … develop[s] strategies to deal with a fluctuating lake level." Lake level planning that occurred as part of this 2013 GSL CMP is a fundamental statutory responsibility of FFSL. As part of the revision process, FFSL and the GSL Planning Team developed a management approach that more fully adheres to the management responsibilities outlined in UTAH CODE § 65A-10-8. Because the Public Trust resources of GSL are differently impacted at different lake levels, FFSL must have the ability to modify their management strategies to avoid substantial impairment of GSL resources as lake levels rise and fall.

INTERAGENCY COORDINATION

During the GSL CMP planning process, FFSL recognized the importance of maintaining the communication that was occurring between the GSL Planning Team over the course of the revision.. Cross-agency coordination and communication are required because GSL resources are complex and because multiple government agencies are involved with various aspects of GSL. As required in UTAH CODE § 65A-2-2, FFSL is interested in maintaining support across state agencies as it implements the 2013 GSL CMP. Chapter 4 of the GSL CMP outlines the proposed Coordinating Framework intended to be carried out by FFSL and other state agencies tasked with research, management, and permitting on GSL. The GSL CMP management strategies allow numerous opportunities for coordination with respect to GSL resources, a fundamental responsibility of FFSL according to UTAH CODE § 65A-10-8.

PUBLIC INVOLVEMENT: NOTIFICATION, COMMENT, AND REVIEW

Public involvement was essential to the GSL CMP planning process. As illustrated in the Public Involvement section above, there were numerous opportunities for the public to play a role in the revision of the GSL CMP. As required by UTAH ADMIN. CODE R652-90-500, FFSL began the planning process with a notification to RDCC in March 2010 on the Project Management System website for 30 days (Exhibit A). Notifications of each GSL CMP draft were also noticed to RDCC. State, federal, local governments, and stakeholders were notified numerous times throughout the planning process, requesting attendance at public meetings and comment response. Notification for each round of public meetings and the announcement of this ROD were sent by postcard to 567 addresses and 416 email addresses (Exhibit B: Notice to Interested Parties). Fifteen public meetings and four stakeholder meetings were held throughout the planning process. A public comment period followed each public and stakeholder meeting; each comment period was 30 days, except the final comment period, which was 75 days. Comments were accepted by comment response forms at public meetings, project website, email, and postal mail. Comments received throughout the planning process were numerous. FFSL received 225 public comment submissions on the draft final GSL CMP and MLP. From the 225 comment letters, 1,211 individual comments were extracted for review of acceptance or non-acceptance. Comments for each phase of the planning process were acknowledged and addressed, as appropriate, by FFSL. As required by rule and statute UTAH ADMIN. CODE R652-90-600 (1)(b-d) and UTAH CODE § 65-A-2-4, comment responses were provided in the final GSL CMP (CMP Appendix B).

CONSTITUTIONAL PROVISIONS, STATUTES, AND ADMINISTRATIVE RULES

Utah Constitution Article XX, Section 1

> All lands of the state that have been, or may hereafter be granted to the State by Congress, and all lands acquired by gift, grant or devise, from any person or corporation, or that may otherwise be acquired, are hereby accepted, and … are declared to be the public land of the State; and shall be held in trust for the people, to be disposed of as may be provided by law, for the respective purposes for which they have been of may be granted, devised or otherwise acquired.

UTAH CODE § 65A-2-1. Administration of state lands - Multiple-use sustained yield management.

> The division shall administer state lands under comprehensive land management programs using multiple-use sustained yield principles.

UTAH CODE § 65A-2-2. State land management planning procedures for natural and cultural resources - Assistance from other state agencies- Division action.

The division:

(1) shall develop planning procedures for natural and cultural resources on state lands; and

(2) may request other state agencies to generate technical data or other management support services for the development and implementation of state land management plans.

UTAH CODE § 65A-2-4. State land management plans -- Division to adopt rules for notifying and consulting with interested parties.

(1) The division shall adopt rules for notifying and consulting with interested parties including the general public, resources users, and federal, state, and local agencies on state land management plans.

(2) Division rules shall provide:

(a) for reasonable notice and comment periods; and

(b) that the division respond to all commenting parties and give the rationale for the acceptance or nonacceptance of the comments.

UTAH CODE § 65A-10-1. Authority of division to manage sovereign lands.

(1) The division is the management authority for sovereign lands, and may exchange, sell, or lease sovereign lands but only in the quantities and for the purposes as serve the public interest and do not interfere with the public trust.

UTAH CODE § 65A-10-8. Great Salt Lake -- Management responsibilities of the division.

The division has the following powers and duties:

(1) Prepare and maintain a comprehensive plan for the lake which recognizes the following policies:

(a) develop strategies to deal with a fluctuating lake level;

(b) encourage development of the lake in a manner which will preserve the lake, encourage availability of brines to lake extraction industries, protect wildlife, and protect recreational facilities;

(c) maintain the lake's flood plain as a hazard zone;

(d) promote water quality management for the lake and its tributary streams;

(e) promote the development of lake brines, minerals, chemicals, and petro-chemicals to aid the state's economy;

(f) encourage the use of appropriate areas for extraction of brine, minerals, chemicals, and petro-chemicals;

(g) maintain the lake and the marshes as important to the waterfowl flyway system;

(h) encourage the development of an integrated industrial complex;

(i) promote and maintain recreation areas on and surrounding the lake;

(j) encourage safe boating use of the lake;

(k) maintain and protect state, federal, and private marshlands, rookeries, and wildlife refuges;

(l) provide public access to the lake for recreation, hunting, and fishing.

(2) Employ personnel and purchase equipment and supplies which the Legislature authorizes through appropriations for the purposes of this chapter.

(3) Initiate studies of the lake and its related resources.

(4) Publish scientific and technical information concerning the lake.

(5) Define the lake's flood plain.

(6) Qualify for, accept, and administer grants, gifts, or other funds from the federal government and other sources, for carrying out any functions under this chapter.

(7) Determine the need for public works and utilities for the lake area.

(8) Implement the comprehensive plan through state and local entities or agencies.

(9) Coordinate the activities of the various divisions within the Department of Natural Resources with respect to the lake.

(10) Perform all other acts reasonably necessary to carry out the purposes and provisions of this chapter.

(11) Retain and encourage the continued activity of the GSL technical team.

UTAH ADMIN. CODE R652-70-200. Classifications of Sovereign Lands.

Sovereign lands may be classified based upon their current and planned uses. A synopsis of some possible classes and an example of each class follows. For more detailed information, consult the management plan for the area in question.

1. Class 1: Manage to protect existing resource development uses. The Utah State Park Marinas on Bear Lake and on GSL are areas where the current use emphasizes development.

2. Class 2: Manage to protect potential resource development options. For example, areas adjacent to Class 1 areas which have the potential to be developed.

3. Class 3: Manage as open for consideration of any use. This might include areas which do not currently show development potential but which are not now, or in the foreseeable future, needed to protect or preserve the resources.

4. Class 4: Manage for resource inventory and analysis. This is a temporary classification which allows the division to gather the necessary resource information to make a responsible classification decision.

5. Class 5: Manage to protect potential resource preservation options. Sensitive areas of wildlife habitat may fall into this class.

6. Class 6: Manage to protect existing resource preservation uses. Cisco Beach on Bear Lake is an example of an area where the resource is currently being protected.

UTAH ADMIN. CODE R652-90-300. Initiation of Planning Process.

1. A comprehensive planning process is initiated by the designation of a planning unit as planning priorities are established by the division.

UTAH ADMIN. CODE R652-90-500. Notification and Public Comment.

1. Once a planning unit is designated for a comprehensive management plan, notice shall be sent to the Office of Planning and Budget for inclusion on the RDCC agenda and, if appropriate, the weekly status report.

2. The Division shall conduct at least one public meeting in the vicinity of a planning unit that has been designated for a comprehensive management plan.

(a) The meeting shall provide an opportunity for public comment regarding the issues to be addressed in the plan

(b) The public meeting(s) shall be held at least two weeks after notice in a local newspaper.

(c) Notice of public meeting(s) shall be sent directly to lessees of record, local government official and the Office of Planning and Budget for inclusion in the RDCC agenda packet and weekly status report. A mailing list shall be maintained by the division.

(d) Additional public meetings may be held.

UTAH ADMIN. CODE R652-90-600. Public Review.

1. Comprehensive management plans shall be published in draft form and sent to persons on the mailing list established under R652-90-400, the Office of a Planning and Budget, and other persons upon request.

(a) A public comment period of at least 45 days shall commence upon receipt of the draft in the Office of Planning and Budget.

(b) All public comment shall be acknowledged pursuant to 65A-2-4(2).

(c) The Division's response to the public comment shall be summarized in the final comprehensive management plan.

(d) Comments received after the public comment period shall be acknowledged but need not be summarized in the final plan.

UTAH ADMIN. CODE R652-90-800. Multiple-Use Framework.

Comprehensive management plans shall consider the following multiple-use factors to achieve sovereign land-management objectives:

1. The highest and best use(s) for the sovereign land resources in the planning unit.

2. Present and future use(s) for the sovereign land resources in the planning unit;

3. Suitability of the sovereign lands in the planning unit for the proposed uses;

4. The impact of proposed use(s) on other sovereign land resources in the planning unit;

5. The compatibility of possible use(s) as proposed by general public comments, application from prospective users or division analysis; and

6. The uniqueness, special attributes and availability of resources in the planning unit.

FINDINGS OF FACT

1. As described herein, FFSL notified the public and local, federal, and state agencies, including the RDCC, of the GSL CMP planning effort.
2. As described herein, FFSL conducted public meetings in conjunction with the GSL CMP planning effort.
3. As described herein, FFSL published a draft of the GSL CMP and accepted comments from the public and other government entities and responded to all comments properly submitted.
4. FFSL considered and implemented legislative directives concerning the content of the GSL CMP.

CONCLUSIONS OF LAW

1. FFSL properly initiated the planning process for a comprehensive plan by designating the planning unit and planning priorities established by FFSL.
2. FFSL fulfilled its notification requirements to the lessees, to local governments, and to the RDCC when the project was initiated. FFSL went beyond its required notification by also notifying upland landowners and stakeholders.
3. The notification requirements for the public meetings have been met or exceeded.
4. The public review requirements have been met or exceeded.
5. FFSL properly responded to comments received in compliance with the applicable law.
6. The GSL CMP fulfills the requirements of applicable statutes, rules, policies, and legal doctrines.
7. The planning process and subsequent GSL CMP complies with the legal requirements for a comprehensive management plan and specifically complies with the requirements for the GSL CMP.

DECISION AND ORDER

Based on the foregoing, FFSL hereby adopts the GSL CMP along with Appendix A through F, which satisfies the requirements of applicable statutes, rules, and policies. The GSL CMP (including Appendix A through F) becomes the comprehensive management plan that guides decision-making on the sovereign lands within the planning unit. The GSL CMP supersedes any and all previous management plans—adopted, draft, or otherwise—and represents the official position of FFSL.

DATED this _27_ day of March 2013.

ADMINISTRATIVE APPEALS

Parties having an interest in this action may file a petition for administrative review by the division pursuant to R652-9. Said petition must be in writing and shall contain

1. the statute, rule, or policy with which the division action is alleged to be inconsistent;
2. the nature of the inconsistency of the division action with the statute, rule, or policy;
3. the action the petitioner feels would be consistent under the circumstances with statute, rule, or policy; and
4. the injury realized by the party that is specific to the party arising from division action. If the injury identified by the petition is not peculiar to the petitioner as a result of the division action, the director will decline to undertake consistency review.

Said petition must be received by the division by 5:00 p.m. on April 22, 2013.

APPROVED BY:

RICHARD J. BUEHLER, DIRECTOR

DATE: 3/27/2013

PREPARED BY:

LAURA VERNON,
SOVEREIGN LANDS PLANNER

DATE: 3/25/2013

REVIEWED BY:

Laura Ault

LAURA AULT,
SOVEREIGN LANDS PROGRAM MANAGER

DATE: 3/27/2013

REVIEWED BY:

FREDRIC J. DONALDSON,
ASSISTANT ATTORNEY GENERAL

DATE: 3/25/2013

EXHIBITS

Exhibit A. Resource Development Coordinating Committee (RDCC) Documentation
Exhibit B. Notice to Interested Parties (GSL CMP Mailing List)

Exhibit A. Resource Development Coordinating Committee (RDCC) Documentation

View Project

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RDCC Project Management System

Public Lands Policy Coordination Office • Resource Development Coordinating Committee

Projects

Government Agency Login

Utah.gov

Main PLPCO Site

View Project

Project #23804

Key Info:

Sponsor: DNR/Division of Forestry, Fire & State Lands
Title of Action: Great Salt Lake Comprehensive Management Plan - Scoping Period
Project Start Date:
Location: 374646 mE, 4548852 mN, UTM Zone 12
Location/Supplemental Attachment:
RDCC_Scoping_GSLPlanning.pdf
Counties: Box Elder, Davis, Salt Lake, Tooele, Weber
Has local government been contacted? Yes
Date Local Government was Contacted: 03/03/2010
Acquisition: No
Date of Acquisition: N/A
Have the state representative and state senator been contacted? No

Project abstract:

The Division of Forestry, Fire and State Lands in conjunction with a number of other partners, stakeholders, lessees, agencies, and other interested parties will be beginning the planning process to review and revise if necessary the Great Salt Lake Comprehensive Management Plan. The Division is looking for issues and concerns that we should be reviewing within the context of the Great Salt Lake that would contribute to the planning process. The final plan will incorporate the Mineral Leasing Plan into the Comprehensive Plan so that the mineral resources are dealt with the other uses.

How is the local government(s) likely to be impacted?

Involved, but no impacts.

Possible significant impacts likely to occur:

None anticipated.

Consistency Review

No Consistency Review Document

Record of Decision

No Record of Decision Document

State Comments

No State Comments

For further information please contact project sponsor.

http://rdcc.utah.gov/plpco/public/viewProject.action?projectId=23804[3/15/2013 3:19:43 PM]

STATE ACTIONS
Resource Development Coordinating Committee
Public Lands Policy Coordination Office
5110 State Office Building
SLC, UT 84114
Phone No. 537-9230

1. State Agency Division of Forestry, Fire and State Lands 1594 West North Temple Box 145703 Salt Lake City, Utah 84114-5703	**2. Approximate date project will start:** Spring 2010

3. Title of proposed action:
Great Salt Lake Comprehensive Management Plan - Scoping

4. Description of Project:
The Division of Forestry, Fire and State Lands in conjunction with a number of other partners, stakeholders, lessees, agencies, and other interested parties will be beginning the planning process to review and revise if necessary the Great Salt Lake Comprehensive Management Plan. The Division is looking for issues and concerns that we should be reviewing within the context of the Great Salt Lake that would contribute to the planning process. The final plan will incorporate the Mineral Leasing Plan into the Comprehensive Plan so that the mineral resources are dealt with the other uses.

5. Location and detailed map of land affected (site location map required, electronic GIS map preferred) (include UTM coordinates where possible) **(indicate county)**
Counties involved: Box Elder, Weber, Davis, Salt Lake, and Tooele
UTM coordinates: Easting: 374646 meters; Northing 4548852 meters UTM

6. Possible significant impacts likely to occur:
None. This is a planning process – no specific projects will be approved.

7. Identify local government affected

a. **Has the government been contacted?** Yes.
b. **When?** With this notice.
c. **What was the response?** None yet.
d. **If no response, how is the local government(s) likely to be impacted?** Involved, but no impacts.

Page 1

8. For acquisitions of land or interests in land by DWR or State Parks please identify state representative and state senator for the project area. Name and phone number of state representative, state senator near project site, if applicable: a. **Has the representative and senator been contacted?** N/A	
9. Areawide clearinghouse(s) receiving state action: (to be sent out by agency in block 1) Bear River Association of Governments Wasatch Front Regional Council Box Elder County Commission Weber County Commission Tooele County Commission Salt Lake County Commission Davis County Commission	
10. For further information, contact: Dave Grierson Planner/Sovereign Lands Coordinator davegrierson@utah.gov **Phone:** 801 538 5504	**11. Signature and title of authorized officer** /s/ Dave Grierson Sovereign Lands Coordinator **Date:** 03 Mar 10

INSTRUCTIONS

Whenever a State agency proposes or is administratively responsible for an action not exempted, it shall complete a State Action form and forward one copy to the Public Lands Policy Coordination Office and the affected areawide clearinghouse(s).

Questions encountered with the areawide clearinghouse review should be directed to the areawide clearinghouse. The Public Lands Policy Coordination Office will wait for the affected areawide clearinghouse(s) to complete their review before issuing a final clearance to the originator on this STATE ACTION.

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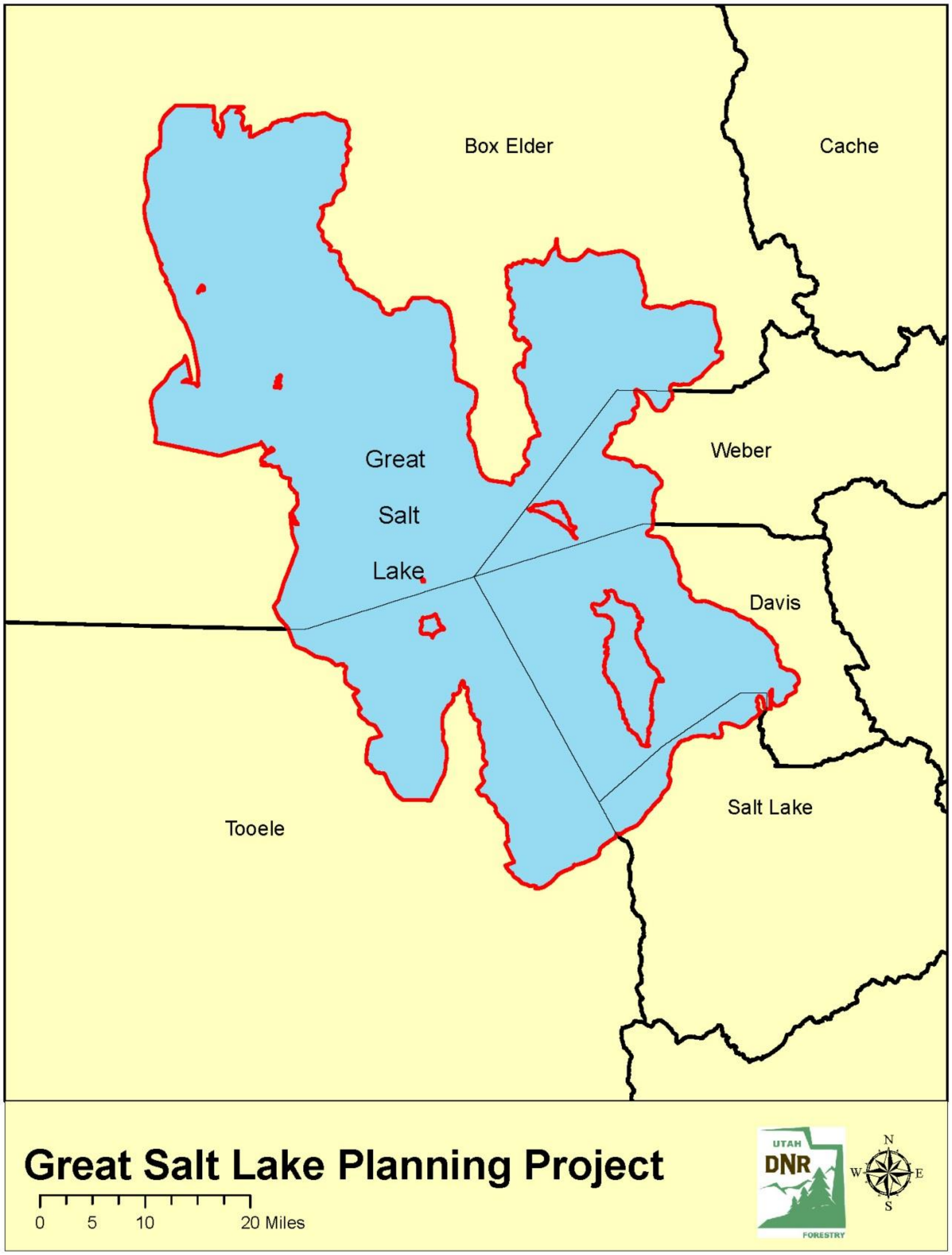
Box Elder
Cache
Great
Salt
Lake
Weber
Davis
Salt Lake
Tooele
Great Salt Lake Planning Project
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DNR
FORESTRY
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RDCC Project Management System

Public Lands Policy Coordination Office • Resource Development Coordinating Committee

Projects

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Main PLPCO Site

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Project #26580

Key Info:

Sponsor: DNR/Division of Forestry, Fire & State Lands
Title of Action: Great Salt Lake Comprehensive Management Plan Current Conditions Draft
Project URL Link: http://forestry.utah.gov/sovlands/greatsaltlake/2010Plan/publicinfo.php
Project Start Date:
Location: 41 10 N/112 35 W
Location/Supplemental Attachment:
Counties: Box Elder, Davis, Salt Lake, Tooele, Weber
Has local government been contacted? Yes
Date Local Government was Contacted: 05/11/2011
Acquisition: No
Date of Acquisition: N/A
Have the state representative and state senator been contacted? No

Project abstract:

The Utah Department of Natural Resources Division of Forestry, Fire and State Lands (FFSL) has recently completed its assessment of existing conditions as part of the Great Salt Lake Comprehensive Management Plan (CMP) and Mineral Leasing Plan (MLP) Revisions and is seeking comment on the draft. The draft can be found at the link below.

How is the local government(s) likely to be impacted?

No adverse impacts expected.

Possible significant impacts likely to occur:

None.

Consistency Review

No Consistency Review Document

Record of Decision

No Record of Decision Document

State Comments

No State Comments

For further information please contact project sponsor.

http://rdcc.utah.gov/plpco/public/viewProject.action?projectId=26580[3/15/2013 3:19:25 PM]

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Projects

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Main PLPCO Site

View Project

Project #31620

Key Info:

Sponsor: DNR/Division of Forestry, Fire & State Lands
Title of Action: Great Salt Lake Comprehensive Managment Plan and Mineral Leasing Plan Revision
Project URL Link:
http://www.ffsl.utah.gov/sovlands/greatsaltlake/2010Plan/publicinfo.php#GSLcmp
Project Start Date:
Location: Lat 41 15' 19" Long 112 29' 46"
Location/Supplemental Attachment:
Counties: Box Elder, Davis, Salt Lake, Tooele, Weber
Has local government been contacted? Yes
Date Local Government was Contacted: 05/17/2011
Acquisition: No
Date of Acquisition: N/A
Have the state representative and state senator been contacted? No

Project abstract:

The Utah Department of Natural Resources Division of Forestry, Fire and State Lands (FFSL) has recently completed the Final Draft of Great Salt Lake Comprehensive Management Plan (CMP) and Mineral Leasing Plan (MLP) and is seeking comment.

How is the local government(s) likely to be impacted?

n/a

Possible significant impacts likely to occur:

n/a

Consistency Review

No Consistency Review Document

Record of Decision

No Record of Decision Document

State Comments

No State Comments

For further information please contact project sponsor.

http://rdcc.utah.gov/plpco/public/viewProject.action?projectId=31620[3/15/2013 3:19:02 PM]

Exhibit B. Notice to Interested Parties (GSL CMP mailing list)

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ABBREVIATIONS

AG	agricultural district
BLM	Bureau of Land Management
CMP	Comprehensive Management Plan
CO	carbon monoxide
CO_2	carbon dioxide
CV	commercial visitor zone
CWA	Clean Water Act
DAQ	Division of Air Quality
DBL	deep brine layer
DGSL	Division of Great Salt Lake
DOGM	Division of Oil, Gas and Mining
DSLF	Division of State Lands and Forestry
DSPR	Division of State Parks and Recreation
DSR	daily survival rate
DWQ	Division of Water Quality
DWR	Division of Wildlife Resources
DWRe	Division of Water Resources
DWRi	Division of Water Rights
EA	environmental assessment
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
F	Fahrenheit
FFSL	Division of Forestry, Fire & State Lands
GEM	gaseous elemental mercury
GOM	gaseous oxidized mercury
GSL	Great Salt Lake
GSL CMP	Great Salt Lake Comprehensive Management Plan
GSLAC	Great Salt Lake Advisory Council
GSLEP	Great Salt Lake Ecosystem Program
HAFB	Hill Air Force Base
HAP	hazardous air pollutants
HB	House Bill
I-80	Interstate 80
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
KUCC	Kennecott Utah Copper Corporation
l	liter
mg	milligrams
mL	milliliters
Ln	natural logarithm
MLP	Mineral Leasing Plan
n/a	not available/applicable
NAAQS	National Ambient Air Quality Standards
ng	nanograms
NOx	nitrogen oxides
O_3	ozone
OHV	off-highway vehicle
OS	open space district
PBN	particulate mercury
PCB	polychlorinated biphenyls
PM	particulate matter
PM_{10}	PM that is 10 micrometers and smaller
$PM_{2.5}$	fine PM that is 2.5 micrometers in diameter and smaller
ppm	parts per million
SAMP	special area management plan
SD	Secchi depth
SHPO	State Historic Preservation Office
SIP	state implementation plans
SLAC	Sovereign Lands Advisory Council
SLCIA	Salt Lake City International Airport
SO_2	sulfur dioxide
SPRR	Southern Pacific Railroad

SRC	Science Review Committee
TMDL	total maximum daily load
TP	Total phosphorus
TSI	trophic state index
U.S.C.	United States Code
UDEQ	Utah Department of Environmental Quality
UDNR	Utah Department of Natural Resources
UDOT	Utah Department of Transportation
UGS	Utah Geological Survey
UPDES	Utah Pollution Discharge Elimination System
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service
USGRP	U.S. Global Research Program
USGS	U.S. Geological Survey
USU	Utah State University
UTAH ADMIN. CODE	Utah Administrative Code
UTAH CODE	Utah Code
VOC	volatile organic compounds
WDPP	West Desert Pumping Project
WMA	waterfowl management area

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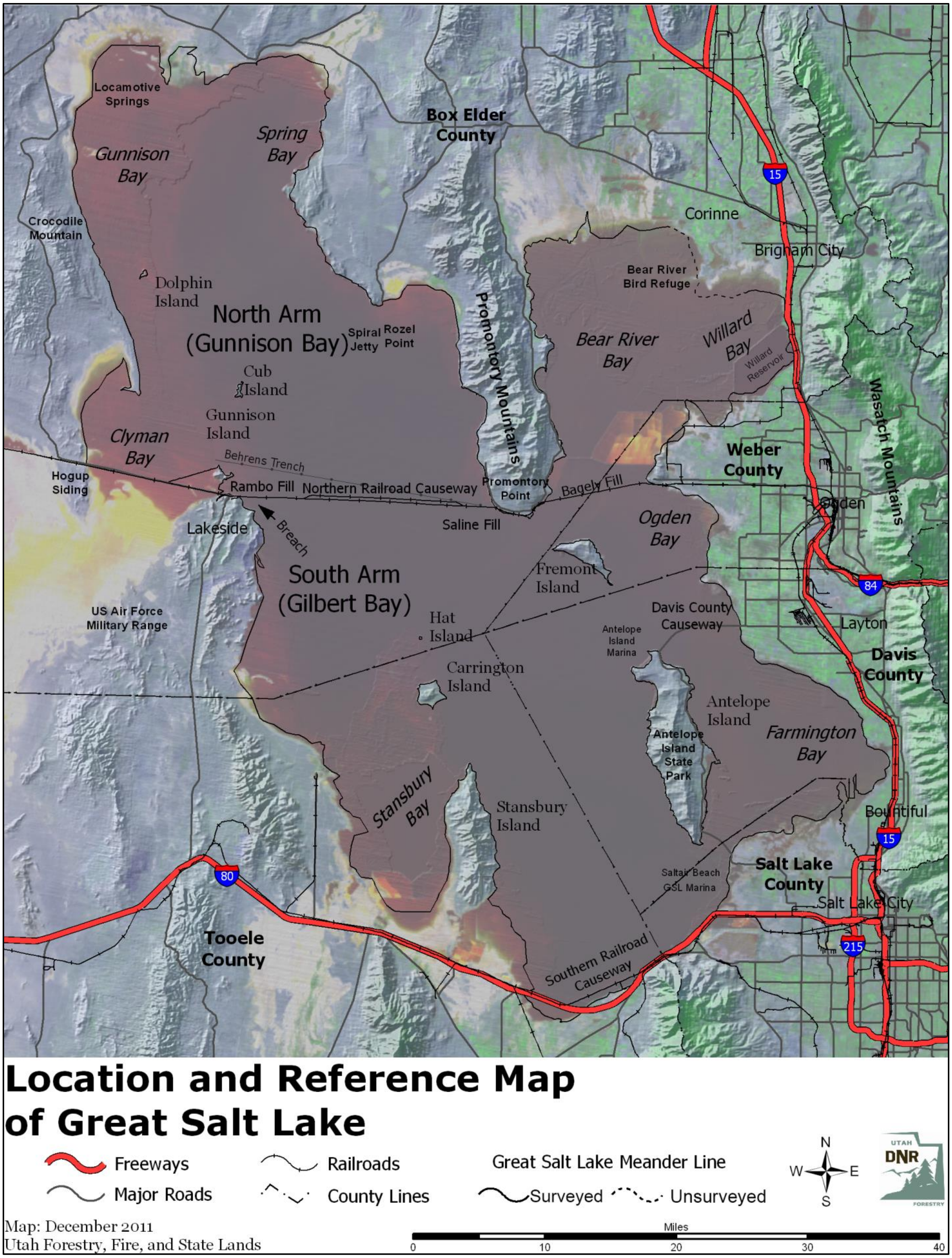
VISION STATEMENT FOR THE GREAT SALT LAKE COMPREHENSIVE MANAGEMENT PLAN - DECEMBER 2010

The State of Utah, through the Equal Footing doctrine, has fee title ownership of the bed of Great Salt Lake (GSL). The Utah Department of Natural Resources Division of Forestry, Fire & State Lands (FFSL) has direct management jurisdiction over lands below the GSL meander line. However, FFSL recognizes the importance of the GSL ecosystem, including resource values and uses outside of the meander line that affect or are affected by actions on sovereign lands. Accordingly, FFSL considers it imperative that management of GSL include coordination in planning and actions by other agencies with jurisdictional responsibility over these resources.

GSL is a unique and complex ecosystem of regional and hemispherical importance. Sustainable use of GSL's natural resources will ensure that the ecological health (e.g., water quality, shoreline condition, salinity, aquatic organisms, wildlife, wetlands), scenic attributes, extractive industries (e.g., minerals, brine shrimp, microorganisms), and recreation opportunities (e.g., bird watching, hunting, sailing) will be maintained into the future. FFSL will coordinate, as necessary, to ensure that the management of these resources is based on a holistic view of the lake-wide ecosystem—including the use of adaptive management, as necessary—to ensure long-term sustainability. Responsible stewardship of GSL's resources will provide lasting benefit to the Public Trust.



Map 1.1. Great Salt Lake location and reference map.

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CHAPTER 1 INTRODUCTION

The Utah Department of Natural Resources (UDNR) and the Utah Division of Forestry, Fire & State Lands (FFSL) are jointly sponsoring the Great Salt Lake (GSL) Comprehensive Management Plan (CMP) revision to develop a coordinated natural resources management plan for the lands and resources of GSL. Primary management responsibility for the lake's resources lies with FFSL, pursuant to Title 65A of the Utah Code, which governs management of all state lands within the jurisdiction of FFSL. Specifically, UTAH CODE § 65A-10-8, *Great Salt Lake - Management responsibilities of the division*, requires the division to do the following:

> (1) Prepare and maintain a comprehensive plan for the lake which recognizes the following policies:
>
> > (a) develop strategies to deal with a fluctuating lake level; (b) encourage development of the lake in a manner which will preserve the lake, encourage availability of brines to lake extraction industries, protect wildlife and protect recreation facilities; (c) maintain the lake's flood plain as a hazard zone; (d) promote water quality management for the lake and its tributary streams; (e) promote the development of lake brines, minerals, chemicals and petro-chemicals to aid the state's economy; (f) encourage the use of appropriate areas for the extraction of brines, minerals, chemicals and petro-chemicals; (g) maintain the lake and the marshes as important to the waterfowl flyway system; (h) encourage the development of an integrated industrial complex; (i) promote and maintain recreation areas on and surrounding the lake; (j) encourage safe boating use of the lake; (k) maintain and protect state, federal and private marshlands, rookeries and wildlife refuges; (l) provide public access to the lake for recreation, hunting and fishing.

UTAH CODE § 65A-2-1 states that "[t]he division [of Forestry, Fire and State Lands] shall administer state lands under comprehensive land management programs using multiple-use, sustained-yield principles." Briefly stated, the overarching management objectives of FFSL are to protect and sustain the trust resources and to provide for reasonable beneficial uses of those resources, consistent with their long-term protection and conservation. This means that FFSL will manage GSL and its resources under multiple-use, sustained yield principles (UTAH CODE § 65A-2-1) by implementing legislative policies (UTAH CODE § 65A-10-8) and accommodating public and private uses to the extent that those policies and uses do not substantially impair Public Trust resources or the lake's sustainability.

Although primary lake planning and management responsibilities lie with FFSL, the other divisions of UDNR also have management responsibilities for resources on and around GSL (Map 1.2[1]). The Division of Wildlife Resources (DWR), for example, has authority for managing wildlife in, on, and around the lake. The Division of State Parks and Recreation (DSPR) manages Antelope Island, Willard Bay, and Great Salt Lake Marina (GSL Marina) state parks and coordinates search-and-rescue and boating enforcement on the lake. The Division of Water Rights (DWRi) regulates the diversion and use of lake and tributary waters. The Division of Water Resources (DWRe) conducts studies, investigations, and plans for water use and operates the West Desert Pumping Project (WDPP). UDNR divisions also

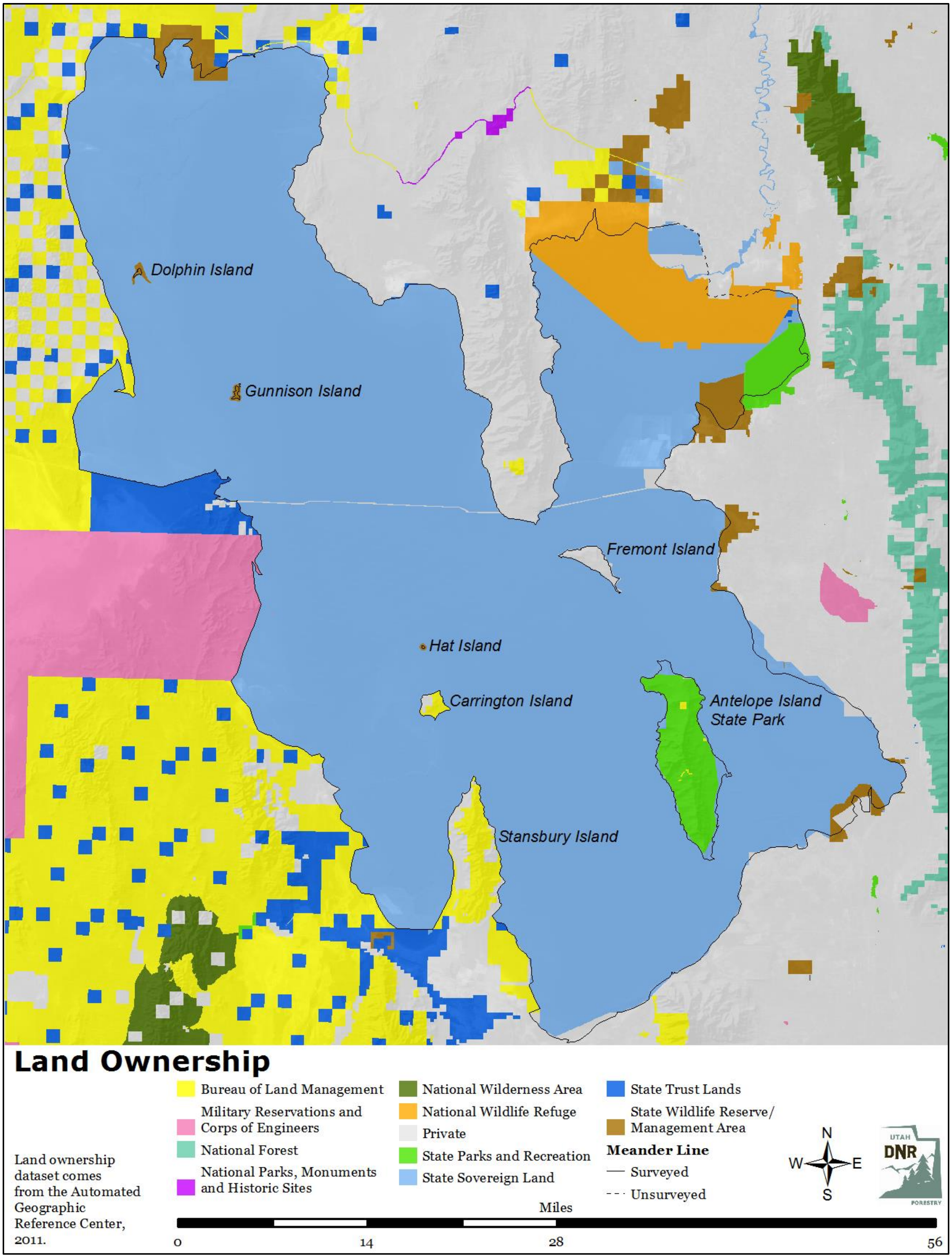
[1] The following statement is a disclaimer from the Utah Automated Geographic Reference Center (AGRC). It pertains to all maps used in this report that have used any dataset created or hosted at AGRC. "This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. AGRC [Automated Geographic Reference Center] provides these data in good faith and shall in no event be liable for any incorrect results, any lost profits and special, indirect or consequential damages to any party, arising out of or in connection with the use or the inability to use the data hereon or the services provided. AGRC provides these data and services as a convenience to the public. Furthermore, AGRC reserves the right to change or revise published data and/or these services at any time."

regulate mineral extraction activities, conduct hydrologic research, and identify and map geologic hazards around the lake.

To more specifically articulate UDNR's management objectives for the resources of GSL and to reconcile the diverse mandates of the divisions of UDNR, the GSL CMP revision was initiated. This revision process provides opportunities for increased coordination and collaboration between agencies responsible for management of the GSL ecosystem.

As determined by FFSL and the GSL Planning Team (see section 1.3.1), the purposes of the GSL CMP revision process are to

- provide updates to the 2000 GSL CMP (FFSL 2000) and the 1996 Mineral Leasing Plan (MLP; FFSL 1996);
- integrate the new data and research that have been developed on GSL over the last ten years;
- coordinate the management, planning, and research activities of UDNR and Utah Department of Environmental Quality (UDEQ) divisions on GSL; and
- ensure that sovereign lands management remains consistent with Public Trust obligations.



Map 1.2. Land ownership around Great Salt Lake.

1.1 State Ownership and Trust Responsibilities

Under English common law, the crown held title to all lands underlying navigable waterways, subject to the Public Trust doctrine. Following the American Revolution, title to such lands in the United States vested in the 13 original colonies. Under the Equal Footing doctrine, fee title to those lands also vested in each state subsequently admitted to the Union, upon admission. Utah-owned navigable waterways, known as “sovereign” lands, lie below the ordinary high water mark of the waterbody. In 1976, the U.S. Supreme Court determined that the state owns all of the lands, brines, and other minerals within the bed and waters of the lake and all shore lands located within the officially surveyed meander line.

1.1.1 The Surveyed Meander Line

The surveyed meander line is not a constant elevation around the lake. The elevation of the meander line generally ranges from approximately 4,202 to 4,212 feet above mean sea level. In some locations, the meander line runs across topographical features of higher elevation substantially inland of the shoreline. Regardless of its location relative to the water’s edge and lake level, the officially surveyed meander is the adjudicated, fixed, and limiting boundary between sovereign land and upland owners (see Map 1.1)

The surveyed meander line is not usually identifiable on the ground without the aid of surveying or global positioning system equipment. To avoid trespass situations, FFSL requires applicants to provide surveyed legal descriptions for leases and easements on GSL. Upland owners likewise should have the meander line located by survey whenever the boundary location between sovereign land and adjoining land is required.

1.1.2 The Public Trust over Sovereign Lands

Under Roman law and perhaps earlier, the air, sea, and running waters were common to all citizens and the separate property of none. All rivers and ports were public, and the right of fishing was common to all. Any person was at liberty to use the seashore to the highest tide, as long as they did not interfere with the use of the sea or beach by others. The influence of Roman civil law carries forward through English common law to today’s Public Trust doctrine, which recognizes the special public interest in rivers, lakes, tidelands, and waters. Thus, sovereign lands are held in trust by the state for the benefit of the public.

The Public Trust doctrine is flexible and accommodates changing demands for Public Trust resources. FFSL is the management authority for sovereign lands. As such, they may exchange, sell, or lease sovereign lands, but only in the quantities and for the purposes that serve the public interest and do not interfere with the public trust (UTAH CODE § 65A-10-1). FFSL administers state lands under comprehensive land management programs using multiple-use sustained yield principles (UTAH CODE § 65A-2-1). There is no particular hierarchy of uses. Uses at GSL include preservation of the lake; availability of brines to lake extraction industries; wildlife protection; protection of recreational facilities; safe boating; availability of appropriate areas for extraction of brine, minerals, chemicals, and petrochemicals to aid the state’s economy; maintenance and protection of marshlands, rookeries, and wildlife refuges; and public access to the lake for recreation, hunting, and fishing (UTAH CODE § 65A-10-8).

Implementation of multiple-use and other legislative polices for GSL are subject to consistency with Public Trust obligations and must avoid substantial impairment of the Public Trust. As trustee, FFSL must strive for an appropriate balance among compatible and competing uses. Given the state’s duty to manage sovereign lands for the public, sale of sovereign lands is generally precluded by the constitutionally imposed duty of the state to manage sovereign lands for the public. Exceptions to the prohibition could be made if the disposition itself further enhances the public interest. The Utah

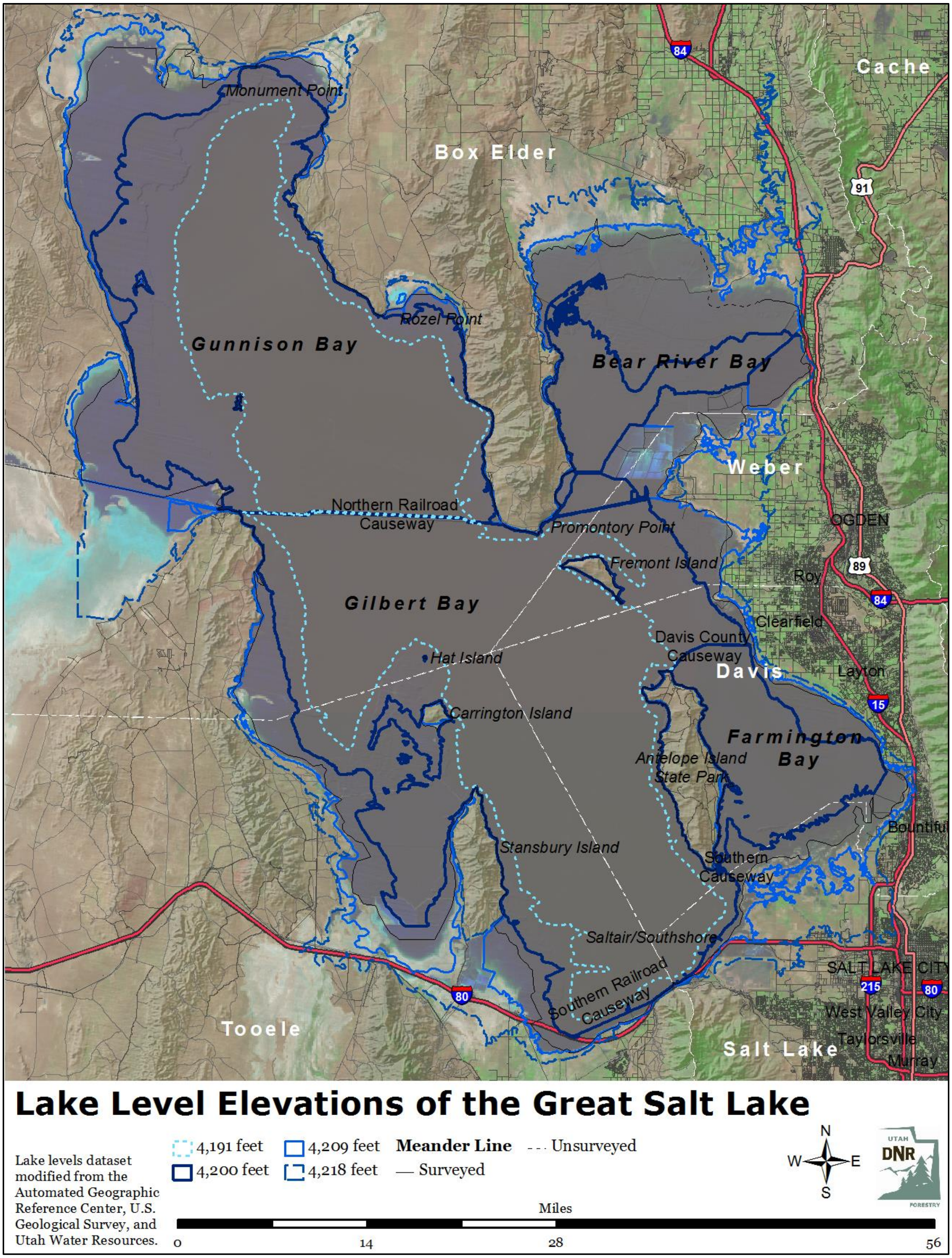
Legislature has chosen to protect the public interest in hunting, trapping, and fishing when sovereign land is sold or leased by requiring that "...the lease, contract of sale, or deed shall contain a provision that provisions be made preserving appropriate public access and use" (UTAH CODE § 23-21-4).

Similarly, under some circumstances, FFSL may authorize through lease provisions a lessee or grantee to restrict public access on affected sovereign land to fully enjoy the rights granted under a lease, permit, or sale. Examples include restrictions during mining operations, construction of improvements, harbor operations, military operations, and access to personal property.

1.1.3 Lake Level Approach

According to UTAH CODE § 65A-10-8, FFSL is required to "prepare and maintain a comprehensive plan for the lake that … develop[s] strategies to deal with a fluctuating lake level." Lake level planning is a fundamental statutory responsibility of FFSL. As part of the 2013 GSL CMP revision process, FFSL and the GSL Planning Team developed a management approach that more fully adheres to the management responsibilities outlined in UTAH CODE § 65A-10-8. Because the Public Trust resources of GSL are differently impacted at different lake levels, FFSL must have the ability to modify their management strategies to avoid substantial impairment of GSL resources as lake levels rise and fall. Map 1.3[2] shows GSL elevations at a range of lake levels.

[2] This dataset is an SWCA modified version of the SGID93_WATER_GSLShoreline feature class (1:500,000) from AGRC. In many areas in that dataset, the elevation contours cross one another. Here, Allen Stutz of SWCA uncrossed these lines with the aid of 7.5-minute USGS topographic quadrangles, though in many areas the edits were somewhat generalized. In other areas (e.g., Bear River), the lines were not modified, therefore the scale denominator remains 1:500,000. A portion of the western boundary has been removed because it was not to be included in the analysis. The 4,191-foot contour line was taken from shapefiles from USGS maps of bathymetry for the North (Gunnison) and South (Gilbert and Farmington) portions of Great Salt Lake (Bashkin and Allen 2005 [http://pubs.usgs.gov/sim/2005/2894]; and Bashkin and Turner 2006 [http://pubs.usgs.gov/sim/2006/2954]), as provided by Robert L Baskin in October 2011.



Map 1.3. Lake levels of Great Salt Lake.

During public scoping for the 2013 revision, it was clear that a primary concern of the public was low lake levels. The 2000 GSL CMP highlights the concerns brought about by *high* lake levels. FFSL can develop a plan that addresses management issues at a range of lake levels, not just a "one-lake-level-fits-all" management approach. GSL is a complex ecosystem that functions differently at different lake levels, and it needs a management plan that can adapt to the changing levels. This 2013 GSL CMP revision is intended to provide FFSL with the following:

- A comprehensive look at how the ecosystem, infrastructure, and industry are impacted at varying lake levels
- Resource-specific management strategies at high, medium, and low lake levels
- Areas of concern based on lake level fluctuations
- Coordination and cooperation opportunities with other state agencies that have the ability to directly impact a specific resource

1.1.3.1 LAKE LEVEL ELEVATION JUSTIFICATION

The development and implementation of a management plan for FFSL that effectively addresses fluctuating lake levels now includes the following:

- Elevation categories or zones that incorporate critical resource thresholds (where known)
- Elevation of key infrastructure
- Existing resource management strategies
- Important biophysical changes in bay and island connectivity from which management decisions are based

Through the 2013 GSL CMP revision process, three lake level management zones are proposed to describe lake resources and develop elevation-specific management strategies: **high, medium, and low.**

The high, medium, and low lake level zones provide a roadmap to a) better understand the relationship between resources with one another at different lake levels, b) improve coordination between state agencies that are responsible for various resources associated with the lake, and c) mitigate impacts associated with lake level fluctuations. Lake level management strategies are developed around the three zones. The high and low zones include management strategies for the lake at its most extreme conditions, whereas the medium zone represents the most typical management condition.

1.1.3.2 LAKE LEVEL RESOURCE MATRIX

The process through which the three zones were derived began with the development of the GSL Lake Level Matrix (Appendix A). The matrix is a summary of elevation-specific GSL resource characteristics derived from available literature and input from at least three dozen stakeholders representing multiple resources and lake characteristics. Most resources outlined in the GSL CMP are characterized by elevation in the matrix (those that do not vary with lake level were not included). When appropriate, specific elevations are labeled *beneficial* or *adverse* for the resource. Elevation-specific but value-neutral characteristics are also noted.

1.1.3.3 LAKE LEVEL MANAGEMENT ZONES

The three lake level management zones illustrated in the matrix were determined by examining existing elevation-specific data (scientific data, grey literature [technical reports and white papers from government agencies or research specialists], and stakeholder communications). The matrix paints a clear picture of how resources change with lake level, and the high, medium, and low zones are visually apparent when examining the matrix. Although statistical frequency was noted during the development of the zones, it was not the driver for the zone determinations. Rather, the driver was the notable changes that the resources experienced at certain elevations. The zones were developed to capture the largest number of resource thresholds or changes across a particular zone. The zones have been determined as follows:

- High: 4,205.0–4,213.0 feet or more
- Medium: 4,198.0–4,204.9 feet
- Low: 4,188.0–4,197.9 feet or less

Within the high and low zones, there are two 3-foot transition zones immediately before and after the medium zone (high transition [4,205–4,207 feet] and low transition [4,195–4,197 feet]). The transition zones are applicable when considering the management strategies at the high and low lake level zones.

The transition zones give FFSL the opportunity to plan for and mitigate impacts to resources prior to the lake reaching levels adverse to a particular resource. This concept is discussed further in Chapter 3 (GSL CMP Management Strategies).

1.2 Project History and Background History of Planning and Management of Great Salt Lake

1.2.1 Great Salt Lake Authority (1963)

In 1963, the Utah Legislature enacted House Bill (HB) 33, creating the GSL Authority and an advisory council to the authority. The authority was empowered to "coordinate multiple-use of [GSL] property for such purposes as grazing, fish and game, mining and mineral removal, development and utilization of water and other natural resources, industrial, and other uses in addition to recreational development, and adopt such reasonable rules and regulations as the authority may deem advisable to insure the accomplishment of the objectives and purposes of the act" (Laws of Utah 1963, Chapter 161). The bill specifies that both the state Department of Fish and Game and the state Land Board would retain the powers and jurisdiction conferred upon them, subject to such reasonable rules and regulations as the authority may make to ensure the accomplishment of the objectives of the act (Laws of 1963). The authority made little progress in discharging its duties, and in 1966, the Utah Supreme Court declared that the act creating the authority was unconstitutional because it failed to define the authority's geographical jurisdiction.

1.2.2 Reestablishment of the Authority (1967)

The legislature cured the jurisdictional defect in 1967 when it re-created the GSL Authority (Laws of Utah 1967, Chapter 187). With legislation, the authority's geographical jurisdiction was defined and consisted of the mainland, peninsulas, islands, and waters within the GSL meander line established by the U.S. Surveyor General.

The purpose of the re-created authority was to establish and coordinate programs for development of recreational areas and water conservation in GSL and its environs. The authority was responsible for 1) providing the development of Antelope Island as a suitable and desirable location for recreational use, 2) determining the impact of Kennecott Utah Copper Corporation (KUCC) tailings on GSL and its environs, and 3) providing the restoration and preservation of historical interest points on Antelope Island.

A preliminary feasibility study for the recreational development of the north end of Antelope Island was prepared by Snedaker & Budd and Allred & Associates for the GSL Authority and was submitted on June 26, 1964. In 1965, *A Preliminary Master Plan for the Development of Great Salt Lake over a Period of the Next 75 Years* was prepared for the GSL Authority. This plan envisions the use of surplus waters from the Bear River, Weber River, and Jordan River drainage areas and the use of KUCC tailings material for the construction of dikes, highways, and land reclamation within Farmington Bay (GSL Authority 1965).

1.2.3 Department of Natural Resources (1967)

After the creation of UDNR in 1967, the GSL Authority was abolished, and functions of the authority were merged into UDNR.

1.2.4 Division of the Great Salt Lake (1975)

The 1975 general session of the Utah Legislature enacted HB 23, which established a board and division within UDNR to establish and coordinate programs for development of recreation areas, flood control, wildlife resources, industrial uses, and conservation of GSL. The Division of GSL (DGSL) was given the responsibility to determine the direction and implementation of all lake-related activities, working through existing UDNR divisions. In addition, DGSL was given the following powers and duties:

> (1) direct the preparation of and adopt a comprehensive plan for the lake in a manner which will assure the maximum interchange of information, ideas and programs with affected state, federal and local agencies, private concerns and the general public. Implement the provisions of the plan by using the existing authority of the various state and local entities or agencies concerned. Weigh the policies and programs of agencies that affect the lake to ensure their compatibility with the adopted comprehensive plan. Revise and update the plan at periodic intervals; (2) employ assistants and advisors deemed necessary for the purposes of the act; (3) initiate studies of the lake and its related resources; (4) publish or authorize the publication of scientific information; (5) define the lake's floodplain; (6) qualify for, accept and administer loan payments, grants, gifts, loans or other funds for carrying out any functions under the act; (7) determine the need for and desirability of public works and utilities for the lake area; (8) cooperate with the state engineer and all upstream entities in considering the water relationship between the lake and its tributaries; and (9) perform all other acts reasonably necessary to carry out the purposes and provisions of the act (HB 23, 1975).

1.2.5 Comprehensive Management Plan (1976)

Under the directive of HB 23, DGSL began preparing a CMP in July 1975. The plan was developed by the interagency technical team, which was established under the terms of the 1975 legislation. The interagency technical team was made up of representatives from various interests (public and private) and included representatives from several divisions of UDNR, Utah Department of Transportation (UDOT), county commissioners of the five counties surrounding the lake, and other representatives who served on the basic committees.

The GSL CMP was intended to serve as a general statement for use and management of the lake. Goals and policies based on the concepts set forth in the legislation, and as adopted by the GSL Board, served as a guide for preparation of the plan. The plan consists of six major sections: minerals, recreation, tourism, wildlife, hydrology, and transportation. The plan for each section was developed after consideration of the interrelationships of plan sections and was not intended to be a detailed development plan for private agencies or for divisions of local, state, or federal government.

1.2.6 Great Salt Lake Environs Report (1976)

The *Great Salt Lake Environs Report* was prepared in 1976 as a companion report to the CMP. The purpose of the report was to summarize and graphically portray the most current, accurate, and reliable data available concerning land use ownership, soils, vegetation, human-made structures, access ways, fresh water, and utilities lying between the water's edge on January 1, 1976 and the upper limits study line established at approximately 4,212 feet (DGSL 1976).

1.2.7 Division of State Lands and Forestry (1979)

In 1979, DGSL was eliminated, and the staff functions for the management of GSL were transferred to UDNR. Management of the state's sovereign lands and school and institutional trust lands was administratively delegated to the Division of State Lands and Forestry (DSLF).

1.2.8 Great Salt Lake Contingency Plan (1983)

In 1982, the water level of GSL began a rapid rise, which prompted DSLF to draft the *Great Salt Lake Contingency Plan*. This plan was designed to meet the legislative mandate for maintaining the water level of GSL below 4,202 feet, and it deals with background, analysis, and recommendations for influencing both the high and low levels of GSL. The contingency plan states that "It is anticipated that lake levels will peak at approximately 4,203 feet in 1983 with potential resultant damages of $20 to $30 million" (UDNR 1983). The lake peaked at approximately 4,205 feet that year and continued upward to nearly 4,212 feet in 1987, with estimated capital damages exceeding $250 million (FFSL 1999). The Northern Railroad Causeway was breached in 1984 to lessen flooding impacts occurring in the South Arm. The WDPP was built in 1986–1987 and operated from April 1987 to June 1989.

1.2.9 Great Salt Lake Advisory Council (1988 and 2010)

In 1988, the GSL Advisory Council (GSLAC) was created by legislative action to advise the Board of State Lands and Forestry through DSLF, which was designated as manager of the lake. The GSL Technical Team, discussed below, was given statutory authorization at the same time. The dissolution of the GSLAC occurred in 1994 with the reorganization of school and institutional trust lands management.

The reestablishment of the GSLAC began in August 2008 when Governor Jon Huntsman signed an executive order creating the new council. At the time, Governor Huntsman tasked the GSLAC with "conducting a comprehensive evaluation of the entire Great Salt Lake, specifically looking at the long term viability of the Lake and its entire ecosystem" (State of Utah 2008). GSLAC was formally reestablished through the adoption of HB 343 during the 2010 Utah Legislative Session. The eleven-member council, appointed by Governor Gary Herbert, consists of county representatives from the five counties surrounding the lake, interest groups, and an elected municipal official (or designee). As per HB 343 (GSLAC Act of 2010), the GSLAC advises the governor, UDNR, and UDEQ on the sustainable use, protection, and development of GSL. They are to assist FFSL in its responsibilities for GSL, as described in UTAH CODE § 65A-10-8. The GSLAC receives technical support from the technical team and may also recommend appointments to the technical team.

In January 2012, the GSLAC released two reports pertaining to GSL resources: *Definition and Assessment of Great Salt Lake Health* (SWCA Environmental Consultants and Applied Conservation 2012) and *Economic Significance of the Great Salt Lake to the State of Utah* (Bioeconomics, Inc. 2012). Due to the timing of the reports' releases, the findings were not incorporated into the 2013 GSL CMP. FFSL acknowledges the importance of the documents and will incorporate them into the next GSL CMP revision. Further, FFSL is interested in using the best available scientific data when making management decisions and will refer to the peer-reviewed research when considering how future proposals would impact the lake.

1.2.10 Great Salt Lake Technical Team (1988)

The GSL Technical Team was formally established in 1988 to provide guidance and recommendations in the monitoring, management, and research efforts of the GSL ecosystem. The creation of the technical team provides a forum for the interchange of information, projects, and programs that affect the GSL ecosystem and uses. The technical team comprises academic, federal, state, political, and special interest representatives. As per the GSLAC Act, the technical team provides technical support to GSLAC.

1.2.11 General Management Plan, Great Salt Lake (1988)

As GSL reached its historic high water level of 4,211.85 feet in 1986 and again in 1987, a five-year *General Management Plan, Great Salt Lake* was prepared for GSLAC. The general management plan and the Beneficial Development Area concept developed by the Utah Division of Comprehensive Emergency Management was a cooperative attempt to outline the best strategies available to avoid flood-related impacts to those using the lake under its high-water and expected near-future conditions for a variety of purposes. Both the plan and the Beneficial Development Area concept were delivered to the five counties bordering the lake for adoption and were adopted by the Federal Emergency Management Agency (FEMA).

1.2.12 Division of Sovereign Lands and Forestry (1994)

In 1994, management responsibilities for school and institutional trust lands were placed with the newly created School and Institutional Trust Lands Administration through legislative action. The Board of State Lands and Forestry and the GSLAC were eliminated, and the Sovereign Lands Advisory Council (SLAC) was created to advise the newly named DSLF. DSLF retained management responsibility for Public Trust lands and resources and became able to devote more time to planning and managing these lands as Public Trust lands, with a broader view of how the lake's many trust resources are interrelated. In 1996, HB 364 changed the name of DSLF to FFSL.

1.2.13 Great Salt Lake Comprehensive Management Plan (1995)

Completed in 1995, the *Great Salt Lake Comprehensive Management Plan: Planning Process and Matrix* was prepared by the GSL Technical Team for FFSL and UDNR. The goal of the plan was to "...provide needed information and guidance in the form of recommendations to federal, state and local governments, and recommended legislation to the state legislature to facilitate and enhance management of GSL and its environs to assure protection of the unique ecosystem of the lake while promoting balanced multiple-resource uses" (FFSL 1999).

As described in its goal statement, the 1995 GSL CMP includes analyses of lake management issues and makes recommendations on those issues to local, state, and federal government. Many of the recommendations in the 1995 plan were acted on by divisions of UDNR, including development of the MLP by FFSL. However, recommendations pertaining to the management actions on the WDPP and development of GSL water quality standards were not acted on. The recommendations involving local government made in the 1995 GSL CMP were not fully analyzed or reported.

1.2.14 Mineral Leasing Plan (1996 and 2013)

As an outgrowth of the 1995 plan, FFSL announced the withdrawal of sovereign lands from minerals leasing as part of a comprehensive planning process for management of minerals on those lands. Included were GSL, Utah Lake, the Jordan River, Bear Lake, and portions of the Bear River, Colorado River, and Green River. To accomplish FFSL's planning and management mandates, they created the GSL MLP. This document reviews the history of mineral ownership and leasing, inventories mineral resources, and examines the existing conflicts among resources on the lake. The MLP identifies categories on the lake bed for mineral commodity production and specifies new mineral leasing procedures.

As part of the 2013 GSL CMP revision process, the MLP has been revised to incorporate management strategies that allow FFSL to avoid substantial impairment to GSL at a range of lake levels.

1.3 Great Salt Lake Comprehensive Management Plan (2000)

In 1997, FFSL began a revision of the 1995 GSL CMP to "more specifically articulate UDNR's management objectives for the resources of GSL and to reconcile the diverse mandates of the divisions of UDNR" (FFSL 1999). As part of the GSL Planning Project, FFSL developed and analyzed four potential management alternatives. After a two-year process, including two rounds of public meetings, FFSL selected a preferred management alternative that was implemented through 2013.

1.3.1 Great Salt Lake Comprehensive Management Plan Revision (2013)

The primary focus of the 2000 GSL CMP was managing the impacts from the flooding and high lake levels of the 1980s and 1990s. In the fall of 2010, the lake level reached a near-record low of 4,193.6 feet (compared to the recorded low of 4,191.4 feet in 1963). To assess the current conditions of GSL at low lake levels and to simply provide updates to a decade-old management plan, FFSL began the GSL CMP revision process in 2010. Further, FFSL was interested in incorporating a decade's worth of GSL research into a management approach that specifically deals with a fluctuating lake level in a collaborative multi-agency manner.

As part of the 2013 GSL CMP revision, FFSL convened the GSL Planning Team comprising UDNR and UDEQ representatives to provide input and support throughout the revision process. Throughout the process, the GSL Planning Team represented the long-term collaborative approach necessary to holistically manage the complex GSL ecosystem. A list of the planning team members is provided in the introductory pages of the 2013 GSL CMP revision. The purposes of the GSL Planning Team are to

- provide resource-specific guidance throughout the planning process;
- provide the most recent, relevant research and data pertaining to the project area;
- provide timely review and comment on the document throughout the revision process; and
- offer project updates, milestones, and opportunities for comment to State of Utah agencies and the general public.

Public involvement was essential to the GSL CMP planning process. As illustrated in the Public Involvement section (Appendix B), there were numerous opportunities for the public to play a role in the revision of the GSL CMP. State, federal, local governments, and stakeholders were notified numerous times throughout the planning process, and their attendance was requested at public meetings and during the comment response. Fifteen public meetings and four stakeholder meetings were held throughout the planning process. A public comment period followed each public and stakeholder meeting; each comment period was 30 days, except the final comment period, which was 75 days. Comments for each phase of the planning process were acknowledged and addressed, as appropriate, by FFSL.

1.4 Current Department of Natural Resources Management Responsibilities

1.4.1 Division of Forestry, Fire & State Lands

FFSL is "the executive authority for the management of sovereign lands" in Utah (UTAH CODE § 65A-1-4), including the sovereign lands of GSL. Title 65A of the Utah Code, entitled *State Lands*, establishes the division and the FFSL Advisory Council, and sets forth the powers and responsibilities of the division and council. UTAH CODE § 65A-10-8 establishes the division's responsibility to prepare and maintain a management plan for GSL under paragraph (1) and establishes other responsibilities for the lake as follows:

> (2) Employ personnel and purchase equipment and supplies which the legislature authorizes through appropriations for the purposes of this chapter.
>
> (3) Initiate studies of the lake and its related resources.
>
> (4) Publish scientific and technical information concerning the lake.
>
> (5) Define the lake's floodplain.
>
> (6) Qualify for, accept, and administer grants, gifts, or other funds from the federal government and other sources, for carrying out any functions under this chapter.
>
> (7) Determine the need for public works and utilities for the lake area.
>
> (8) Implement the comprehensive plan through state and local entities or agencies.
>
> (9) Coordinate the activities of the various divisions within the UDNR with respect to the lake.
>
> (10) Perform all other acts reasonably necessary to carry out the purposes and provisions of this chapter.
>
> (11) Retain and encourage the continued activity of the Great Salt Lake Technical Team.

1.4.2 Division of Wildlife Resources

Title 23 of the Utah Code establishes DWR and the Wildlife Board and establishes their duties and powers. UTAH CODE § 23-14-1 states that "The Division of Wildlife Resources is the wildlife authority for Utah and is vested with the functions, powers, duties, rights and responsibilities provided in this title and other law." The section goes on to state that "Subject to the broad policy making authority of the Wildlife Board, the Division of Wildlife Resources shall protect, propagate, manage, conserve and distribute protected wildlife throughout the state."

DWR manages wildlife areas on GSL, regulates hunting, manages all protected wildlife species, and regulates the commercial harvest of brine shrimp (*Artemia franciscana*) from the lake. UTAH CODE § 23-21-5 authorized DWR to use all or parts of 39 townships of sovereign lands on the lake for the "creation, operation, maintenance and management of wildlife management areas, fishing waters, and other recreational activities."

1.4.3 Division of State Parks and Recreation

Title 79-4 of the Utah Code establishes DSPR and the Board of Parks and Recreation and sets forth their responsibilities. DSPR manages Antelope Island State Park, Willard Bay State Park, and the GSL Marina on the south shore of the lake.

DSPR is also directly responsible for boating enforcement on GSL. DSPR is the lead agency for all search-and-rescue efforts on the lake. DSPR personnel also work closely with five county sheriff offices (Box Elder, Davis, Salt Lake, Tooele, Weber) in the coordination of search and rescue as well as law enforcement on and around the lake.

1.4.4 Division of Water Rights

DWRi regulates the appropriation and distribution of water in the State of Utah, pursuant to Title 73 of the Utah Code. The State Engineer, who is the director of DWRi, gives approval for the diversion and use of any water, regulates the alteration of natural streams, and has the authority to regulate dams to protect public safety. All diversions from the lake for all purposes, including mineral extraction by evaporation, require the prior approval of the State Engineer. Any dam or dike placed in the lake requires consultation from DWRi.

1.4.5 Division of Oil, Gas and Mining

The Division of Oil, Gas and Mining (DOGM) is the regulatory agency for mineral exploration, development, and reclamation on GSL, pursuant to Title 40 of the Utah Code. This regulatory role is conducted in close coordination with FFSL.

1.4.6 Utah Geological Survey

The Utah Geological Survey (UGS), a nonregulatory agency, is responsible for collecting, preserving, publishing, and distributing reliable information on geology, brine and mineral resources, and geologic hazards related to the state, including GSL. UGS is also responsible for assisting, advising, and cooperating with state and local agencies and state educational institutions on all subjects related to geology.

1.4.7 Division of Water Resources

The mission of the Utah Water Quality Board and DWRe is to direct the orderly and timely planning, conservation, development, protection, and preservation of Utah's water resources used to meet the beneficial needs of Utah citizens. Although the division does not have direct regulatory responsibilities on GSL, it conducts studies, investigations, and planning for water use and is responsible for maintenance and operation of the WDPP.

1.5 Other State Agencies

1.5.1 Utah Department of Environmental Quality

1.5.1.1 DIVISION OF ENVIRONMENTAL RESPONSE AND REMEDIATION

Federal and state laws require prompt reporting of environmental incidents. Depending on the nature of the incident, reports may be made to specific regulatory agencies, but in all cases, the Division of

Environmental Response and Remediation may be contacted to forward the report to the appropriate agency. Follow-up activity often involves preparation of a written report summarizing the incident and remedial actions taken.

1.5.1.2 DIVISION OF WATER QUALITY

The Utah Water Quality Board and the Division of Water Quality (DWQ) have the responsibility to maintain, protect, and enhance the quality of Utah's surface and groundwater resources. Title 19, Chapter 5 of the Utah Code charges the board and division to develop programs for prevention and abatement of water pollution. The board is also responsible for establishing water quality standards throughout the state; enforcing technology-based, secondary treatment effluent standards, or establishing and enforcing other more stringent discharge standards to meet in-stream standards; reviewing plans, specifications, and other data relative to wastewater disposal systems; and establishing and conducting a continuing planning process for control of water pollution.

DWQ's mission is to protect public health and all beneficial uses of water by maintaining and enhancing the chemical, physical, and biological integrity of Utah's waters. Objectives designed to achieve this mission are as follows:

- Classify waters according to beneficial use and set water quality standards, including numeric and narrative criteria, to protect those uses.
- Achieve full compliance with treatment and water quality standards by ensuring the adequacy of planning, design, construction, and operation of municipal and industrial wastewater standards through appropriate technical assistance, regulation, and enforcement.
- Develop and update pertinent regulations, policies, and strategies.
- Generate a comprehensive water quality database.
- Conduct water quality management planning and continue to implement an effective statewide nonpoint source control program.
- Implement the groundwater quality protection strategy.

1.5.1.3 DIVISION OF AIR QUALITY

The Division of Air Quality (DAQ) and the Air Quality Board address air pollution issues and shape environmental policy. The following objectives support DAQ's mission:

- Develop state implementation plans (SIP), issue permits, and conduct compliance and other public process activities.
- Partner with other in-state government agencies to develop and implement programs for the protection of statewide air quality, and achieve and maintain acceptable air quality along the Wasatch Front.
- Maintain delegation of federal air quality programs by developing appropriate plans, programs, policies, procedures, and rules.
- Influence state, regional, and national policy through active involvement with the legislature and policy-making organizations.
- Increase public awareness to educate the general public and businesses on emissions reduction.

1.6 Federal Agencies

1.6.1 U.S. Air Force

Hill Air Force Base (HAFB) operates the Utah Test and Training Range west of GSL. The range is used by the military for a range of uses, including a practice bombing and gunnery range for aircraft, rocket motor test firing, missile storage, and small arms and machine-gun firing ranges.

1.6.2 U.S. Army Corps of Engineers

Under Section 404 of the Clean Water Act (CWA), the U.S. Army Corps of Engineers (USACE) is responsible for regulating placement of fill material and excavation in the nation's waters, including GSL. USACE's management responsibilities under the CWA are to protect the nation's aquatic resources from unnecessary adverse impacts.

1.6.3 U.S. Bureau of Land Management

The Bureau of Land Management (BLM) Salt Lake Field Office is responsible for the management of lands along GSL's western edge. Stansbury Island is primarily managed by the BLM. BLM lands around GSL are governed by the 1986 Box Elder Resource Management Plan, 1990 Pony Express Management Plan, and the 1985 Isolated Tracts Planning Analysis. The BLM lands are managed for a range of land uses, including wild horses, livestock grazing, and recreation.

1.6.4 U.S. Environmental Protection Agency

The Environmental Protection Agency (EPA) has partnered with UDEQ to implement CWA and Clear Air Act programs on and around GSL. The EPA jointly administers the CWA Section 404 permit program with USACE. The EPA also has direct regulatory responsibilities for the Superfund Program under the Comprehensive Environmental Response, Compensation, and Liability Act.

1.6.5 U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (USFWS) manages the Bear River Migratory Bird Refuge at the mouth of the Bear River west of Brigham City. The USFWS is responsible for the protection of migratory birds as well as threatened and endangered species found in GSL environs (Gwynn 2002).

1.6.6 U.S. Geological Survey

Since 1875, the U.S. Geological Survey (USGS) has measured the elevation of GSL and has conducted numerous studies on hydrology, salinity, water quality, and lake ecology. In cooperation with DWR and the Utah State University (USU) Department of Fisheries and Wildlife, USGS is studying the ecology of brine shrimp on GSL. They currently operate two lake level gages: one gage at the Saltair Beach State Park (South Arm) and one at the Little Valley boat harbor (North Arm). From October 1986 to September 1999, a third gage was operated at Promontory Point. Lake level elevations are recorded every 15 minutes from the two current gages, and every four hours, the data are uploaded to a satellite. USGS captures the data and calculates mean daily elevations, which are made available to the public on their website (USGS 2011a).

1.6.7 U.S. Bureau of Reclamation

The U.S Bureau of Reclamation is responsible for the construction and management of the Arthur V. Watkins Dam that creates Willard Bay Reservoir. The dam was built in 1964 and is 14.5 miles long. The reservoir, located on the GSL shores, encloses 215,000 acre-feet and has a surface area of approximately 9,900 acres (Bureau of Reclamation 2006).

CHAPTER 2 CURRENT CONDITIONS

2.1 Overview

The assessment of current conditions for each GSL resource is fundamental to the development of an effective management plan. The initial resource inventory compilation was completed during the GSL CMP 2000 planning process. This GSL CMP revision process, including a public and agency scoping period, incorporated all new GSL data developed from 2000 through 2010.

This chapter represents a baseline picture of the current conditions and trends of GSL and its resources. It is organized by resource category and includes ecosystem, water (hydrology and quality), wetlands, biology, air, land use, minerals, and cultural resources. The utilization trends of GSL resources for agriculture, recreation, tourism, industry extraction, transportation, law enforcement, and search and rescue are also provided in this chapter.

This 2013 GSL CMP revision is intended to comprehensively develop strategies to deal with a fluctuating lake level. Within this Current Conditions chapter, the effects of lake level on each resource are provided. The Lake Level Effects subsections within each resource section provide a detailed look at how the ecosystem, infrastructure, and industry are impacted at varying lake levels. The consideration of how resources are impacted at a range of lake levels allows FFSL to develop management strategies for a range of lake levels. As discussed in the Introduction and illustrated in the GSL Lake Level Matrix, when high, medium, and low elevations are discussed throughout this chapter, the range of elevations are as follows:

- High: 4,205–4,213 feet or more
- Medium: 4,198–4,204 feet
- Low: 4,188–4,197 feet or less

It should be noted that the lake levels referred to throughout the following chapter may refer to the static lake levels; however, they may also refer to elevations that take into account wind tide and wave action. Based on weather conditions, the lake level could rise 5–7 feet with wind and wave actions. For example, at a static lake level of 4,205 feet, water would not overtop the Davis County Causeway; however, with a 3-foot wind tide and 2-foot wave action, that elevation could temporarily increase to 4,210 feet and make the causeway impassable.

2.2 Ecosystem

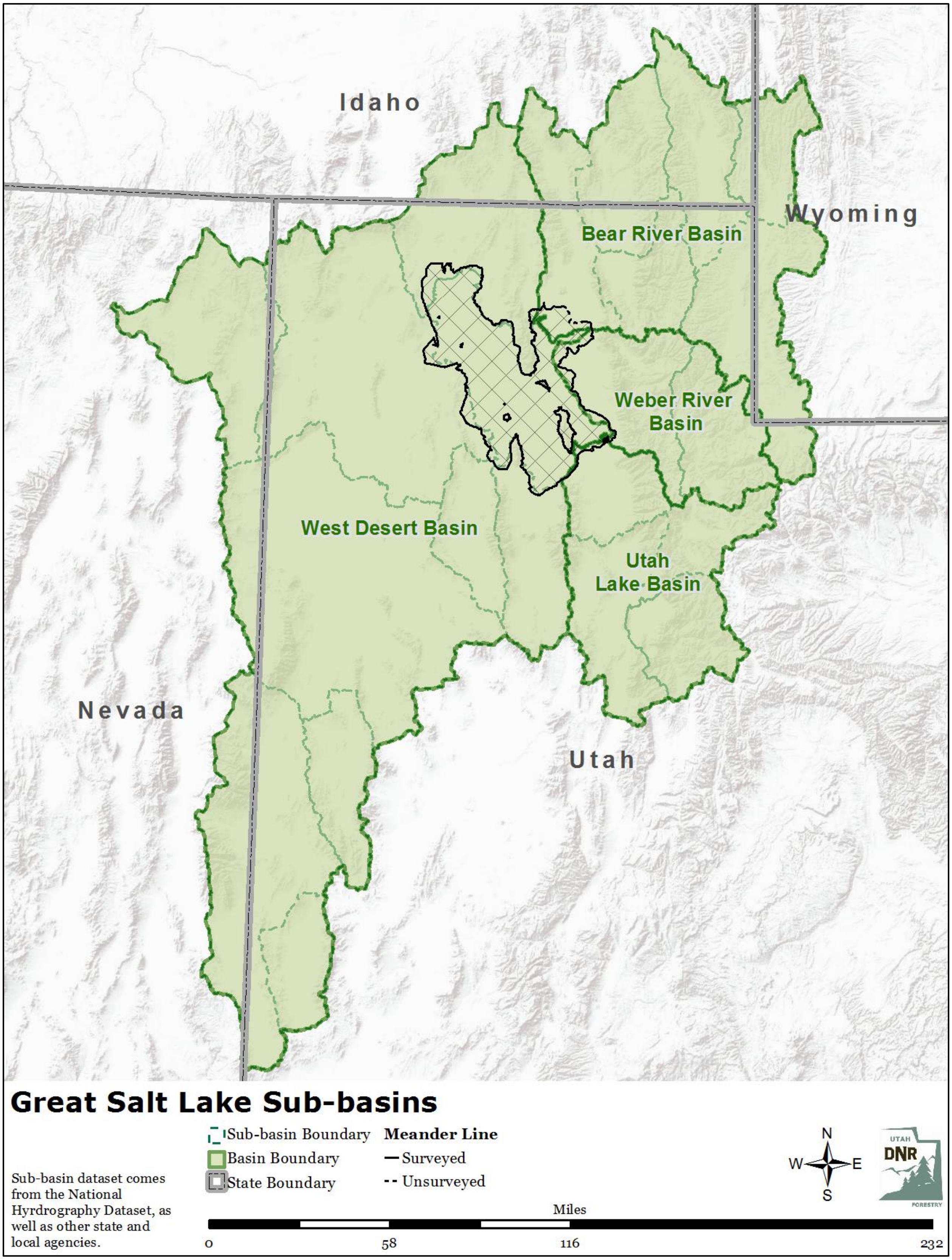
The GSL ecosystem is of worldwide importance for migratory bird populations as well as for the brine shrimp and mineral extraction industries. GSL is one of the premier wetland areas of the United States and is a major recreational and aesthetic resource for Utah (FFSL 1999). Located on the eastern edge of the Great Basin, GSL is a hypersaline, terminal waterbody and remnant of Pleistocene Lake Bonneville. Current physical, biological, and socioeconomic parameters reflect natural and anthropogenic processes occurring within the GSL Basin. The GSL ecosystem, although fundamentally a set of relationships between the parameters listed above, can be delineated at multiple scales, which may be as expansive as its watershed or as refined as the open water component of GSL. This GSL CMP revision considers the GSL ecosystem to be the lake itself as well as surrounding wetlands, including the physical, biological, and socioeconomic processes that occur in this delineated area. This in turn becomes the unit of management, but it acknowledges that stressors occur outside the boundaries of the ecosystem, chemical and biological processes occur at the microlevel within the water column, and FFSL jurisdiction is limited to those resources below the meander line.

At approximately 34,000 square miles, the GSL Basin contributing surface and groundwater flow to GSL and surrounding wetlands includes parts of Wyoming, Idaho, Utah, and Nevada (Map 2.1). It spans four geologic provinces, consisting of the Wasatch Plateau, the Uinta Mountains, the Rocky Mountain thrust belt, and the Basin and Range (GSL Information System 2011). GSL Basin habitat types include high elevation alpine systems, mountain streams, and fresh and salt-water wetlands. In a system driven by snowmelt, the major sources of water entering GSL are the Bear River, Weber River, and Jordan River. These are also sources of sediment and contaminants, with some pollution point sources discharging directly into GSL. In addition, land use and water management practices within the watersheds of the main river systems may affect hydrological processes that in turn may alter the volume and salinity of GSL. Land cover types within the GSL Basin are described in Table 2.1.

Table 2.1. *Land Cover Types within the Great Salt Lake Basin (square miles)*

Land Cover Type	Bear River	Weber River	Jordan River/ Utah Lake	West Desert	Total
Urban	31	85	244	28	388
Forest	1,111	783	1,520	1,996	5,410
Rangeland	4,478	1,304	1,537	10,327	17,646
Agricultural	1,390	180	280	420	2,270
Other	425	124	267	6,193	7,009
Total	**7,435**	**2,476**	**3,846**	**18,964**	**32,723**

Source: GSL Information System (2011).



Map 2.1. Great Salt Lake sub-basins.

Population centers around the GSL ecosystem are primarily at the base of the Wasatch Range along the east side of GSL. Intensive human interaction with the GSL ecosystem occurs here but also extends along the northern and southern shores.

The GSL ecosystem comprises many subecosystems (FFSL 1999), and each is strongly influenced by changing lake levels and lake chemistry. Shallow water, wetland areas, and deep water portions of the lake are spatially heterogeneous and temporally dynamic in response to changing environmental and management conditions. Variations in precipitation and freshwater inflows together create a dynamic mosaic of habitat types along the shores of the lake over time. In addition, variations in salinity affect species community composition and structure, which also vary across all of the lake's habitats. There is a distinct difference in salinity between the North Arm and South Arm of GSL, and this directly influences species distribution and abundance. There is also a strong east-to-west ecosystem gradient in regard to GSL habitat and productivity (FFSL 1999). Natural and human-induced inputs and outputs occur by means of tributary inflow, atmospheric deposition and climate, and other mechanisms (FFSL 1999). GSL resources are interconnected and human use influences ecosystem response. GSL components and interactions are closely associated, making the management of GSL ecosystems complex and challenging.

2.2.1 Subsystems of the Great Salt Lake

GSL and its watershed represent a complex web of interacting physical, socioeconomic, and ecological subsystems (FFSL 1999). A subsystem analysis emphasizes the linkages between these components and human interactions from a large-scale perspective (Figure 2.1). The subsystems approach can be a management tool for resource planners and managers to identify issues, limitations, and areas of uncertainty. In addition, the comprehensive nature of these subsystems and their interlinkages supports interdisciplinary and interagency management of GSL.

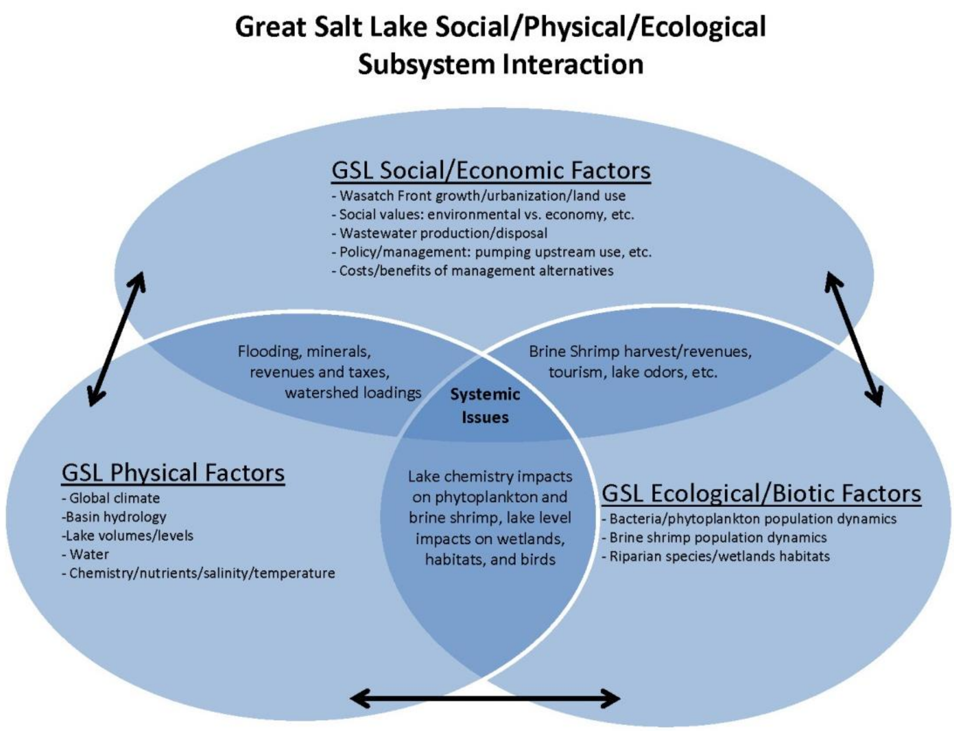


Figure 2.1. Great Salt Lake social, physical, ecological, and subsystem interaction (FFSL 1999).

2.2.1.1 PHYSICAL SUBSYSTEMS

Physical subsystems represent the physical environment or setting and include basin geology, hydrodynamics, and lake chemistry. The geologic setting and geography of the landscape create this watershed and terminal basin. Hydrologic processes cause fluctuations of lake volume, lake level, and salinity. All are strongly influenced by each other and respond to regional and global climatic factors (see section 2.3.1). Climatic forces drive watershed response and lake level fluctuations at multi-year, decadal, and longer time scales. Currently, the ability to predict lake level fluctuation can be limited, although recent work, including research conducted at USU (Wang et al. 2010), is unraveling the relationship between precipitation, streamflow, water vapor flux, and drought conditions in the Great Basin and the delayed response in GSL elevation. Resource managers will likely continue to deal with long-term uncertainty but will be better able to predict lake levels in the short term and understand associated management implications and ramifications.

2.2.1.2 SOCIOECONOMIC SUBSYSTEMS

Socioeconomic subsystems relate to human interactions that influence the GSL ecosystem; they include population, economic, and other human-related interactions. Mineral extraction, brine shrimp harvesting, and oil and gas reserves are also important lake economic resources. Tourism and recreation are additional important lake uses. Activities within socioeconomic subsystems occur and affect the lake at seasonal to multi-year time scales.

Rapid urbanization continues to occur in GSL uplands, most notably in areas draining to Bear River and Farmington bays. These subwatersheds contribute most of the freshwater inflows to GSL. This human-induced impact changes the amount and temporal distribution of runoff into the lake, as well as the quality of runoff water. These changes affect lake level, water chemistry, and ultimately other subsystem components. Management strategies may also influence lake level, lake chemistry, air quality, and water quality. Upstream and watershed activities such as discharges, development, and water allocation all interact with other lake ecosystems and the three conceptual GSL subsystems. In 2010, the GSLAC was formally reestablished through the adoption of HB 343. Among its tasks are to develop a vision for the future of GSL and make policy recommendations concerning the long-term viability of the entire GSL ecosystem (HB 343, 2010). Political and economic arenas will continue to drive management actions within this subsystem.

2.2.1.3 BIOLOGICAL AND ECOLOGICAL SUBSYSTEMS

These subsystems focus on biological and ecological interactions. Lake level fluctuations, salinity, and water quality affect the dynamics of the lake's ecosystems, which, as illustrated in the GSL Lake Level Matrix, has positive, negative, and neutral implications for the areal extent of wetland habitats and the population dynamics of algae, brine shrimp, brine flies (*Ephydra* spp.), and birds. There are further implications for tourism and commercial brine shrimp harvesting. Nutrient availability and air and water quality have ecological consequences that lake managers have yet to fully understand, although research on the effect of lake chemistry on biota is currently underway. For example, a model recently refined by Belovsky et al. (2011) illustrates some of the fundamental biological linkages of GSL (Figure 2.2). Understanding cause-and-effect chains and their interconnected linkages helps resource managers identify potential methods of altering conditions or managing a system.

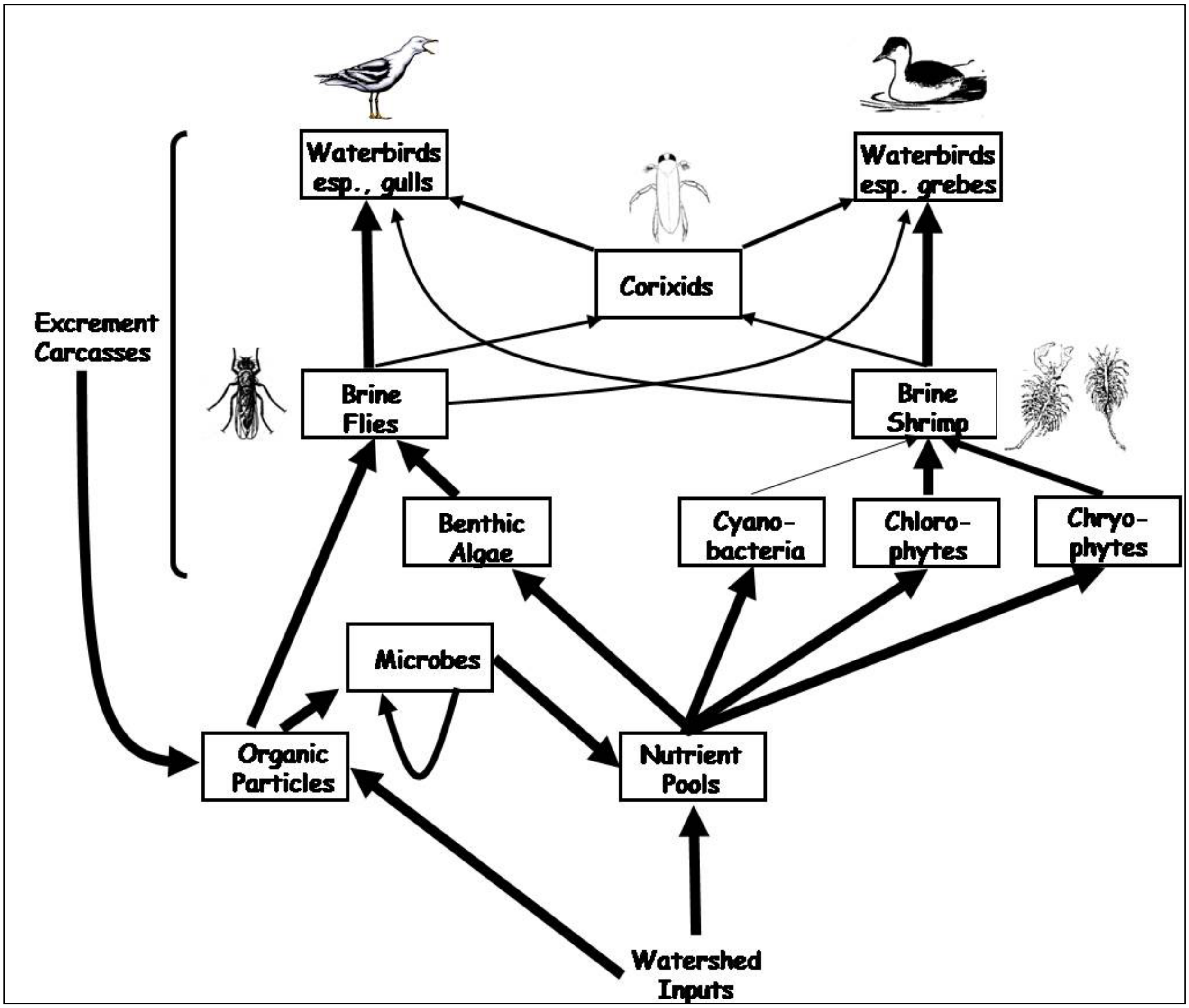


Figure 2.2. Great Salt Lake ecosystem food web comprising two linked food chains: 1) phytoplankton consumption by brine shrimp and 2) detritus and benthic algae consumption by brine flies (Belovsky et al. 2011).

2.2.1.4 LINKAGES AMONG SUBSYSTEMS

The physical arrangement of the subsystems sets the stage for biological subsystems' ability to function. Temperature, light, salinity, nutrients, and many other factors have an effect on both shallow and open water, which creates dynamic biological systems with respect to their seasonal and annual variability (FFSL 1999). Recreation and industry make use of and affect physical conditions and biological populations. For example, as surface-water inputs to GSL increase, salinity decreases; both high and low salinity levels can negatively affect brine shrimp populations. The eggs or cysts of brine shrimp are harvested commercially and regulated based on density in the water column.

This GSL CMP revision acknowledges not only that there are significant linkages between subsystems, but it also acknowledges that linkages can be affected by lake level. The GSL Lake Level Matrix illustrates the effects the lake level has on physical, socioeconomic, and biological subsystems. Within the matrix, each subsystem is broken into component resources or parameters and discussed in detail in the following sections. The matrix is a heuristic tool and will aid in the development of management strategies that consider the complex associations between resources and explicitly account for lake level variation.

2.2.2 Ecosystem Management

The USFWS defines ecosystem management as the "protection or restoration of the function, structure and species composition of an ecosystem while providing for its sustainable socioeconomic use" (USFWS 2011). Human needs are dependent on the capacity of an ecosystem to meet those needs in perpetuity, which is limited by the functionality of the ecosystem. It goes beyond conducting management activities in an ecosystem, and for this reason, it must include a set of common principles. Table 2.2 outlines the principles of ecosystem management.

Table 2.2. *Principles of Ecosystem Management*

Principle	Description
Sustainability	Ecosystem management does not focus primarily on deliverables but rather regards intergenerational sustainability as a precondition.
Goals	Ecosystem management establishes measurable goals that specify future processes and outcomes necessary for sustainability.
Sound Ecological Models and Understanding	Ecosystem management relies on research performed at all levels of ecological organization.
Complexity and Connectedness	Ecosystem management recognizes that biological diversity and structural complexity strengthen ecosystems against disturbance and supply the genetic resources necessary to adapt to long-term change.
The Dynamic Character of Ecosystems	Recognizing that change and evolution are inherent in ecosystem sustainability, ecosystem management avoids attempts to freeze ecosystems in a particular state of configuration.
Context and Scale	Ecosystem processes operate over a wide range of spatial and temporal scales, and their behavior at any given location is greatly affected by surrounding systems. Thus, there is no single appropriate scale or timeframe for management.
Humans as Ecosystem Components	Ecosystem management values the active role of humans in achieving sustainable management goals.
Adaptability and Accountability	Ecosystem management acknowledges that current knowledge and paradigms of ecosystem functions are provisional, incomplete, and subject to change. Management approaches must be viewed as hypotheses to be tested by research and monitoring programs.

Source: Ecological Society of America (2011).

This GSL CMP revision recognizes many of the principles outlined above. Later sections of the plan explore the development of ecological models that reflect complexity, interconnectedness, dynamism, and scale of the GSL ecosystem. With regard to ecosystem management and GSL, it is important to note that FFSL recognizes the human component of the ecosystem as it must for the Public Trust.

Adaptive management, a compliment to ecosystem management, is a process through which partnerships of managers, scientists, and other stakeholders learn together to create and maintain sustainable ecosystems (U.S. Department of Interior 2011). It is applicable to GSL and the GSL CMP revision because it links scientific understanding to management objectives, allows for uncertainties that may result in a change in management objectives, and takes action to achieve management objectives.

Driving forces behind the GSL ecosystem are lake level and salinity, and both are integral parts of the lake's ecosystem. FFSL intends to allow for as much natural lake level fluctuation as reasonably possible to enhance ecosystem processes. It is also important to recognize when human-induced impacts are altering or restricting lake hydrodynamics and the lake's ability to exist as a natural body of saline water.

This planning effort aims to initiate in-house collaborative coordination to resolve long-standing issues, integrate GSL management policies, and help determine gaps in information that require research or monitoring for this valuable local, state, and worldwide resource.

This GSL CMP revision provides a framework to help guide this activity. However, initiating more comprehensive planning efforts for the lake and its watershed will require legislation and financial backing. Multiagency collaborative efforts are essential to accomplish and support planning research and ecosystem monitoring objectives and to continue ongoing efforts.

This planning process has improved coordination among the divisions of UDNR. GSL management requires a coordinated front to address lake management issues. However, many issues transcend the state and private land boundaries, and post-plan watershed coordination will also help protect long-term sustainability.

As with watershed-level programs implemented in other areas (e.g., the Great Lakes and Chesapeake Bay), coordination at this scale can be harnessed in the GSL watershed (Adler 1999). A benefit to considering watershed-level management is that it focuses on restoration and protection rather than optimal resource use and development. Also, it considers conditions in which often overlapping or conflicting laws, regulations, and entities collectively develop comprehensive, science-based, long-range, and iterative solutions to GSL management.

2.2.2.1 SUBSYSTEMS MANAGEMENT AND PLANNING

Many management issues occur at the interface among the three subsystems. Each subsystem varies spatially, temporally, and structurally and impacts each of the others. As such, management actions intended to influence environmental conditions in one subsystem may impact another. For example, high lake levels in the 1980s and flooding (physical subsystem changes) impacted infrastructure and other major economic resources (socioeconomic subsystem) around the lake. Physical subsystem changes, such as fluctuations in lake level and salinity, influence the productivity of lake aquatic organisms (phytoplankton and brine shrimp populations). These changes also have implications for the quantity of wetland and riparian habitat available to migratory birds and other wildlife, thus demonstrating that GSL subsystems have many linkages and are dynamic and interactive (FFSL 1999).

2.2.3 Ecosystem Impacts

There are several types of ecosystem impacts that managers consider in planning and managing for important natural resources. Managers consider direct and indirect, short- and long-term, immediate, and site-specific impacts. Direct impacts are the result of circumstances or activities that occur at the same time and place and hence alter a system. Indirect impacts are further removed but are still reasonably foreseeable and influence a system. Cumulative impacts occur when there are multiple effects on the same resources. Gradual impacts occur on resources when combined with past, present, and future actions (FFSL 1999). There are many direct, indirect, and cumulative impacts to GSL and its environs. Developed for the 2000 GSL CMP, the following list cites some examples of human-related direct and indirect GSL impacts:

- Dikes and causeways
- Brine shrimp harvesting
- Upstream water allocation
- Water and air quality

- Exotic species introduction
- Mineral extraction
- Oil and gas production
- Lake level modification
- Recreational activities
- Grazing
- Discharges/accidental spills
- Population growth
- Wetland-nutrient loading
- Loss of GSL wetlands
- Agriculture activities
- Road salts
- Mosquito abatement
- Trash and pollution

Some GSL impacts have a positive effect on lake resources, such as the creation of state and federal wildlife management areas and duck club habitat enhancements. These alterations enhance habitat resources and provide forage and cover for wildlife. Other impacts may cause degradation over time. Ecosystem threats include population growth, water and air pollution, commercial and industrial development such as diking, and mineral extraction pond conversion.

The sovereign land multiple-use and sustainable yield management framework requires that lake managers consider the impacts listed above and others that could affect lake resources. Resource planners and managers consider impacts in lease permits, management activities, and in protecting resource sustainability. Better monitoring and research adds to the information base and helps managers make good management decisions and minimize impacts to the ecosystem.

Cumulative impacts to GSL resources are difficult to identify but will play an increasingly important role in lake management. As the GSL knowledge base continues to increase through monitoring and research, the consequences and mitigation measures to avoid cumulative impacts on lake resources will be better understood.

It is noted that the GSLAC-sponsored report, *Definition and Assessment of Great Salt Lake Health*, contains findings that are relevant to this section (and numerous other sections) of the 2013 GSL CMP. FFSL supports incorporating findings of the GSL health report into management of the lake. Unfortunately, the findings of the GSL health report could not be incorporated in the 2013 GSL CMP due to the timing of the health report's release (January 2012). FFSL will consider the GSL health report and its updates into future management plans and future management decisions.

2.2.4 Ecosystem Health and Salinity Considerations

A *healthy* ecosystem is one that existed before significant anthropogenic impact (FFSL 1999); however, the components of ecosystem health are difficult to define. By using the concept of ecological integrity, researchers and managers can assess the ability of ecosystems to support and maintain the full suite of functions, processes, and communities found within a range of natural variation. Although not all human impacts to the lake degrade ecosystem health, human-induced change to the larger system can degrade ecological integrity by modifying the range of natural variation and/or by limiting the ability of the ecosystem to adjust to variation. For example, modifications to the flood regime of GSL tributaries have truncated the upper extreme of natural flow variation, which has likely reduced the dynamism of wetlands around the GSL. Similarly, the introduction of invasive, non-native species, such as common reed (*Phragmites australis*; hereafter referred to as *Phragmites*) limits the establishment of native plants when opportunities for colonization due to variation exist. The effect of current conditions (e.g., low lake level and high salinity) on the health of brine shrimp populations is a concern for overall ecosystem health. Brine shrimp are important consumers of algae and are also an important food source for GSL birds. Brine shrimp are also commercially harvested, which complicates an ecosystem analysis. Brine shrimp population studies indicate that lower salinity levels in the South Arm can impact algal community compositions, specifically *Dunaliella virdis*, which have lower tolerance for salinity change. These green algae are a major food source for brine shrimp and have been replaced by larger pennate diatoms (Belovsky et al. 2011), which are difficult for brine shrimp to digest (Stephens and Gillespie 1976). Reduced salinity appears to contribute to a higher winter loss of brine shrimp cysts, making it difficult for the population to restart when conditions are favorable in the spring. Conversely, high salinity impacts brine shrimp populations by diminishing the *Dunaliella virdis* crop, which in turn results in lower oxygen levels that stress the organism during all life stages (Van Leeuwen 2011). Finally, because other environmental variables (e.g., nutrient inputs and algal species composition and abundance) also impact brine shrimp population numbers, this organism may not be the best indicator of ecosystem health or of the overall condition of the lake (FFSL 1999).

The manner in which ecosystem health is evaluated is an important factor to consider. Historical measurements of lake level and salinity along with paleolimnological studies conducted by USGS, USU, and DWQ (FFSL 1999) were used to assess the health of GSL ecosystems. An additional method to eventuate ecosystem health would be to investigate how a community or group of species responds to ecosystem change; however, historical data of this type are very limited. No single species is a reliable indicator of GSL ecosystem condition. In 1999, the Science Review Committee (SRC) suggested that other factors whose interactions and variability are less known (such as nitrogen, water transparency, temperature, brine shrimp harvesting, algae, diatoms, other primary producers, and invertebrates and their interactions) should be studied (FFSL 1999). The results of such a study (Belovsky et al. 2011) are discussed in more detail in section 2.7 (Biology).

Diatoms are often used as bioindicators of environmental change and are well preserved in lake sediments. They can be used to indicate past environmental conditions (FFSL 1999). Other past limnological variables can be inferred from the sediment record. This makes diatoms a powerful and robust tool for ecosystem management. However, this information is either limited or not available at this time (FFSL 1999).

The physical, socioeconomic, and biological/ecological subsystems and their resulting interactions describe one approach to investigate the implications of salinity and human impacts on GSL ecosystems. The economic and political reality in the context of GSL ecosystems planning is that the Northern Railroad Causeway is a human-induced change that is altering the function of GSL ecosystems. The Northern Railroad Causeway has restricted natural lake hydrodynamics (lake circulation, lake level, and lake salinity, or the movement of fluid in the lake) to a point at which environmental conditions have been noticeably altered. Undoubtedly, the human-induced alterations to GSL provide great challenges to GSL managers when attempting to define and manage the health of the GSL ecosystem.

2.2.5 Ecosystem Sustainability

Sustainability is “a system’s ability to maintain its structure (organization) and function (vigor) over time in face of external stress (resilience) … In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, attack, and prevent causes of environmental degradation where there are threats of serious or irreversible damage; lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation” (FFSL 1999).

Sustainability is achieved by knowing the state of the environment. This is achieved by conducting a resource inventory and provides the baseline to evaluate monitoring and to identify trends that are useful for formulating effective management policies. Managing for sustainability assumes that resource managers understand management actions and their consequences (impacts) on dynamic systems. Precise cause-and-effect observations are often vague and problematic because scientific information may have several different interpretations. Therefore, research and monitoring objectives must be carefully designed. Sustainable planning for the GSL ecosystem should include targets or objectives for determining the effectiveness of sustainable multiple-use and management. Management targets should be based on a scientific understanding of GSL ecosystems' limits and tolerances to human-induced change. Management targets may be established at different scales and levels (FFSL 1999). A few ideas to evaluate management objectives are as follows:

- Identify sustainability indicators or targets for resource management and decision making.
- Identify tradeoffs and determine if acceptable tradeoffs will maintain the integrity of GSL resources to ensure that each generation should at least inherit a similar natural environment.
- Identify environmental quality or performance measures that are reportable and measurable over time.
- Determine a conceptual approach for monitoring and assessing the state of the environment.
- Identify information needed to assess the state of the environment.
- Identify vigorous monitoring strategies.
- Design analysis and reporting strategies.

Sustainable use of GSL ecosystems means limiting the use of renewable natural resources (e.g., resources that naturally regenerate/replenish themselves) at a pace where they can renew themselves through natural processes (FFSL 1999). Ecosystem management objectives should include and consider the following:

- Allow for reasonable multiple-uses.
- Allocate resources wisely to ensure long-term sustainability.
- Establish checks and balances to ensure an acceptable level of environmental protection.
- Minimize negative impacts on GSL ecosystems.
- Engage industry in ensuring sustainable resources by preventing and managing for crises in their operations and to help in monitoring impacts.

These measures will allow for economic growth that is mindful of the limited natural resource base (FFSL 1999). It will be challenging to balance public needs and ensure long-term resource protection with projected population growth scenarios. Sustainable management ensures that GSL natural resources will be available for future uses.

2.2.5.1 LAKE LEVEL EFFECTS

Capturing the relationship Utahns have with GSL is enigmatic, but most often it is one of indifference. Other than the occasional odor emanating from the lake under certain weather conditions (Marcarelli et al. 2001), one aspect of GSL that reminds residents of its existence is lake level. It is during periods of high lake level that personal property and infrastructure are threatened by flood waters, whereas low lake levels result in access issues for industry, recreationists, and other user groups, which alert the larger population to this resource of worldwide significance. For example, at elevations above 4,208 feet, management thresholds for wildlife, infrastructure, and industry are impacted because the system of dikes, which impounds water for a specific use, becomes inoperable. Conversely at elevations below approximately 4,195 feet, critical wildlife habitat (e.g., Gunnison Island) may be accessible to predators by land. Similarly, as lake levels recede, access to brine by the evaporative mining industry and access to the lake itself by boats is impossible without dredging deeper channels.

These naturally occurring "extreme" conditions may or may not result in competition for resources by different user groups. It is at those lake levels in the middle of the historic range of 4,192–4,212 feet that the human environment has typically adapted to and manages for.

Lake level fluctuations are a natural component of the GSL ecosystem. Although specific lake levels may be ideal for industry and recreation uses, there is no one ideal lake level for the ecosystem as a whole. Rather, the system benefits from natural fluctuations in lake level. Fluctuating lake levels reset the successional clock, preserve the diversity of habitat around the lake, and reduce the presence of invasive species (such as *Phragmites*). At any given lake level, some resources will benefit or be harmed more than others (see Appendix A. GSL Lake Level Matrix). Even within a resource area, such as wildlife, there are some species or guilds that may fare better than others. Finally, lake level affects different areas of the lake in different ways. For example, whereas fringe wetlands may become inundated at higher lake levels, higher lake levels generally provide isolated habitat for nesting birds on many islands.

As illustrated by the GSL Lake Level Matrix, this GSL CMP revision intends to develop management strategies that consider lake level effects at a range of elevations and to offer prescriptive solutions to avoid adverse impacts to resources and mitigate competition among user groups.

2.3 Water

2.3.1 Natural Properties of Great Salt Lake

2.3.1.1 GREAT SALT LAKE PHYSICAL CONFIGURATION

GSL is a remnant of Pleistocene Lake Bonneville and occupies the lowest point in a 34,000-square mile drainage basin. Climate, basin configuration, and the result of erosion and deposition determine lake depth, size, and salinity. At the water elevation of 4,200 feet above sea level, GSL has a surface area of 1,608 square miles, making it the fourth largest terminal lake in the world. The average depth of the lake is approximately 14 feet when it is at an elevation of 4,200 feet. Because of the broad, shallow nature of GSL, a small change in lake level results in a large change in lake area. Bear River Bay is the freshest part of the lake due to inflow from the Bear River and the relatively small outlet to the main body of the lake. Bear River Bay is bounded by the Promontory Mountains to the west and the Northern Railroad Causeway to the south. The North Arm of GSL, also known as Gunnison Bay, is naturally more saline than the rest of the lake because it receives the least amount of freshwater inflow. Since the 1960s, Gunnison Bay has become hypersaline due to restricted flow between the North and South arms due to the Northern Railroad Causeway. The South Arm of GSL, including Gilbert Bay and Ogden Bay, is the largest area of the lake and receives inflow from the Weber River. Farmington Bay, in the southeast of GSL, receives inflow from the Jordan River and is also fresher than the South Arm. Although salinity gradients exist naturally in GSL, they have been accentuated by the fragmentation of the lake through causeway and dike construction (see section 2.3.2). There are several large islands in GSL. From largest to smallest, these include Antelope Island, Stansbury Island, Fremont Island, and Carrington Island (see Map 1.1).

2.3.1.2 GREAT SALT LAKE BASIN HYDROLOGY

The GSL Basin is one of many closed basins in the Great Basin and encompasses most of northern Utah, parts of southern Idaho, western Wyoming, and eastern Nevada. GSL receives approximately 3.5 million acre-feet of fresh water each year, primarily from the Bear River, direct precipitation, the Weber River, and the Jordan River (Table 2.3). Groundwater flows are a minor hydrologic contributor to the lake and occur in the form of subsurface flow. These freshwater additions are incorporated into the tributary values in Table 2.3 and account for only 3.6% of total inflow (DWRe 2001). The western portion of the basin includes the West Desert, which does not produce any notable surface-water flows but does contribute a small amount of groundwater to GSL. The three major rivers to GSL carry water and constituents from complex watersheds that include diverse land cover types, geomorphic structures, and land uses as well as a wide range in elevation, slope, and physical and ecological characteristics (see Map 2.1).

Table 2.3. *Summary of Water Inflow to Great Salt Lake*

Tributary	Drainage Area (square miles)	Average Annual Precipitation (inches per year)	Average Annual Flow to GSL (acre-feet per year)	Total (%)	Discharge Location in GSL
Bear River	7,118	21	1,450,000	40.5%	7% to Bear River Migratory Bird Refuge 93% to Bear River Bay
Weber River	2,476	26	640,300	18%	Ogden Bay Waterfowl Management Area (WMA), other waterfowl management areas, and Willard Bay
Jordan River	805*	23	438,000	12%	Farmington Bay, Gilbert Bay, various duck clubs, and the Inland Sea Shorebird Reserve
West Desert Basin	18,281	10	54,000	2%	Gilbert Bay and Gunnison Bay
Direct precipitation	1,500	12.5	1,000,000	28%	Entire lake
Total	**30,180**[†]	**–**	**3,582,300**	**100%**	**–**

Source: DWRe (2001).

* 4,651 square miles if including Utah Lake Basin.

[†] 34,026 including the Utah Lake Basin.

2.3.1.2.1 Bear River

The Bear River is the largest tributary to GSL, contributing an average of 1.45 million acre-feet of fresh water per year (DWRe 2001). The Bear River enters GSL at Bear River Bay and is the main freshwater source for the Bear River Migratory Bird Refuge as well as other wildlife areas along the northeastern shores of GSL.

The headwaters for the Bear River begin in the Uinta Mountains and travel 500 miles before discharging into GSL. The Bear River Basin drains approximately 7,118 square miles of northeastern Utah (including Cache Valley), southwestern Wyoming, and southeastern Idaho. Logan City, Brigham City, Tremonton City, and many small communities in southern Idaho lie in the Bear River Basin. Precipitation in the Bear River watershed averages 21 inches per year.

Steep terrain (with slopes as high as 85 degrees) characterizes the mountains surrounding the relatively flat valleys (including Cache Valley), where soils consist of alluvium and ancient lacustrine sediments. The Bear River and its tributaries flow through old lake bottoms; this river system consists of a complex channel with many oxbows, backwaters, eddies, and side channels. Major tributaries to the Bear River include the Logan River, the Little Bear River, and the Cub River.

The hydrology of the Bear River has been modified significantly over the past century, with six hydroelectric plants on the main stem and over 450 irrigation companies that own and operate systems in the basin. In 1911, a canal was constructed to connect the Bear River to Bear Lake, which had been hydrologically disconnected for approximately 11,000 years. Water released from Bear Lake during hot summer months supplements the flow of the Bear River during low-flow periods. During the winter, water from the Bear River is diverted into Bear Lake. Additional diversions and hydrologic modifications occur to supply water to municipalities, individual families, agricultural lands, waterfowl refuges, industries, and others.

2.3.1.2.2 Weber River

The Weber River is the second largest tributary to GSL, contributing an average of 640,300 acre-feet of fresh water per year (DWRe 2001). The Weber River enters GSL through the Ogden Bay WMA, the Harold Crane State WMA, and Willard Bay, which ultimately flows into Bear River Bay and then into the main body of GSL.

The headwaters for the Weber River begin in the Uinta Mountains and travel 125 miles before discharging into GSL. The 35-mile-long Ogden River flows into Weber River west of Ogden City. The Weber River Basin drains approximately 2,476 square miles of northeastern Utah, including most of Summit County and much of Morgan and Weber counties. Park City and Ogden City lie within the Weber River Basin. Steep mountain terrain characterizes the upper reaches of the basin, whereas most of the system flows through flat alluvial valleys that were formed by Lake Bonneville. The major tributaries to the Weber River are East Canyon Creek and Ogden River. Precipitation in the Weber River Basin averages 26 inches per year (DWRe 2009).

The hydrology of the Weber River has been modified significantly over the past century, with seven large reservoirs in the system that primarily retain water for agricultural and recreation uses. Just upstream of the Weber River Delta, water is diverted from the Weber River into Willard Bay Reservoir (DWRe 2009). Another diversion includes a pipeline from Rockport Reservoir into Park City; however, most of this water returns to the Weber River system after being treated at the Silver Creek Water Reclamation Facility and discharged into Silver Creek.

2.3.1.2.3 Jordan River

The Jordan River contributes an average of 438,000 acre-feet of fresh water per year to GSL, including surface flow from the Jordan River and surplus canal as well as groundwater recharge (DWRe 2001). The Jordan River Basin drains approximately 805 square miles, including Salt Lake Valley and its surrounding mountains. However, the Jordan River also receives water from the upstream Utah Lake Basin, which encompasses an additional 3,846 square miles (FFSL 2010). From Utah Lake, the Jordan River flows 44 miles to Farmington and Gilbert Bay.

Steep mountain terrain in the Wasatch, Oquirrh, and Traverse mountains surrounding Salt Lake Valley characterizes the headwaters of the Jordan River Basin. Six tributaries comprise 80% of the annual surface-water flow to the Jordan River (excluding Utah Lake and the Provo River) and include City Creek, Red Butte Creek, Parleys Creek, Mill Creek, Big Cottonwood Creek, and Little Cottonwood Creek. Precipitation in the Jordan River watershed averages 23 inches per year (DWRe 2010). The Jordan River itself flows through the relatively flat Salt Lake Valley. The Jordan River Basin is the most populous in Utah and provides municipal water to the large communities within Salt Lake County.

The hydrology of the Jordan River has been modified significantly over the past century; however, Mountain Dell and Little Dell reservoirs are the only reservoirs in the basin (DWRe 2010). Jordan River receives approximately 295,000 acre-feet of water from Utah Lake releases each year. An additional 173,500 acre-feet of surface water is contributed to the Jordan River from Wasatch Mountain streams and 4,500 acre-feet per year from Oquirrh Mountain streams. An estimated 219,000 acre-feet per year enters the basin as groundwater recharge. Up to 171,000 acre-feet of water can be imported to the basin from elsewhere. Municipal and industrial water use was 333,700 acre-feet in 2005 (DWRe 2010).

2.3.1.2.4 West Desert Basin

The West Desert Basin covers approximately 11.7 million acres (22% of Utah); however, it is the most sparsely populated area of the state due to its aridity and remoteness. The West Desert Basin extends along the Utah–Nevada state line to the west and by GSL itself to the east. Mountains surrounding desert valleys within the basin catch precipitation and supply intermittent and ephemeral streams. Tooele is the largest population area in the basin. All of the populations in the West Desert Basin obtain their water from groundwater sources. Groundwater recharge areas include the Oquirrh Mountains, South Mountains, and Stansbury Mountains. The West Desert Basin contributes approximately 54,000 acre-feet of water, primarily through groundwater flows, to GSL.

2.3.1.3 NATURAL SOURCES OF SALINITY AND MINERALS

The inflow waters to GSL carry natural salinity and minerals from the weathering of the diverse rock types in the GSL Basin. Lake Bonneville, the larger predecessor to GSL, routinely deposited carbonate into lake-bottom sediments. Today, the largest mineral inputs come from the three large river systems that primarily carry calcium bicarbonate, and GSL continues to deposit carbonate on the bottom of the lake. In addition, each of the large river systems carries unique combinations of secondary constituents, primarily sodium and carbonate (Jones et al. 2009). The Bear River to the north generally contains a higher portion of sodium carbonate originating in its upper watershed. The rivers to the south that drain into Utah Lake and that are eventually drained by the Jordan River contain higher concentrations of sulfate. The Weber River is typically the most dilute source due to the predominance of silicate rocks in its watershed (Jones et al. 2009). In addition, springs and groundwater around the lake are characterized by sodium chloride (Jones et al. 2009). Once deposited in GSL, water evaporation results in increased concentrations of salts. Because there is no outlet from the lake, these salts stay within the GSL system, and as is the case in closed basin systems, evaporative effects are the driving forces that affect mineral formation and solute evolution. The accumulation of salts over a millennia has resulted in the hypersaline conditions in portions of GSL today.

GSL is one of the most saline waterbodies in the world (Sturm 1980). Prior to segmentation of the lake through dikes and causeways, lake brines were similar in composition and concentration throughout the lake (Loving et al. 2000). Today, Gunnison Bay (the North Arm) continues to be hypersaline, with salinities over 25%. The other bays of GSL typically range in salinity from 5% to 15%, depending on freshwater inputs, circulation, and lake level (see section 2.3.3.2).

2.3.1.4 LAKE LEVEL EFFECTS

2.3.1.4.1 Natural Fluctuations of Lake Level

Lake fluctuations are natural, expected, and an integral component to the lake system. The watershed of GSL responds to global and regional climatic variability, including precipitation, streamflow, temperature, and other hydrologic processes. Lake hydrology, watershed processes, and regional and global climatic processes affect lake level. As the lake level goes down, the volume of the lake also goes down and salinity increases.

Water enters GSL from freshwater rivers (Bear River, Weber River, and Jordan River), groundwater, and as direct precipitation. At present, natural evaporation from the lake surface and from evaporation ponds is the only way water leaves GSL. Further, the average, total, annual evaporation roughly equals average annual inflow, although inflow exceeds evaporation during cooler, wetter weather cycles, and evaporation exceeds inflow during hotter, dryer cycles. All water that is diverted from the lake is used for mineral extraction by evaporation and is included in the annual evaporation estimates. A GSL evaporation estimate that does not include diverted water has yet to be determined.

The physical configuration of the lake and its high salinity create a “buffering” effect on the rate of evaporation of the lake. In general terms, as the lake rises, it increases significantly in surface area and declines in salinity. These factors contribute to an increase in annual lake water evaporation and tend to slow the rise of lake level. Conversely, when the lake level drops, the surface area diminishes and the salinity increases, reducing the total annual evaporation. The lake, therefore, has a natural mechanism to inhibit drying up and has a tendency to slow its own rate of rise. It has been suggested that a one-time removal of water from the lake, while noticeable at the time of removal, will eventually “heal” itself through this buffering effect, returning to pre-removal elevations. Long-term increases in diversions will, however, produce long-term changes in lake level.

The naturally occurring water level fluctuations of GSL are termed *flooding* when the level of the lake begins to adversely affect structures and developments that are located within the floodplain. However flooding is a natural process and is mostly beneficial to species adapted to this dynamic environment. The impact of flooding is greatest around the shores of the South Arm where most of the recreational, industrial, wildlife management, and transportation facilities have been built. To minimize the impact of flooding, the present and past elevations of the lake and its anticipated short- and long-term fluctuation (rises and falls) should serve as guides to determine “safe” construction areas. These should also identify areas that may be subjected to inundation, wind tides, ice damage, or shallow groundwater problems.

An extensive geologic record of prehistoric lake fluctuations is preserved in the form of shorelines and other geomorphic evidence in the sediments underlying the lake bed and in the lagoons around the lakeshore. This prehistoric record reveals that GSL has risen twice above the 4,220-foot level in the last 10,000 years and numerous times to elevations between 4,212 and 4,217 feet. The rises above the 4,220-foot level are exceptional. They result from significant departures from what is considered normal climate for the Great Basin in nonglacial times. The rises to the 4,217-foot level occur with climate that is "normal” for the region. They result from a series of years with precipitation above average, but normal for the region. An initial high lake level coupled with consecutive years of above-average precipitation will result in a high lake level.

GSL has historically (defined as the period from 1847 to the present) experienced wide cyclic fluctuations of its surface elevation (Figure 2.4). Since 1851, the total annual inflow (surface, groundwater, and precipitation directly on the lake surface) to the lake has ranged from approximately 1.1 to 9.0 million acre-feet. This wide range of inflow and changes in evaporation have caused the surface elevation to fluctuate within a 20-foot range. Historically, the surface elevation of the lake reached a high of 4,212 feet in the early 1870s and a low of 4,191 feet in 1963 (Figure 2.4). The lake reached 4,212 feet again in 1986 and 1987 (FFSL 1999).

Because GSL is a terminal lake, the surface level of the lake changes continuously. Short-term changes occur in an annual cycle of dry, hot summers and wet, cool winters. The annual high lake level, which normally occurs between May and July, is caused by spring and summer runoff. The annual low lake level occurs in October or November at the end of the hot summer evaporation season (Figure 2.5).

The average, annual (pre-1983) fluctuation of the South Arm, between high and low, was approximately 1.48 feet; the North Arm fluctuation averaged 0.99 feet. The difference between the magnitude of the South and North Arm fluctuations is due mainly to the flow-restrictive influence of the Northern Railroad Causeway and the lack of tributary inflow to the North Arm.

Long-term climatic changes occur with overlapping periods of approximately 20–120 years and perhaps longer. Historically, the magnitude of annual lake level change has been greatest when the lake rises. The largest recorded annual rise of the South Arm is 4.8 feet (in 1983); whereas, the largest recorded annual fall is 3.2 feet (in 1989). The 1983 rise was exceptional and was due to high snow pack and above-normal spring precipitation (FFSL 2000). From 1904 to 2010, the lake rose during a 52-year nonconsecutive period an average of 1.6 feet per year. During the same period, the lake fell during a 55-year nonconsecutive period an average of 1.5 feet per year (Figure 2.3). This suggests that outside of the unusual event in the early 1980s, the magnitude and frequency of lake level fluctuations are roughly equal for years when it rises versus falls.

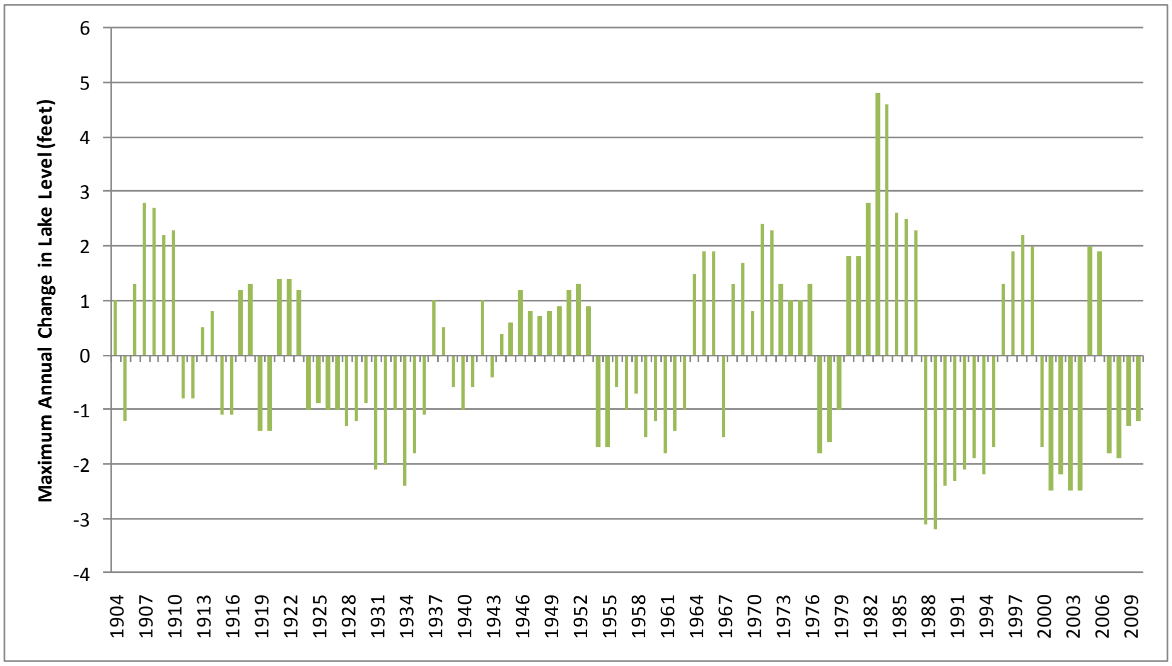


Figure 2.3. Maximum annual change in GSL level as measured by the USGS Gage 100100000 at the Saltair Beach State Park.

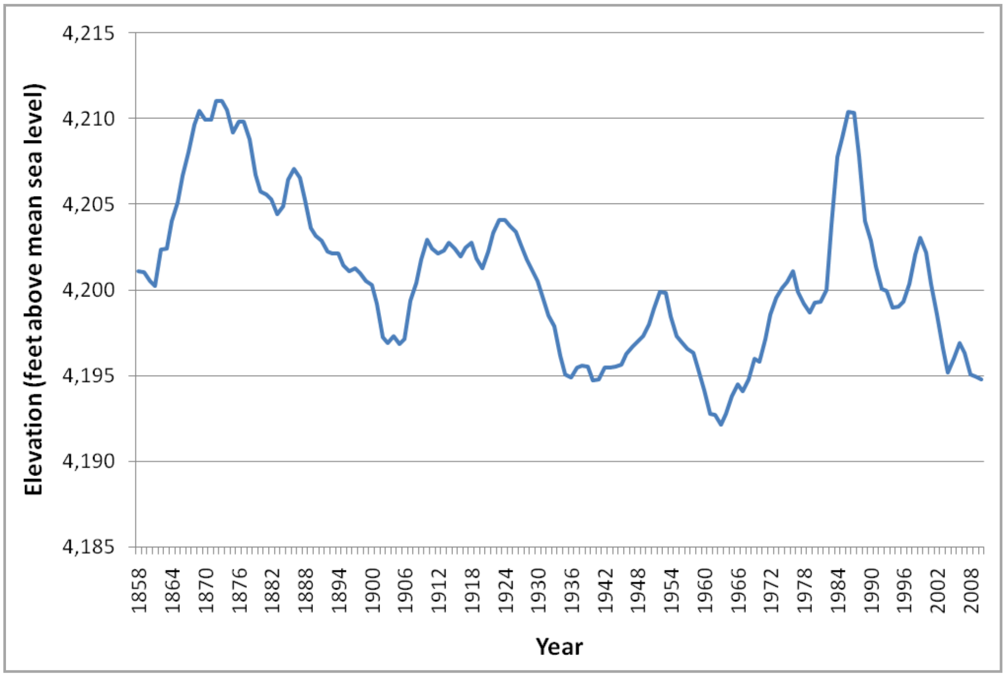


Figure 2.4. Historic, average, annual level of Great Salt Lake as measured at Saltair.[3]

[3] The historic hydrograph of GSL in Figure 2.4 is based on measurement at a series of lake gages since 1875 and on estimates of the lake level for the period prior to 1875. These estimates are based largely on interviews with stockmen who moved livestock to and from Antelope and Stansbury islands from 1847 to 1875. The annual variations shown for this early period are the average of those measured since 1875. Although the major features of the pre-1875 hydrograph are real, the details are uncertain. For the period since 1875, a small but significant uncertainty exists in the elevation of the various gages used and thus an uncertainty of several tenths of a foot exists in the absolute elevation of the lake level shown on the hydrograph for certain periods. Any analysis of the hydrograph should consider the uncertainties in the data upon which it is based.

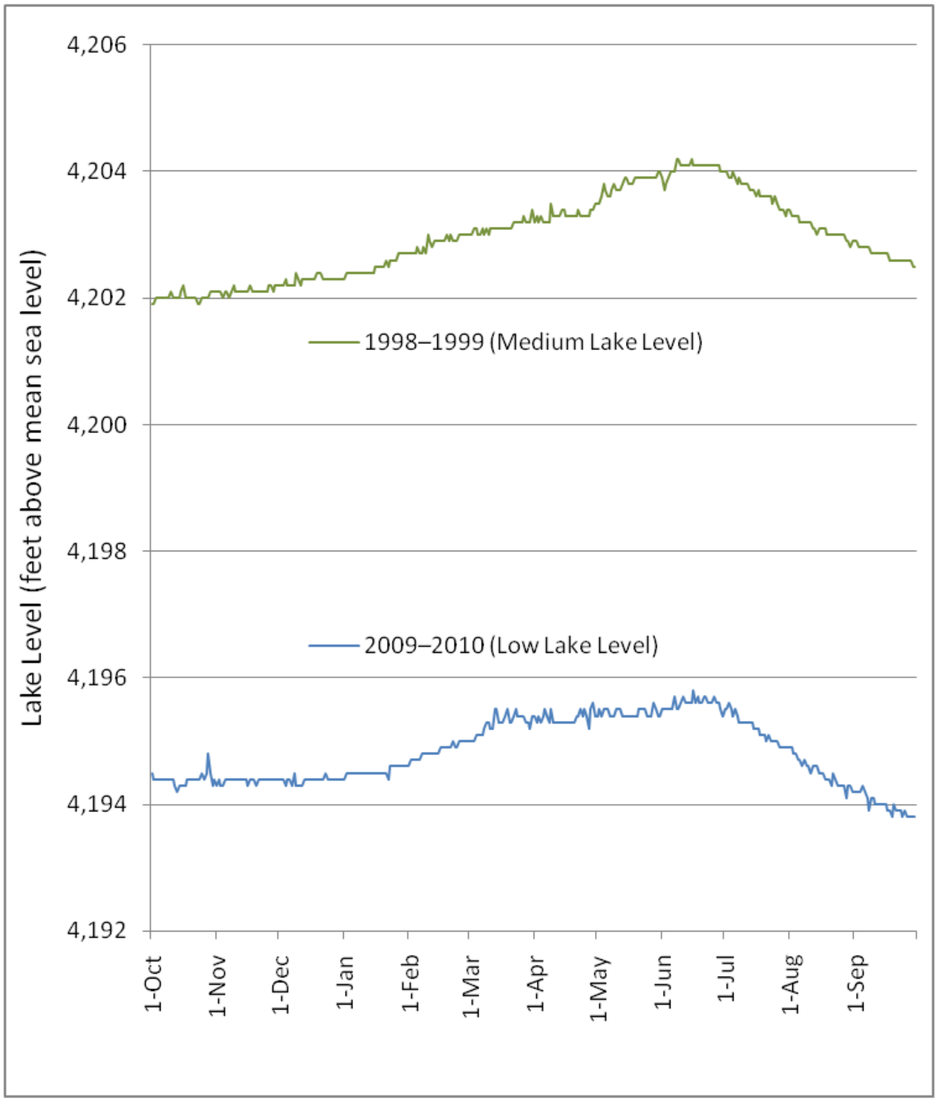


Figure 2.5. Annual fluctuation in level of Great Salt Lake between water year 1999 and 2010, as measured at Saltair.

2.3.1.4.2 Area and Volume Relationship to Lake Level

Because of the broad, shallow nature of GSL, its surface area expands rapidly as its elevation increases. Elevations of approximately 4,200 feet and approximately 4,213 feet represent a common lake level and the historical high lake level, respectively. Between these two elevations, the area of the lake increases more than 47% from approximately 892,900 to 1,867,900 acres (Figure 2.6). Within this range, flooding potential exists. Above-normal annual fluctuations, such as those experienced in 1983 and 1984, result in extensive flooding. At low lake levels, large areas of playa are exposed; at high lake levels, large areas of lake shoreline can be inundated. Seasonal and long-term fluctuations in lake level produce dramatic changes in the lake's shoreline. These fluctuations are an integral part of the lake ecosystem.

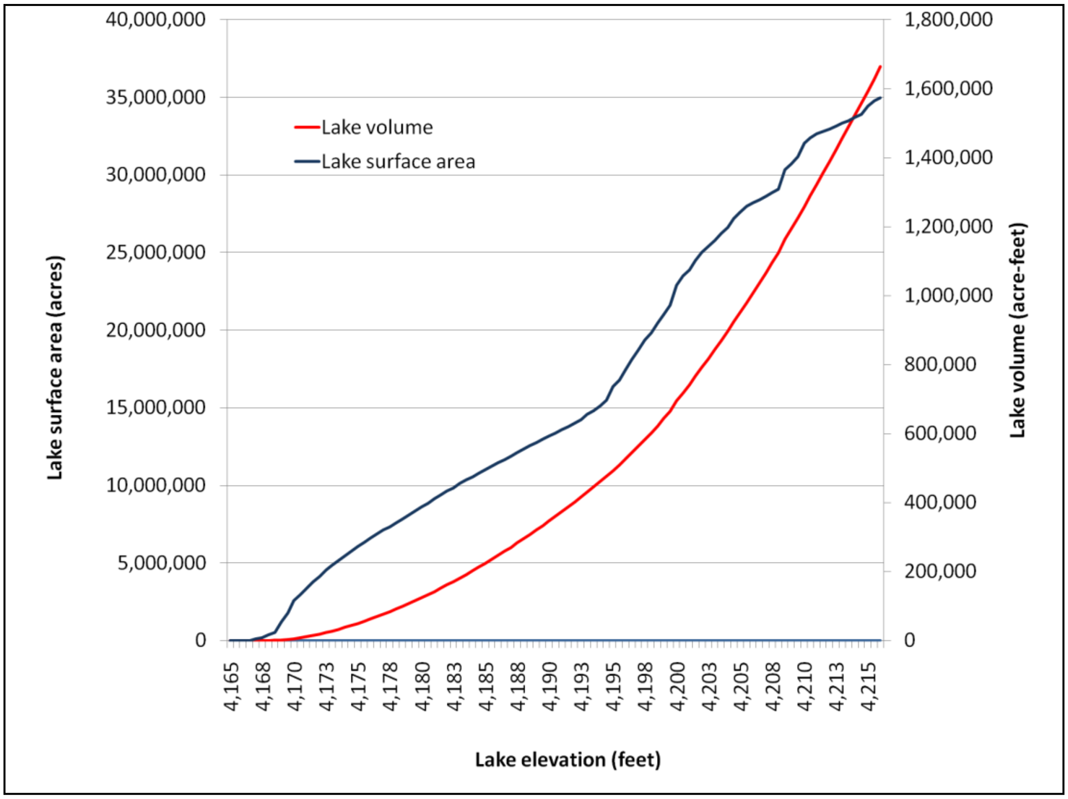


Figure 2.6. Great Salt Lake elevation compared with lake area and volume (Baskin 2011).

2.3.1.4.3 Islands

Islands are an important component of the habitat of many bird species found at GSL (see section 2.7 [Biology]). As GSL lake levels go down, some islands become accessible from the mainland by predators, reducing their value as nesting or foraging refuges. Likewise, as lake levels rise, island habitat becomes scarcer, especially habitat that is located at lower elevations on the islands. This can have important implications for wildlife management on GSL (see section 2.7 [Biology]).

In general, most island habitats are protected at lake elevations (levels) of 4,199–4,206 feet, with the notable example of Stansbury Island, which is landlocked below 4,207 feet. Table 2.4 highlights when GSL islands are accessible by land and when they are inundated. The information is also highlighted in the GSL Lake Level Matrix (see Appendix A).

Table 2.4. *Great Salt Lake Island Accessibility and Inundation*

Island	Elevation (feet)	
	Accessible by Land	Inundated
Stansbury	4,207	n/a*
Carrington	4,203	n/a*
Hat	4,199	n/a*
Gunnison	4,195	n/a*
Fremont	4,195	n/a*
Antelope	4,200	n/a*
Dolphin	4,198	n/a*
Mud	4,201	n/a*
Egg	4,195	4,205
White Rock	4,195	4,212
Other small islands	4,195	4,205

* Inundation occurs at elevations above 4,213 feet.

2.3.1.4.4 Predicting Lake Levels

For planning purposes, it is important to know the maximum movement that might be expected during a given period of time. Based on historic estimated and measured lake levels, it is estimated that during six-year blocks of time from 1847 through 1982, the maximum measured one-year upward fluctuation was approximately 6 feet. A notable exception to this was seen in the 1980s when the level of the lake increased by more than 12 feet over the course of five years. When the trend is downward, the maximum one-year downward fluctuation is approximately 2.5 feet.

During the early 1980s when the lake rose to 4,211.85 feet, there was a great deal of interest in forecasting future levels of GSL (FFSL 1999). With hindsight, some of these forecasts seemed to show some promise; however, there was a general consensus by researchers and climatologists at the time that predictions could not be made with any degree of assurance. There still remains a general skepticism by researchers and climatologists that these forecasts can be made with any assurance. A recent paper compared four models for forecasting GSL levels and found that Fractional Integral Generalized Auto-Regressive Conditional Heteroskedasticity (or FIGARCH) to be the best predictive model (Li et al. 2007; Wang et al. 2010); however, these models are not widely used by the planning community.

2.3.2 Human Modifications to the Natural Lake System

2.3.2.1 FRAGMENTATION OF GREAT SALT LAKE THROUGH CAUSEWAYS AND DIKES

Since the early 1900s, GSL has been fragmented by dikes and causeways constructed for a variety of purposes. Several of these inhibit the unrestricted movement of lake brines among large areas of the lake (Map 2.2). Before this fragmentation, there was substantially more exchange of water between bays, although there was still a salinity gradient from the areas of the lake near river inflows and the North Arm of GSL.

2.3.2.1.1 IMC Kalium Ogden Corp's Dike, ca. 1900

Bear River Bay is separated from the main body of the lake by IMC Kalium Ogden Corp.'s dike and the Bagley Fill, which was constructed around 1900 and extends eastward from Promontory Point to Little Mountain.

2.3.2.1.2 Northern Railroad Causeway, ca. 1959

Construction on the Northern Railroad Causeway began in 1956 and was completed in 1959. This rock-fill causeway separates the main body of the lake between Promontory Point and Lakeside and was known as the Southern Pacific Railroad (SPRR) Causeway. This causeway includes the Rambo and Saline fills, which were constructed around 1900. Construction of this rock-filled causeway replaced a wooden trestle that had been constructed in the early 1900s. The wooden trestle provided more circulation between the North and South arms of the lake (Gwynn 2002). The causeway created a separation between Gunnison Bay and the main body of GSL, now referred to as the North and South arms of the lake. The causeway also separates Bear River Bay from the South Arm. Even with the engineered permeability of the causeway and the incorporation of two 15-foot-wide × 20-foot-deep box culverts through the causeway, brine mixing was greatly diminished.

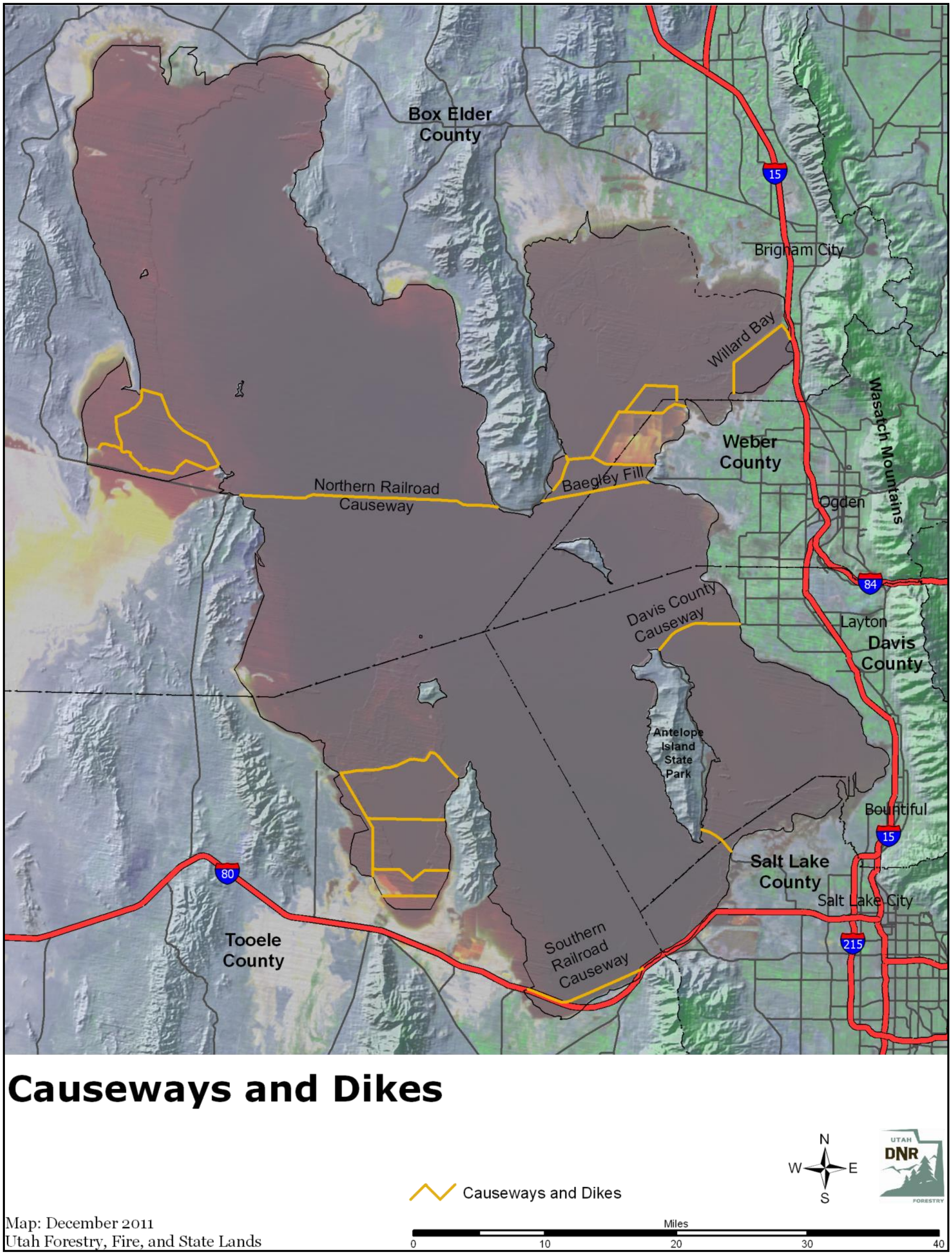
2.3.2.1.3 Modifications to the Northern Railroad Causeway, ca. 1984 and ca. 1996

The Northern Railroad Causeway was modified in the mid-1980s to increase circulation between the North and South arms. During the 1980s, fill material was added to the causeway, and in 1984, a 290-foot-wide breach was opened near the western end of the causeway to reduce the elevation difference between the two arms. Work on the causeway continued to the late 1980s, and the original culverts were largely plugged, limiting most return exchange of water from the North Arm to the South Arm. In August 1996, the breach in the causeway between Gunnison and Gilbert bays was lowered from 4,200 feet to 4,198 feet (Loving et al. 2000). DWRe was responsible for further decreasing the causeway breach elevation to 4,193 feet in 2000 (Klotz 2011). Today, Bear River and Gunnison Bay remain largely separated from the main body of the lake by the rock-fill causeway.

2.3.2.1.4 Antelope Island Causeways, ca. 1952 and 1969

Farmington Bay was part of the main body of the South Arm of GSL until it was isolated by the construction of two earthen causeways. The first causeway (the Southern Causeway) was built from the south end of Antelope Island southeastward to the mainland in 1952. This causeway inhibited water exchange between the main body of the lake and the bay at the south end of the island and channeled the full flow of the Jordan River into Farmington Bay. The causeway is no longer used and is not visible at mid-lake levels. There is no public for this causeway.

The second causeway (the Davis County Causeway) extends from the north end of Antelope Island eastward to the mainland and was constructed in 1969. With the construction of this causeway, Farmington Bay was essentially isolated from the main South Arm of the lake (with the exception of two bridged openings) and mixing between the two bodies of water was severely restricted (Gwynn 1998).



Map 2.2. Causeways and dikes on Great Salt Lake.

2.3.2.2 WATER DIVERSIONS AND WATER RIGHTS

2.3.2.2.1 Administration of Water Rights and Diversions

The diversion of water from GSL is governed by the same Utah water appropriation laws and regulations as the diversion of water from streams, springs, or wells. Under Utah law, all waters of the state are the property of the public (UTAH CODE § 73-1-1). A water right secures to an individual or entity the right to divert the water and place it to a recognized beneficial use. All water rights in the state are administered by the State Engineer with the assistance of DWRi staff.

A water right is acquired by filing an application with the State Engineer and receiving approval. If the application is approved, the applicant generally has five years to develop the project, place the water to beneficial use, and submit proof of the beneficial use to the State Engineer. Extensions of time for filing proof can be requested. An approved water right is considered to be the property of the applicant. Once proof of beneficial use is submitted (defining the quantity of water developed and the water uses), the State Engineer issues a Certificate of Appropriation, which the applicant may file with the local county recorder. At this point, the water right is said to be perfected and is treated similar to real property. To maintain a water right, the water must be diverted or physically removed from its natural source. The only exception to this rule is approved in-stream flow rights, which must be held by either DWRi or DWR.

For an application to be approved for development, the following conditions must exist:

- There must be unappropriated water in the proposed source.
- The proposed use must not impair existing rights or interfere with a more beneficial use of the water.
- The proposed development must be physically and economically feasible and not prove detrimental to public welfare.
- The applicant must have the financial ability to complete the proposed works.
- The application must be filed in good faith and not for speculation or monopoly (UTAH CODE § 73-3-8).

If there is reason to believe that an application will interfere with a more beneficial use, unreasonably affect public recreation or the natural stream environment, or prove adverse to public welfare, the State Engineer will reject the application.

There are several reasons a water right may be terminated. An unperfected water right may be terminated by the State Engineer 1) at the applicant's request, 2) if the applicant fails to meet the criteria for appropriation or the conditions of approval, or 3) the applicant fails to develop the project in the time allotted. Once a water right is perfected, there are two reasons it may be terminated: 1) The water right holder can file a statement of abandonment and forfeiture with the State Engineer and the local county recorder, or 2) the courts may terminate the water right as part of a civil proceeding.

2.3.2.2.2 Existing Water Rights in the Great Salt Lake Basin

Tributary Water Rights

Except for the Bear River drainage, the West Desert, and the lake itself, all surface waters of the GSL Basin are considered to be fully appropriated, except during high water years. On the Bear River, appropriations are still allowed; however, there are factors that may restrict the amounts available. At present, the Board of Water Resources, by statute, is considering various alternatives for the development of Bear River water for use in various locations along the Wasatch Front. Development of the Bear River is subject to the limitations of the Bear River Compact.

Groundwater Rights

The Jordan River Basin, the upper Weber River Basin, and Tooele Valley are closed to new appropriations of groundwater. Groundwater is still available in the Bear River Basin, the West Desert Basin, and on portions of the eastern shore of GSL.

Groundwater withdrawals from Curlew Valley could impact freshwater flows to Locomotive Springs, an important area for wildlife on the north shore of the lake. The groundwater system in Curlew Valley is the source of water for Locomotive Springs. The basin is in both Idaho and Utah. Most of the groundwater withdrawals from this flow system are in Idaho. Due to decreased hydrostatic pressure in this aquifer, the potential for salt-water intrusion is another concern. The Utah portion of the valley has been closed to new groundwater applications, except single-family domestic wells, since 1976. The data show that the discharge from Locomotive Springs has dropped considerably during the last 40 years. The solution to this matter is complex and potentially very controversial—it will most likely take considerable effort to resolve.

Great Salt Lake Water Rights

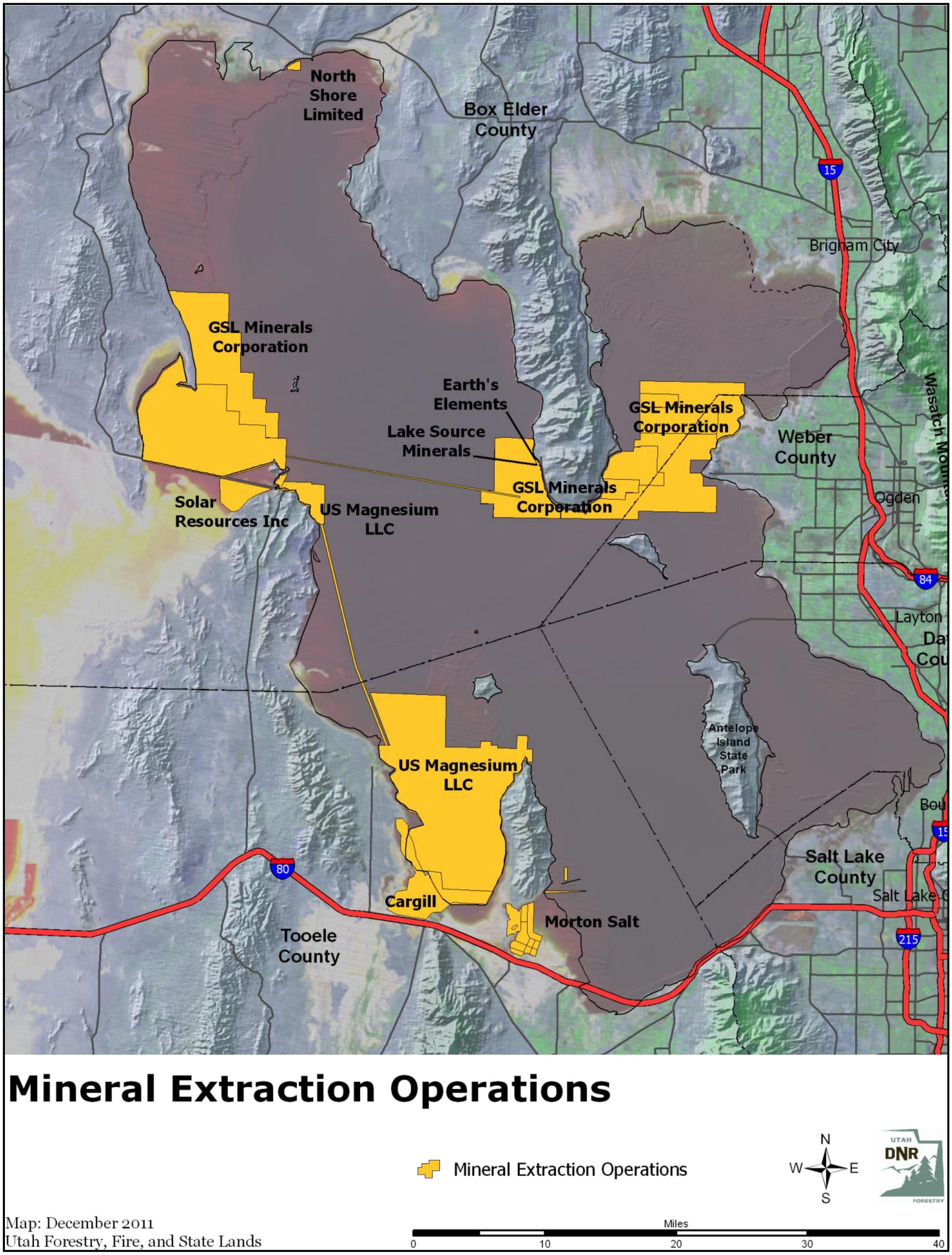
For administrative purposes, the State Engineer has divided the GSL Basin into sub-basins. Each sub-basin has its own set of policies governing the appropriation and management of its water. GSL itself is open to appropriation. However, the sitting of diversion facilities is dependent on the applicant securing the proper easements and/or permits from the responsible regulatory agencies and landowner.

There are currently 13 perfected water rights to divert water from the lake (Table 2.5); all are owned by companies or individuals in the mineral extraction industry (Map 2.3). The earliest priority date of these rights is 1940; the latest is 2003. Under these rights, if used to their fullest, it is possible for the rights holders to divert 416,776 acre-feet per year from GSL. Due to economic limitations, climatic conditions and the available evaporative surface, only 77,600–338,000 acre-feet per year are currently diverted. Most of this water is evaporated, whereas very small amounts return to the lake through pond leakage and flushing.

Table 2.5. *Perfected Water Rights for Great Salt Lake in Order of Priority Date as of 9/7/2011*

Water Right No.	Owner	Status	Priority Date	Cubic Feet per Second	Acre-feet	Use
15-306	Salt Point Land Company, LLC	Certificated	12/21/1940	10.31	3,436*	Salt
15-341	Salt Point Land Company, LLC	Certificated	09/15/1949	10.31	961*	Salt
15-414	Morton Salt, Inc.	Adjudication decree	05/13/1955	20	14,479*	Salt
13-228	Lake Crystal Salt Company	Water user's claim	01/24/1961	12	7,300*	Salt
15-517	Key Minerals	Adjudication decree	07/20/1961	0.1	72*	Salt
13-246	GSL Minerals	Certificated	01/08/1962	134	27,000*	Salt
15-616	US Magnesium	Adjudication decree	03/22/1965	–	54,750	Magnesium
15-2161	US Magnesium	Adjudication decree	05/09/1967	–	54,750	Magnesium
13-2137	Lake Crystal	Water user's claim	10/19/1967	10	7,240*	Salt
16-727	US Magnesium	Certificated	10/16/1972	–	35,290	Magnesium
16-748	US Magnesium	Certificated	07/21/1986	103	75,000	Magnesium
15-2182	Morton Salt, Inc.	Certificated	03/04/1993	75.2	54,442*	Salt
13-3723	North Shore	Certificated	09/03/2003	–	125	Brine
Total possible diversions					**334,845**	

*Acre-feet estimates based on water rights for an instantaneous flow (cubic feet per second) assuming the right is exercised during its full period of use.



Map 2.3. Mineral extraction operations.

Eight water rights applications have been approved for development (Table 2.6). Seven of these rights, all owned by mineral extractors, represent a possible diversion of 377,768 acre-feet per year for mineral extraction. The earliest priority date of these rights is 1962; the latest is 2008. Like the perfected rights, most of the water diverted under these applications would be consumed by evaporation.

Table 2.6. *Approved but Undeveloped Water Rights on File with the Utah Division of Water Rights as of 09/07/11*

Water Right Number	Owner	Priority Date	Cubic Feet per Second	Acre-feet	Use
13-3091	GSL Minerals	01/08/1962	46	67,000	Salt
13-3569	GSL Minerals	01/08/1962	50	62,000	Salt
13-3345	GSL Minerals	02/20/1981	–	49,802*	Salt
13-3404	GSL Minerals	12/14/1981	8,000†	–	Salt
13-3457	Colman, W. J.(Solar Resources)	04/10/1984	250	180,992‡	Salt
15-3850	Morton International	03/04/1993	24.8	17,954‡	Salt
13-3866	Lake Source Minerals	08/30/2007	–	10	Brine
13-3884	Earth's Elements	11/26/2008	–	10	Brine
Total possible diversions for mineral extraction				**377,768**	

*This is a mostly nonconsumptive, freshwater right from the Bear River. The nature of the use is for pond flushing.

†This is a mostly nonconsumptive, freshwater right from the Bear River that is intended for conservation.

‡Acre-feet estimates based on water rights for an instantaneous flow (cubic feet per second) assuming the right is exercised during its full period of use.

Under all eight existing, approved rights, an additional 456,000–787,000 acre-feet of water per year could be diverted from GSL and consumed by evaporation. However, unless this diverted water is evaporated in ponds constructed outside the lake area, thereby increasing the effective surface area of the lake, such additional diversions should have no measurable effect on average lake level. The possibility that all the water approved under existing applications will be diverted and consumed at some time in the near future is unlikely. It is, however, likely that existing mineral extraction operations will seek to expand their evaporation ponds and brine diversions.

2.3.2.2.3 Future Depletions

It is expected that depletions to the inflow of GSL from historical sources will continue through water development on tributaries to the lake and other water uses. In the Jordan and Weber basins, which have been highly developed by the Weber Basin Water Conservancy District and Central Utah Water Conservancy District projects, it is expected that already diverted and developed water will be converted from agricultural uses to meet municipal and industrial demands, rather than large, new water projects being developed. Another mitigating factor may be the importation of Uinta Basin water (a portion of Utah's Colorado River allocation) to the GSL Basin by the Central Utah Project. The amount of water that could be imported from the Uinta Basin is 321,567 acre-feet per year under rights for the Strawberry Valley, Provo River, and Central Utah projects. Presently, approximately 180,000 acre-feet per year enter the GSL Basin from the Uinta Basin. This inflow reduces the impact of depletions within the GSL Basin to enhance lake level.

Four applications have not been approved for development (Table 2.7). The earliest priority date is 1966; the latest is 2009. These applications represent a potential additional diversion of 413,000 acre-feet per year for mineral extraction. The State Engineer has on file one unapproved application that does not divert water from the lake, but that would have a large impact on it; this application calls for the diking of Farmington Bay and its use as a freshwater reservoir.

In the Bear River Basin, it is expected that major new water diversions and developments will occur. Alternatives for development of water resources in the GSL drainage area have been documented in the Utah state water plans. These plans guide management and development of water resources in the GSL Basin, but are not for the purposes of managing inflow, level, or surface area of GSL. These plans are available from DWRe.

Table 2.7. *Unapproved Water Rights on File with the Utah Division of Water Rights as of 09/07/11*

Water Right Number	Owner	Priority Date	Cubic Feet per Second	Acre-feet	Use
29-1478	DWR	01/24/1966	638	–	Wildlife
13-2130	National Lead	08/22/1967	150	60,000	Salt
31-4963	Maughan Family	05/05/1989	–	15,000,000	Lake Maughan Freshwater Lake
13-3896	GSL Minerals	05/12/2009	–	353,000	Salt
Total possible diversions				**15,413,000**	

In 2009, Great Salt Lake Minerals Corporation (a subsidiary of Compass Minerals and hereafter referred to as GSL Minerals) submitted an application to DWRi to withdraw 353,000 acre-feet of water from GSL. The water would be diverted into 91,000 acres of new solar ponds. The additional ponds would add to GSL Minerals' existing 45,000-acre footprint around GSL. The USACE is in the process of completing an environmental impact statement (EIS) to analyze the impacts of the proposed expansion on GSL resources. GSL Minerals is working with regulatory agencies and stakeholders to reduce impacts associated with this project by implementing adaptive management solutions.

2.3.2.3 MINERAL EXTRACTION

Salt extraction is one of Utah's oldest industries; salt has been produced from the waters of GSL for over 100 years (Miller 1949). In addition, magnesium metal, potassium sulfate, magnesium chloride, and other products are harvested through extraction processes. These newer industries began in the 1960s. All major ions contained in the lake water are extracted by solar evaporation in large pond systems (Trimmer 1998).

Five companies have active mineral extraction operations on the lake; three of the companies produce sodium chloride salt from the lake: Morton Salt in Tooele County, GSL Minerals in Weber County, and Cargill Salt in Tooele County. US Magnesium LLC, located 60 miles west of Salt Lake City, produces magnesium metal sodium chloride and other salable by-products. North Shore Limited Partnership/Mineral Resources International (Earth's Elements and Lake Source Minerals) is located in the North Arm of GSL in Box Elder County and produces nutritional supplements. GSL Minerals produces potassium sulfate and magnesium chloride from GSL brines in Weber and Box Elder counties (see section 2.14.4 [Mineral Salt Extraction]).

The amount of salt ions entering the lake is approximately 2.2 million tons per year (Gwynn 2011a; Gwynn 2005). However, approximately 1.0 million tons of this is calcium carbonate that precipitates out of solution leaving 1.2 million tons of salt ions in solution. In recent years, approximately 3.0 million tons of minerals are extracted from lake water annually (UGS 2011c). Therefore, approximately 1.8 million more tons of minerals are removed from the lake than enter each year. This equates to approximately 0.04% of the lake's total salt load of 4.5 billion tons (Gwynn 2011a).

2.3.2.4 FLOODING MANAGEMENT AND MITIGATION

To help alleviate the flooding of the 1980s, the Utah State Legislature directed and provided funding to the DWRe to implement two flood control measures; these achieved minor lake level reductions and resulted in millions of dollars in saved infrastructure around GSL. In addition, since their original construction, the conveyance properties of the two largest causeways on GSL (the Northern Railroad Causeway and Davis County Causeway) have been modified in an attempt to improve circulation within the lake (Loving et al. 2000). However, the effectiveness of increased circulation through these causeways is lake level dependent. In spring 2011, Union Pacific Railroad began exploring the possibility of building a 180-foot bridge along the Northern Railroad Causeway that would replace the existing, failing 15-foot-wide culverts between the North and South arms. Presumably, this might increase circulation between the North and South arms. FFSL and USACE are currently evaluating this project. In January 2012, Union Pacific Railroad plugged the causeway's west culvert to avoid damage to the railway.

2.3.2.4.1 Breaching the Northern Railroad Causeway

In August 1984, DWRe created a breach in the Northern Railroad Causeway to reduce the difference in lake level between the North and South arms (Figure 2.7). The breach consisted of a 300-foot-long opening near Lakeside to allow faster flow of brine from the South Arm to the North Arm. At the time the breach was opened, the water elevation of the South Arm was approximately 3.5 feet higher than the North Arm (Figure 2.7). After the breach was opened, large quantities of less-concentrated South Arm brine flowed north into the North Arm, whereas large quantities of dense North Arm brine flowed south into the depths of the South Arm as bidirectional flow (Gwynn and Sturm 1987). This bidirectional interchange of brine increased the South Arm density and salt load and decreased those of the North Arm.

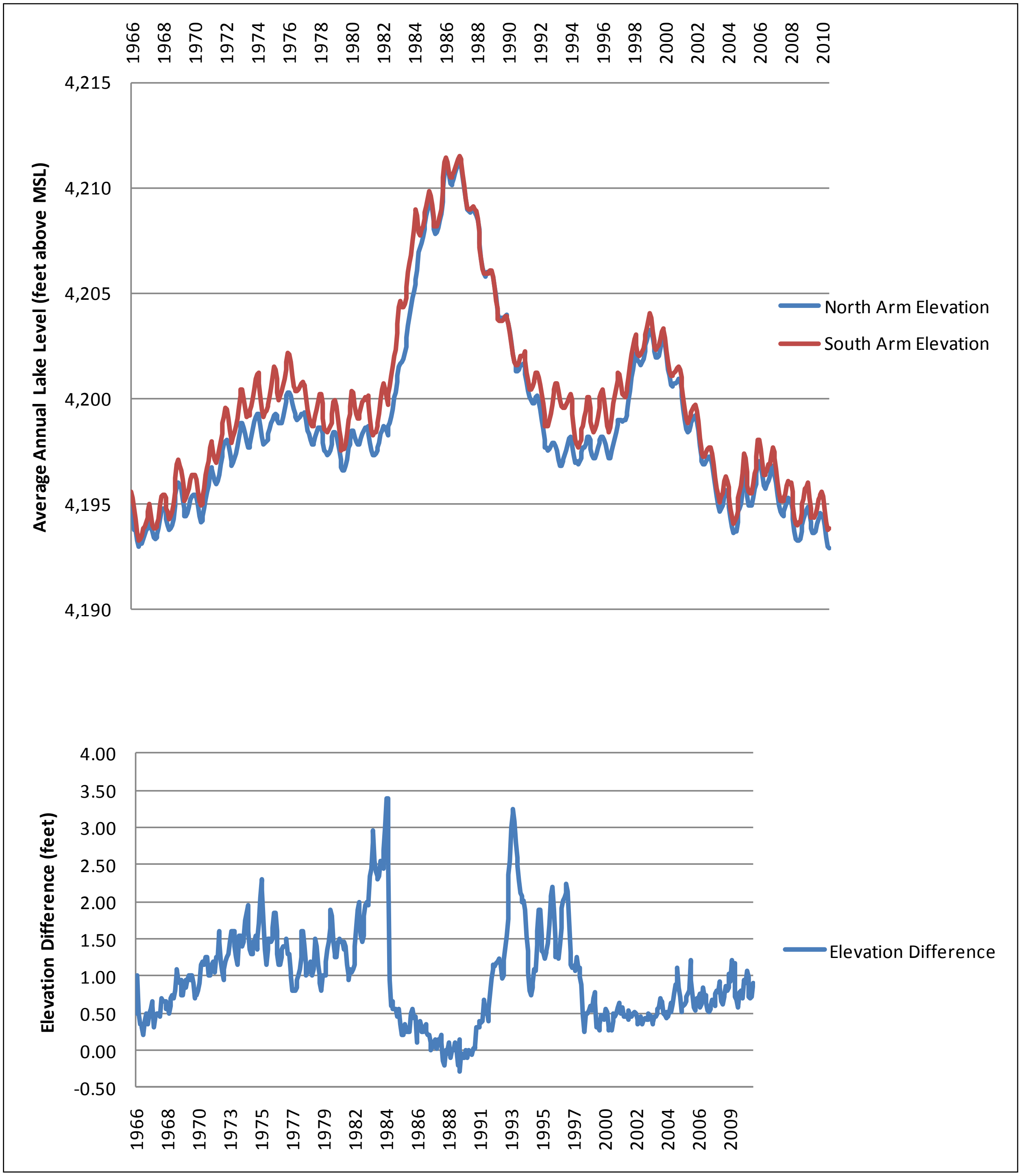


Figure 2.7. Average annual lake level differences between the North and South arms of Great Salt Lake (based on U.S. Geological Survey Gage 100100000 at the Saltair Boat Harbor and U.S. Geological Survey 10010100 at Great Salt Lake near Saline, Utah).

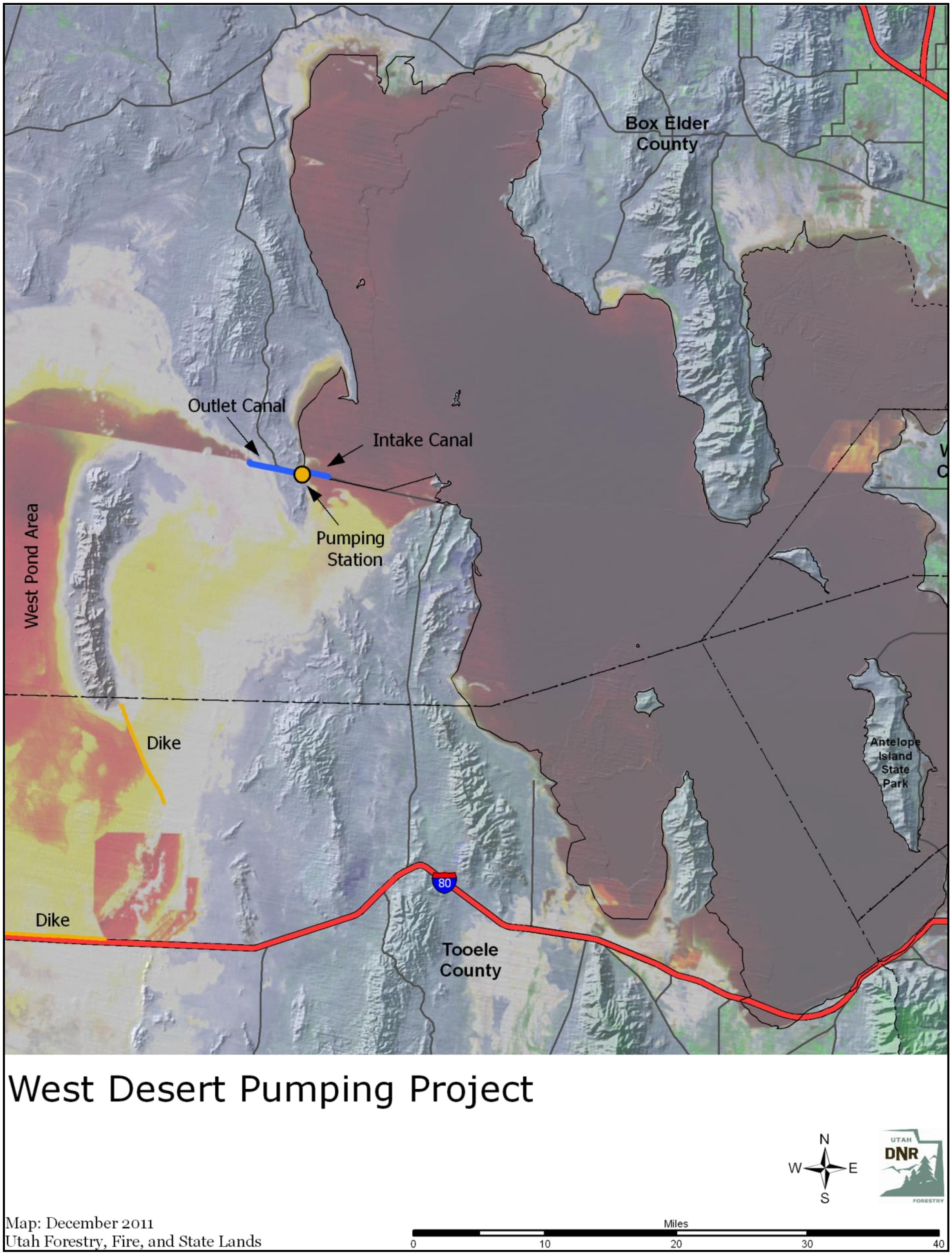
Bidirectional flow continued until the end of 1988 when the lake dropped to the point that return flow through the breach opening ceased. From that time until 1999, flow through the breach opening was mainly south-to-north. Early in 1999, there was very little bidirectional flow observed moving through the breach. Later in the year, however, as the level of the lake rose and the head differential across the causeway decreased, deep north-to-south return flow was again observed within the breach opening.

In 2000, driven by the salt level in the South Arm decreasing to the point where brine shrimp production was suffering, the state legislature directed and provided funding for the DWRe to deepen the breach to ensure bidirectional flow to somewhat equalize the salinity levels of each arm. The bottom of the breach was dredged to an elevation of 4,193 feet, thus allowing increased bidirectional flow of brines at lower GSL levels. Since the breach was dredged, bidirectional flow has been observed through the breach at GSL elevations as low as 4,195 feet (Klotz 2011).

2.3.2.4.2 West Desert Pumping Project

During the GSL historic rise between 1982 and 1987 (the GSL rose to a historic peak of 4,211.85 feet in June 1985), shoreline flooding caused an estimated $240 million in damages to Interstate 80 (I-80), mineral industries, railway systems, sewage treatment plants, wildlife habitat, recreation areas, and public and private property. When GSL rises to an elevation of 4,204 feet above sea level, economic damages begin to occur. Weather experts in the mid-1980s could predict no immediate change in the wet weather pattern, which led to fears that I-80 would be lost to flooding, requiring a new rerouted freeway. The Southern Pacific and Union Pacific railroads considered shutting down operations because of flood damage. Fears grew that the Salt Lake International Airport (SLCIA) would stop flights because runway drains were starting to fill up and would not function properly. To mitigate these damages, the DWRe was directed by the Utah State Legislature to develop strategies on how to lower the lake's elevation. The DWRe determined through several studies, including looking at capturing the water upstream of GSL by building additional storage reservoirs, that pumping GSL water out into the West Desert to increase surface evaporation would be the best mitigation tactic to solve the short-term flooding impacts. This measure involved pumping water from the North Arm of the lake out into the West Desert to increase the total evaporative surface area and to physically remove and evaporate water from the lake. After much discussion concerning the lake's elevation, a special session of the Utah State Legislation in May 1986 authorized $60 million to the DWRe to construct and operate the WDPP.

The WDPP consists of a 10-mile-long access road along a portion of the Northern Railroad Causeway (owned by Union Pacific Railroad), a pumping station containing three large natural gas–fueled pumps, canals, trestles, dikes, a 37-mile natural gas pipeline, and a 320,000-acre evaporation pond area in the desert west of GSL. To accomplish the task of lowering the lake elevation, a short intake canal (4,207-foot elevation) exists to deliver North Arm brines south under the railroad line (a small trestle was constructed) to the West Desert Pumping Plant located on Hogup Ridge (approximately 12 miles west of Lakeside) (Map 2.4). The water is pumped up by three large natural gas pumps to an elevation of 4,224 feet above sea level and discharged to a 4.1-mile outlet canal that delivers the water by gravity out to the West Pond. The West Pond has a surface area of 320,000 acres, approximately 508 square miles, and a volume of 800,000 acre-feet at an elevation of 4,216.5 feet.



Map 2.4. West Desert Pumping Project.

A 24.4-mile dike with a maximum height of 6 feet retains the southwest portion of the West Pond and prevents water from the WDPP from flooding I-80 and the famous Bonneville Speedway. A second dike 8.1 miles long with a maximum height of 7 feet extends southeast from the southern tip of the Newfoundland Mountains. It is used to contain the water and restrict the surface flooding of the U.S. Air Force (USAF) Military Test Range. Multiple gates on a weir in this dike are used to regulate the pond's surface level at approximately 4,217 feet and the return of concentrated brine to GSL. Return flow through the test range is not confined and flows over the natural topography in an expansive path on its return to the lake (FFSL 1999).

The WDPP expanded the average surface area available to evaporate the flow into GSL by approximately 26%. The increased evaporation slows lake level increases and accelerates lake level declines during periods of pump operation. The WDPP is designed to pump approximately 2 million acre-feet of water per year into the West Pond to evaporate up to 825,000 net acre-feet of water each year (FFSL 1999). This is in comparison to the average inflow of approximately 2 million acre-feet of water to GSL through surface streamflows and groundwater.

Excavation of the pumping station began on July 7, 1986, and by June of the following year, the three pumps were in full operation. The pumps are designed to operate down to 4,205 feet. However, as stated earlier, the intake canal that brings North Arm water to the pumps will only intake water at 4,207 feet. The upper limit of the pumps is set at 4,216.5 feet, at which point the engine room floor would be flooded. The operational range of the WDPP is directly linked to the water surface elevation of GSL. Other constraints alter the way the project operates. Design features allow pumping down to an elevation of 4,205 feet (if the intake canal is dredged), but when the WDPP was in operation, the USAF only allowed pumping to an elevation of approximately 4,208 feet. At a water surface elevation of approximately 4,217 feet, GSL would naturally flow into the West Pond area and submerge the Newfoundland Dike Weir. The West Pond would then be an extension of GSL, and pumping would be unnecessary.

Pumping started on April 10, 1987, and continued until June 30, 1989. During this period, an estimated 2.73 million acre-feet was pumped from GSL. The pumping project was successful in increasing the rate of decline of GSL, lowering the level of the lake by 15 inches, and causing the lake to recede by approximately 50,000 acres of shoreline. After pumping ceased, because of a changed weather pattern, the lake level continued to drop an additional 2 feet through the end of 1989. The WDPP was shut down on June 30, 1989, after more than two years of successful operation. The shutdown process took approximately eight weeks, requiring the pumping plant to be secured and dismantling, preserving and storing tools and system control devices.

The design of the WDPP was modified prior to construction. The original design called for water to be pumped from the fresher South Arm of GSL. The final plan was a shorter inlet canal from the North Arm, which reduced the cost of the project and sped construction by pumping brine from the North Arm. However, the use of more concentrated North Arm brine reduced the evaporation potential of the project and resulted in more salt being left in the West Pond.

In 1994, USGS published a report called *Salt Budget of the West Pond, Utah, April* 1987 *to June 1989.* The report summarized the salt budget as follows:

> During operation of the West Desert pumping Project, April 10, 1987, to June 30, 1989 data were collected as part of a monitoring program to evaluate the effects of pumping brine from GSL into West Pond in northern Utah. The removal of brine from GSL was part of an effort to lower the level of GSL when the water level was at a high in 1986. These data were used to prepare a salt budget that indicates about 695 million tons of salt

> or about 14.2 percent of salt contained in GSL was pumped into West Pond. Of the 695 million tons of salt pumped into West Pond, 315 million tons (45 percent) were dissolved in the pond, 71 million tons (10.2 percent) formed a salt crust at the bottom of the pond, 10 million tons (1.4 percent) infiltrated the subsurface areas inundated by storage in the pond, 88 million tons (12.7 percent) were withdrawn by US Magnesium and 123 million tons (17.7 percent) discharged from the pond through the Newfoundland Weir. About 88 million tons (13 percent) of the salt pumped from the lake could not be accounted for in the salt budget. About 94 million tons of salt (1.9 percent of the total salt in GSL) flowed back to Great Salt Lake. (USGS 1994)

Therefore, at the end of pumping operations, approximately 484 million tons of salts were either in the West Pond or infiltrated into the subsurface. Another 211 million tons were withdrawn by US Magnesium or discharged over the Newfoundland Weir. Approximately 94 million tons of the 211 million tons had returned to GSL. Therefore approximately 600 million tons (as of 1989) had been pumped but not returned to the lake (FFSL 1999).

It is believed that some portion of the precipitated salt, approximating 180 million tons, has been re-dissolved by rainfall and removed from the West Pond by either US Magnesium or by flow over the Newfoundland Weir. This removal of salt has had an impact on the overall salinity of GSL (FFSL 1999).

In its present configuration, the WDPP is capable of operating only at South Arm lake levels of 4,208 feet or more (the WDPP operation is referenced to South Arm lake level), due to constraints stated earlier such as intake canal elevation and prior USAF limits. The current configuration of the WDPP will allow the pumping of only North Arm brines.

The relationship between lake levels, the pumping of brine from the North and South arms, and the build-up of salts in the West Pond are presented in Figure 2.8. The upper, more densely stippled shading shows the upper and lower limits of salt precipitation for North Arm brines at varying lake level elevations. The lower, less densely stippled shading shows the same limits for South Arm brines. Figure 2.8 shows that the WDPP could operate without precipitation of salts in the West Pond if operation is started only at lake elevations of 4,210 feet above sea level and higher. Unless the West Pond is significantly reduced in size, which would significantly reduce the effectiveness of the system, operation of the WDPP in its current configuration would result in precipitation of additional salts into the West Pond.

Construction and operation of the WDPP was controversial, and it spawned considerable public and political debate about costs and alternatives to pumping. Project engineers faced and overcame unique challenges, including the harsh environment of GSL, remoteness of the pumping plant, and difficult access to construction areas. The WDPP was nominated for the prestigious Outstanding Civil Engineering Achievement Award from the American Society of Civil Engineers and won the society's Civil Engineering Achievement of Merit Award.

Since pumping ceased, the DWRe has a continual operation and maintenance program at the pumping plant. The budget for this work is approximately $9,000 per year. Current maintenance is minimal and consists of keeping corrosion at bay in the engines at the pumping plant. If the pumps were to be operated again, a very large financial commitment would need to be made to prepare the pumping plant for operation once again.

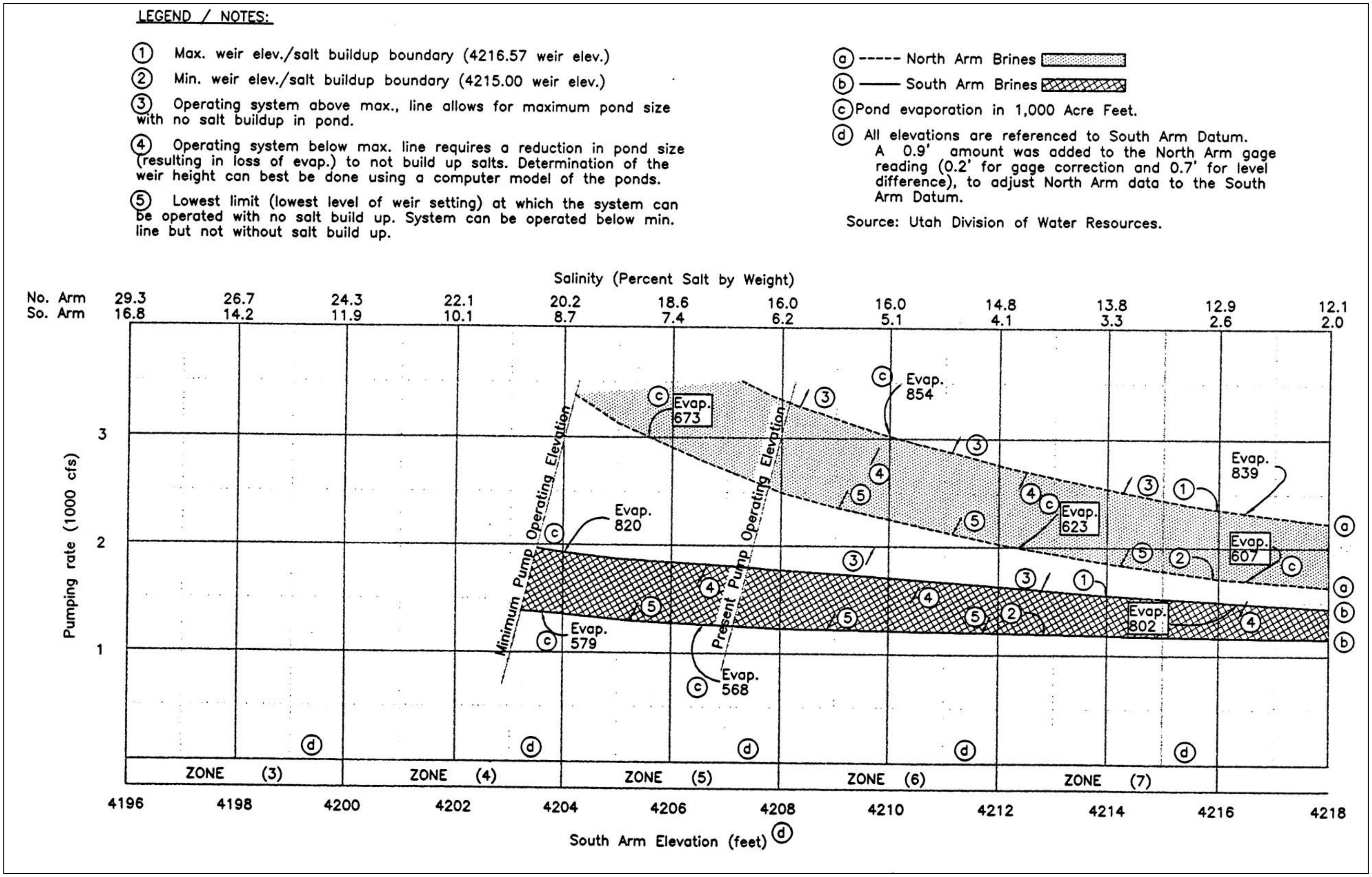


Figure 2.8. West Desert Pumping Project with pumping rate vs. South Arm elevation vs. salinity (FFSL 1999).

Administrative and Legal Considerations

As part of the WDPP, various rights-of-way, permits, and memoranda of understanding were executed among the State of Utah, BLM, USAF, and USACE. Several of these were long-term agreements to operate the WDPP, such as the right-of-way issued by BLM. Others were short-term, temporary permissions arising out of the emergency nature of the project. USAF never granted an official approval for the use of the Utah Test and Training Range in operation of the WDPP, but instead issued a letter of approval for temporary operation for the duration of the flooding emergency. In addition, as stated earlier, they allowed pumping only at GSL elevations above 4,208 feet. In recent discussions, USAF notified the state that an environmental baseline study would be required and perhaps an update of the original project EIS, before HAFB would grant permission to flood parts of the Utah Test and Training Range. HAFB has indicated that a proposal to use the WDPP would require the state to address several HAFB concerns. Use of the WDPP raises several safety concerns such as the impact of the West Pond on fog levels and increased bird use, both of which affect flight safety. Presence of the West Pond will also affect planning for flying missions, operating of target complexes, and conducting environmental clean-up activities. All of these concerns would have to be addressed before USAF would allow operation of the WDPP to resume. HAFB also indicated that any proposal to use the WDPP for lake levels below 4,208 feet may make it more difficult to obtain USAF approval.

USACE also expressed concern over the impacts the WDPP may have had on the ecology of GSL, such as the removal of salts from the lake. USACE issued a Section 404 permit for construction of much of the WDPP, which also covers operations. USACE has indicated that a resumption of pumping or a change in the use or protocols of the WDPP could trigger an evaluation of the state's performance under the permit in light of these concerns.

The DWRe has developed an internal procedure that outlines steps the state will need to take based on a rising lake level. It addresses many of the issues that are discussed above. However, the DWRe has no long-term management authority of the WDPP. The Utah State Legislature would again have to direct the DWRe to assess and prepare the WDPP for operation. Funding for this effort would also have to be provided by the legislature. In addition, recently installed dikes owned by GSL Minerals would have to be breached in order for the intake canal to bring water to the WDPP.

2.3.2.5 LAKE LEVEL EFFECTS

2.3.2.5.1 Bay Connectivity and Fragmentation

Fragmentation of GSL, as a result of the dikes and causeways, has resulted in the loss of connectivity between the main areas of the lake. This is despite the design of semipermeable causeways as well as breaches, openings, and culverts to encourage exchange of water between fragmented bays. At low lake levels, below the bottom of culverts and other causeway openings, GSL is especially fragmented, and bays tend to operate in isolation. However, as lake levels rise, more water is exchanged through openings. Also, when causeways and dikes are overtopped, there is increased mixing between bays that may have been isolated from one another for some time. However, even when the causeways are overtopped, these structures continue to impede mixing and circulation such that pre-causeway levels cannot be achieved.

Bay connectivity and fragmentation has important implications to salinity, circulation, and brine stratification. For more information, see section 2.3.2 as well as section 2.3.4 (Water Quality).

The connectivity of GSL bays is described here in relation to Gilbert Bay. The three largest bays are separated from Gilbert Bay by the Northern Railroad Causeway (Gunnison and Bear River bays) and the Antelope Island Causeways (Farmington Bay). Farmington Bay is dry from the shoreline to Antelope

Island below 4,191 feet, and it is isolated from the main lake between lake elevations of 4,191 and 4,195 feet. Farmington Bay becomes connected through bridged openings in the Antelope Island Causeways between lake elevations of 4,195 and 4,205 feet. When the lake's elevation rises above 4,211 feet and the causeway is over topped, the waters of Farmington Bay and the main body are free to mix (Gwynn 1998). However, when lake levels rise above 4,205 feet (the elevation of the Southern Causeway), there is partially mixing with the South Arm through the narrow channel between Antelope Island and the mainland.

Bear River Bay is isolated from the main lake when the lake elevation is below 4,196 feet. Bear River Bay is connected to Gilbert Bay through two bridges (one in the GSL Minerals dike and one on the Bagley Fill portion of the causeway). Willard Bay is isolated from the main lake body below a lake elevation of 4,202 feet and is connected above this elevation. Gunnison Bay is isolated from Gilbert Bay below 4,193 feet and is connected through a breach and two box culverts above this elevation. When the GSL lake elevation is above 4,213 feet and the causeway is overtopped, Gunnison Bay is fully connected to Gilbert Bay (Klotz 2011).

There are several other small bays that become isolated at low lake levels. Carrington Bay is relatively dry below a 4,189-foot lake elevation. The bay is narrowed when the lake elevation is between 4,190 and 4,199 feet. At this time, Carrington Bay is used by phalarope (*Phalaropus* spp.) for foraging during migration. When GSL is at a lake elevation of 4,199 feet or more, Carrington Bay is connected to the main body of the lake. Ogden Bay is relatively dry when the lake elevation is below 4,191 feet and is connected above this elevation.

2.3.3 Hydrological and Geochemical Dynamics of Great Salt Lake

2.3.3.1 LAKE STRATIFICATION AND CIRCULATION

Because the density of water is proportional to its salinity, mixing of water between fragmented bays of varying salinity is limited. At causeway openings and breaches, fresh water flows above more saline water to create a bidirectional flow. Brine flowing to a bay of less salinity tends to resist mixing with the fresher water and remains in a fairly coherent "tongue," which can extend some distance into a fresher bay. This forms a stratified brine condition within the central, deeper portions of bays (Gwynn 1998). For instance, deep brine from the North Arm flows to the South Arm as lighter surficial brine flows from the South Arm to the North Arm simultaneously and in opposite directions. These directions occasionally reverse due to storm events (DWQ 2010a).

In some cases, a very saline deep brine layer (DBL) periodically forms underneath the less saline water where waters of two different salinities come into contact as a result of bidirectional flow. This stratification can remain for several years at a time (Gwynn 2000; Naftz et al. 2005). During these periods, as a result of limited turnover, the DBL has limited exposure to oxygen, resulting in anoxic conditions. Anoxic conditions contribute to sulfate reduction, methylation of mercury and phosphorus, and nitrogen cycling. Brine density stratification occurs in the South Arm, Farmington Bay, and Bear River Bay (Gwynn 2002). The DBL is hypersaline and turbid. The DBL is generally anoxic and plays an important role in mercury cycling in the lake (see mercury discussion in section 2.3.4.5).

Today, Bear River Bay is separated from the South Arm by the Bagley Fill that was constructed when the original Lucin Cutoff was constructed, which extends east and west across the lake. The opening in the Bagley Fill is approximately 600 feet long. One culvert in the causeway provides for bidirectional flow between Bear River Bay and the South Arm below the 4,202-foot level. The upper layer of water near the culvert is relatively fresh, with average salinity values of 1%–2%. The DBL in Bear River Bay is approximately 14% salinity, similar to the main body of the South Arm. There is only one opening, an approximately 50-foot bridge, in the dike north of the causeway; it is managed by GSL Minerals.

From 1966 until approximately mid-1991, the South Arm of the lake was density-stratified into two brine layers. This stratification was primarily driven by the differences in lake level in the South and North arms, and secondarily due to differences in brine densities in the two arms (Gwynn 2002). In the South Arm, a dense and turbid, hydrogen sulfide–laden brine extended from an elevation of approximately 4,180 feet to the bottom of the lake. Less dense, clearer, odor-free brine extended upward from approximately 4,180 feet in elevation to the surface. The two brines were separated by a relatively sharp transition zone. From 1991 until recently, brines of the South Arm have been thoroughly mixed from top to bottom, causing the deeper, denser brine layer to disappear. This disappearance occurred after the high-water years (1983–1987). During the 1980s, the surface elevation of the lake rose from approximately 4,200 feet to approximately 4,212 feet by 1986–1987. The disappearance of South Arm stratification is probably due to diminished north-to-south return flow through the causeway from the apparent changes in the hydraulic conductivity (permeability) in the Northern Railroad Causeway. It was recently reported that a DBL occurs intermittently in the South Arm and Carrington Bay (Naftz et al. 2008a).

Brine stratification was not present in the North Arm of the lake from approximately 1966 to 1983. When the lake began its rapid rise from approximately 4,200 feet in 1983 to its historic high of 4,211.85 feet in 1986–1987, a layer of less-dense brine formed on top of the very-dense North Arm brine. This could be due to 1) increased precipitation causing an enormous amount of inflow of less-saline, South Arm water as the Northern Railroad Causeway was breached in August 1984 and 2) the large, bidirectional exchange of brines between the North and South arms through the breach opening that followed. By mid-1991, the level of the lake had dropped below the 4,199.5-foot bottom elevation of the breach opening. Because of this, the constant flow of South Arm brine into the upper light-brine layer in the North Arm nearly ceased, and the stratified-brine condition in the North Arm soon disappeared due to vertical mixing (Gwynn 1998). To improve the bidirectional exchange of brines, the bottom of the breach was lowered to 4,198 feet by Union Pacific Railroad in August 1996 (Klotz 2011). DWRe lowered the breach opening to its current elevation of 4,193 feet in 2000.

2.3.3.2 SALINITY AND SALT BALANCE OF GREAT SALT LAKE

Historically, lake salinity was inversely proportional to lake level and lake volume (FFSL 1999). However, since 1930, precipitation and re-solution of salts into minerals, primarily halite and mirabilite, have complicated brine chemistry and dynamics. Prior to completion of the Northern Railroad Causeway in 1959, the lake was considered to be well mixed from top to bottom with no density stratification (Gwynn 1998). As lake volume, area, and elevation increased, salinity decreased.

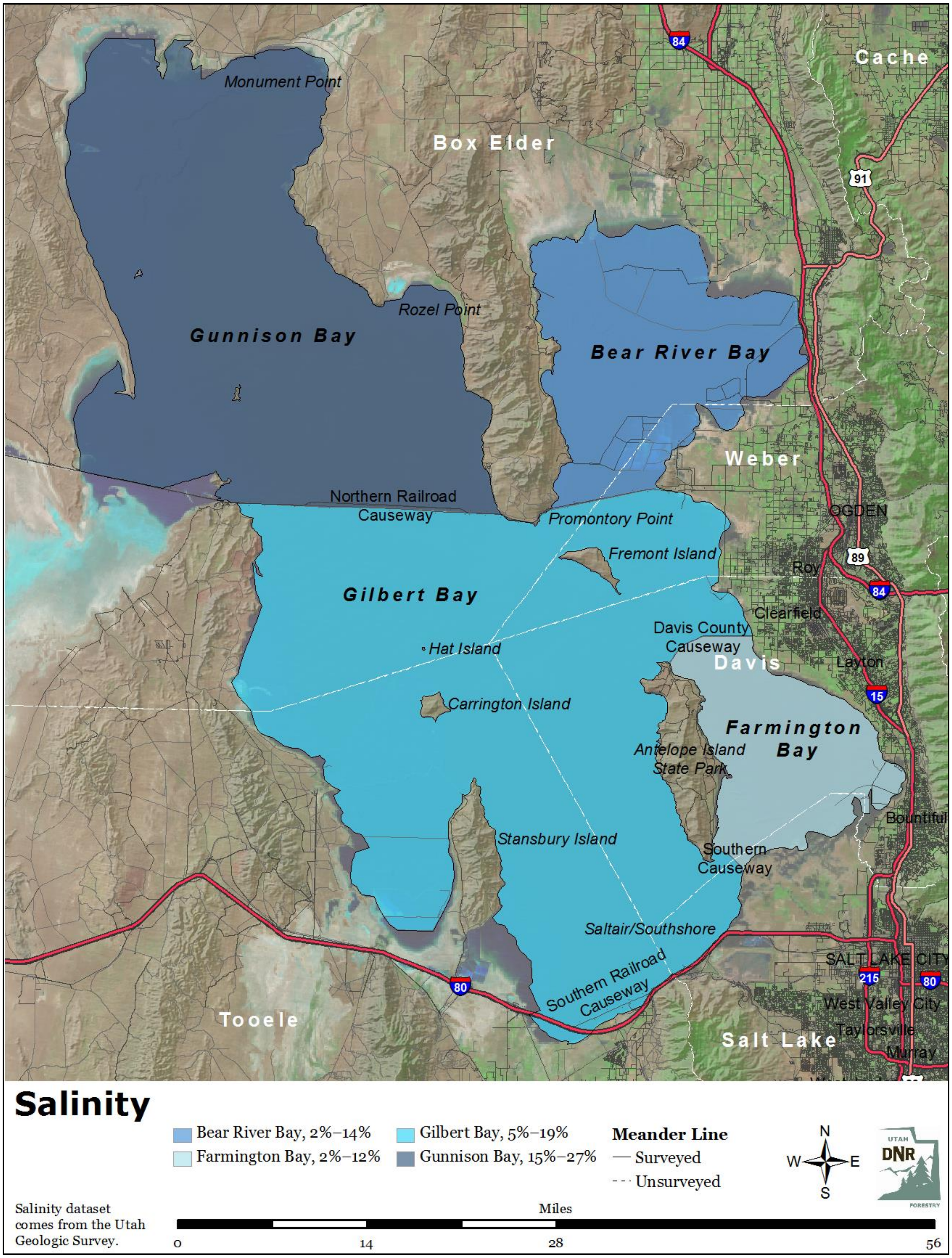
Hypersaline waters are denser than the rest of the lake and periodically result in stratification of portions of the lake. Stratification typically occurs as North Arm brine flows into the South Arm, sinks to the bottom, and forms the deep, dense brine layer. Furthermore, the chemistry of precipitation and re-solution of salts can result in changes to the composition of brines in dissolved form in the lake (Jones et al. 2009). These patterns have been further complicated by the fragmentation of the lake due to the construction of dikes and causeways as well as the removal of lake brines by the mineral extraction industry.

The amount of salt currently extracted from GSL annually through mining operations is estimated to be slightly greater than the amount of salt that is delivered to the lake from freshwater tributaries (See section 2.3.2.3). The chemical composition of freshwater inflows to the lake and the chemical composition of extracted salts further change the distribution of salt throughout the lake. The WDPP removed 0.5 billion tons of salt from the lake in the late 1980s. The USGS has developed a salt balance model that simulates salinity and dissolved solids concentrations in each of the four distinct bays (or areas) of GSL under different mixing conditions and lake levels (Loving et al. 2000).

Salinity throughout GSL is governed by lake level, freshwater inflows, precipitation and re-solution of salt, mineral extraction, and circulation and constriction between bays of the lake. Distinct salinity conditions have developed in the four main areas of the lake as a result of 1) fragmentation of the lake resulting from causeways and dikes and 2) the fact that 95% of the freshwater inflow to the lake occurs on the eastern shore south of the causeway (Loving et al. 2000). From freshest to most saline, the largest bays in GSL today are Bear River Bay, Farmington Bay, Gilbert Bay (the main body of the lake also referred to as the South Arm) and Gunnison Bay (i.e., the North Arm). Since 1982, the salinity in Bear River Bay and Farmington Bay ranges from 2% to 9% (Map 2.5), though it typically stays between 3% and 6%. USACE is currently developing a model of salinity at varying lake levels for use in the GSL Minerals Corporation EIS (Gibson 2010).

From approximately 1966 to 1982, the salinity of the North Arm remained within the range of 25%–28%. Due to this high salinity, a layer of sodium chloride precipitated on the lake's bottom during this time. North Arm salinity dropped to only 15% in 1987, because evaporation was unable to keep up with increased, less saline inflows from the South Arm. Since the high-water years, the North Arm salinity has climbed back into the 290–310 grams per liter range of 25%–26% (Figure 2.9; UGS 2011c).

Bear River Bay receives the most freshwater inflow of any of the bays from the Bear River; as a result, it is the least saline. At an elevation of 4,200 feet, the maximum depth of water is 8 feet and the average depth of water is 2 feet (Gwynn 1986). Before reaching GSL, the Bear River flows through the Bear River Migratory Bird Refuge, managed by the USFWS since 1928. The breach in the Northern Railroad Causeway in 1984 resulted in a correction in the lake level imbalance between the North and South arms. Because fresh water flows into the South Arm of the lake, there is a net movement of water and thus brine to the North Arm. This is reflected in Figure 2.9, which shows the relationship between salinity and lake level before and after the breach in the causeway. Since the initial causeway breach in 1984 and the WDPP in 1986, the overall salinity and the total amounts of salts contained in the South Arm have decreased. Sodium chloride, which continually enters the North Arm from the South Arm, precipitates out of the brine and forms a layer of salt on the bottom of the North Arm. For example, at a lake level of 4,195 feet, salinity in the lake is currently approximately 15%, whereas before the breach, it would have been close to 23% (Figure 2.9). There has been a similar shift down in salinity in the North Arm. Because the North Arm is saturated, this brine effectively precipitates out to bottom sediments.



Map 2.5. Salinity range in Great Salt Lake bays from 1982 to 2010.

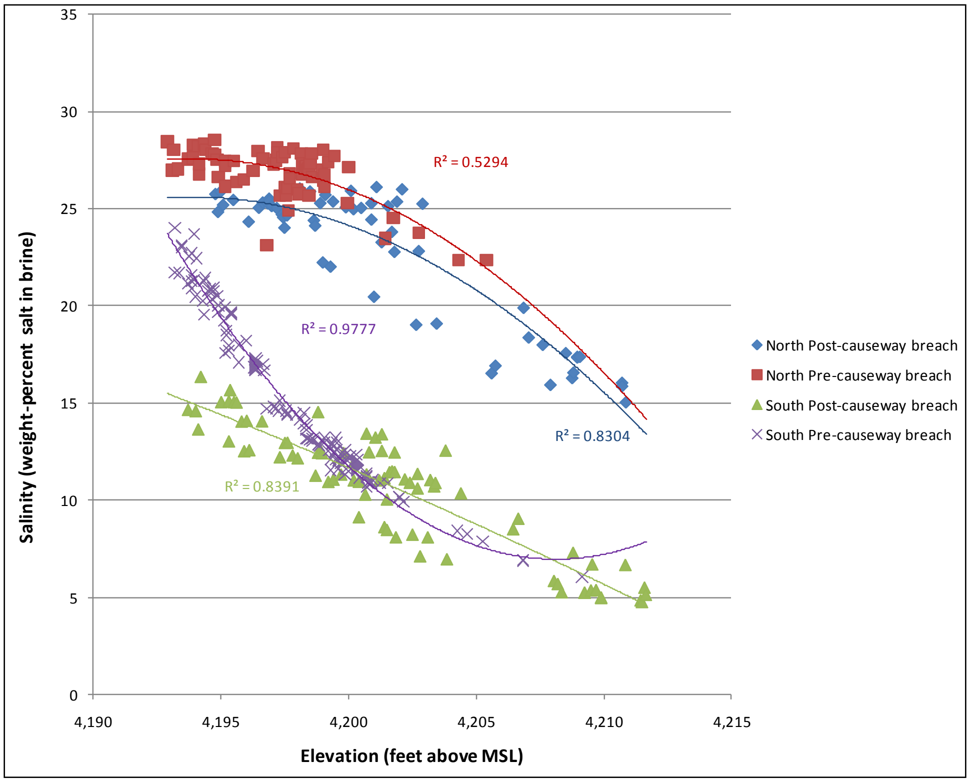


Figure 2.9. Difference in salinity in South Arm (Gilbert Bay) and North Arm (Gunnison Bay) over two periods: 1966–1984 and post-causeway breach/WDPP (1984–2010) (Gwynn 2007; UGS 2011d).[4]

2.3.3.3 COMPOSITION OF LAKE BRINE

Unlike the lake's variable salinity (total grams of dissolved salt per liter of solution), its chemical composition (ratio of various dissolved ions to one another) is relatively constant throughout the lake. Six major ions occur in GSL: sodium (Na^{+}), potassium (K^{+}), magnesium (Mg^{++}), calcium (Ca^{++}), chloride (Cl^{-}), and sulfate (SO_4^{-}). The combination of natural and human-influenced processes in GSL has resulted in a brine composition that is dominated by sodium chloride (Na-Cl) (Naftz et al. 2011). This chemical consistency exists because 1) chemical homogeneity existed throughout the lake prior to the construction of the railroad and other causeways and 2) continual brine mixing, however limited, occurs among all portions of the lake. Slight, long-term changes in ion ratios have been observed throughout the lake as a whole. Table 2.8 shows the average concentrations of multi-element analysis in raw acidified GSL water samples from the shallow and deep brines (Diaz et al. 2009). Although the volume of dissolved solids varies between the shallow (139,217 mg/L) and deep brines (315,592 mg/L), the percentage of concentrations of elemental salts is relatively the same. In addition to the main ions listed above, three other elements are most abundant in GSL: lithium (Li), bromine (Br), and boron (B). Although historic data were inaccurate because of salt interferences with analytical methods, recently reported average concentrations of metals in raw acidified GSL water samples are listed in Table 2.9 (Diaz et al. 2009).

[4] Data points are depth-integrated averages for the top 20 feet of the water column. The following UGS sites were used in the analysis: AS2 and FB2 for the South Arm; LVG4 and RD 2 for the North Arm.

Table 2.8. *Elemental Chemical Composition of the Dissolved Salts (in deep and shallow brines) in the Waters of the South Arm of Great Salt Lake (mg/L)*

Elemental Salt	Mean Raw Acidified Water Samples (shallow brine)	TDS (%)	Mean Raw Acidified Water Samples (deep brine)	TDS (%)
Sodium	44,539.20	32.0%	56,787.75	32.2%
Magnesium	4,585.77	3.3%	5,927.74	3.4%
Sulfur	3,325.41	2.4%	4,207.50	2.4%
Chloride	83,917.80	60.3%	105,842.25	60%
Potassium	2,576.07	1.9%	3,309.98	1.9%
Calcium	272.88	0.2%	299.89	0.2%

Source: Diaz et al. (2009).

Table 2.9. *Minor Trace Metals in Great Salt Lake Brines (measured in µg/L)*

Metal	Mean Raw Acidified Water Samples (shallow brine)	Mean Raw Acidified Water Samples (deep brine)
Aluminum	82.73	1,960.98
Arsenic	139.47	188.08
Barium	143.33	159.14
Cobalt	0.40	0.73
Chromium	<5	<5
Copper	5.22	17.12
Iron	60.86	1,675.98
Lead	0.54	5.80
Manganese	14.77	105.10
Molybdenum	51.71	45.35
Uranium	9.44	7.87
Zinc	<20.0	30.23

Note: < = less than; µg/L = micrograms per liter.
Source: Diaz et al. (2009).

It has been postulated that the absolute quantities of the ions of magnesium, potassium, calcium, and sulfates in lake brines is decreasing relative to sodium and chloride. Data collected by UGS since 1966 show a slight decline in the yearly average. South Arm dry-weight percentages of magnesium, potassium, calcium, and sulfates decrease over time, whereas sodium and chloride show a slight increase (FFSL 1999). This trend is also supported by analyses completed by Diaz et al. (2009). During the low surface-elevation stages of the lake, from 1935 to 1945 and from 1959 to the mid-1960s, sodium chloride precipitated in the main body of the lake (South Arm) and in Gunnison Bay (North Arm). Madison (1970) states that salt precipitated at lake elevations below 4,195 feet, and Whelan (1973) reports that approximately 1.21 billion metric tons of sodium chloride precipitated throughout the lake at those low elevations.

Although the precipitated salt in the South Arm had redissolved by mid-1972, it took until approximately 1986 before all the salt in the North Arm had been redissolved (Wold et al. 1996). In 1992, salt again began to precipitate on the floor of the North Arm during the summer months, and it is believed that precipitation continued through 1997. Dry-weight percentages of magnesium, potassium, and calcium were increased during historic low lake levels because sodium chloride is the first salt to precipitate as the concentration of lake brine increases. Notwithstanding slight fluctuations in relative ion ratios in lake water with changes in lake level, it is believed that the overall chemistry of lake brines has not changed greatly. Between 1966 and 1996, the re-solution of sodium chloride that had precipitated on the bottom of the lake's North Arm and South Arm resulted in a decline of the dry-weight percentages of potassium, magnesium, and sulfate in comparison to sodium and chloride (Gwynn 2002).

2.3.3.4 LAKE LEVEL EFFECTS

2.3.3.4.1 Farmington Bay

Farmington Bay is isolated from the main body of GSL when its level is below the top elevation of the Davis County Causeway (4,208 feet) and the Southern Causeway fill (4,205 feet). The limited exchange of flow between Farmington Bay and the South Arm is through two culverts and a bridge. Because of the inflow of fresh water from the Jordan River and groundwater inflows, the lake brines tend to be "flushed" from the bay through openings in the Davis County Causeway at lake levels higher than 4,195 feet (the bottom elevation of the culverts). Brine returning to the bay from bidirectional flow tends to resist mixing with the fresher water and remains in a fairly coherent "tongue," which extends some distance to the south underneath the lighter Jordan River/brine mixture. This forms a stratified brine condition within the central, deeper portions of Farmington Bay. The salt content of the upper Farmington Bay waters is maintained through vertical mixing of the tongue of denser, main body brine with the fresher water above it (Gwynn 1998).

Because of freshwater flows of the Jordan River into the bay, when the lake's elevation is below 4,208 feet, the salinity of Farmington Bay is approximately half or less than that of the main body of the lake.

2.3.3.4.2 Bear River Bay

Bidirectional flow occurs between Bear River Bay and Gilbert Bay above a lake elevation of 4,196 feet, which is the bottom elevation of the culvert opening in the Northern Railroad Causeway that separates the two bays (C. Miller 2011). The DBL in Bear River Bay varies seasonally and annually depending in part on lake level and wind conditions. Under calm conditions, there is little difference in lake level on either side of the railroad. There will, however, be a tongue of South Arm water extending into Bear River Bay, the extent of which depends on the density differential between lake water and Bear River Bay water. As winds blow strong from the north, water elevation against the north side of the railroad increases, whereas the elevation on the south side of the railroad decreases. When this occurs, the tongue of water from the South Arm does not extend as far into Bear River Bay. When there is a strong wind from the south, the opposite occurs and the tongue extends further than normal (Gwynn 2011b). When the tongue of main body brine thickens and extends farther into the bay, the overlying fresher brine layer thins (Butts 1998). This could have important implications to wildlife that use Bear River Bay (see section 2.7 [Biology]).

Salinity in Bear River Bay remains relatively low due to freshwater inflows. However, at a lake level of 4,217 feet, the Northern Railroad Causeway would be overtopped. Mixing with the South Arm would lead to increased salinity in Bear River Bay.

2.3.3.4.3 Gilbert Bay

The salinity of the South Arm varies inversely with lake level, and since 1984, it has fluctuated from a high of 16% in 2004 to a low of approximately 5% total salinity in 1985 (Figure 2.10). Average salinity in the South Arm, as recorded at Saltair since August 1984, is 11% (UGS 2011c; Gwynn 2007).

A DBL has historically developed in the South Arm due to differences in lake level and density between the South and North arms. This has partially been relieved through a breached opening in the Northern Railroad Causeway between the two bays. However, when hydraulic conditions are right (head differential and North and South Arm brine densities), the DBL changes direction and extends into the North Arm. The bottom elevation of the breach was originally at an elevation of 4,198 feet, but then was lowered to an elevation of 4,193 feet (Loving et al. 2000; Klotz 2011). When the lake is below the bottom elevation of the breach opening, there is little exchange of water between the two bays, and the DBL mixes with the upper less saline waters. Aside from the breach, exchange between the two bays is limited to two culverts in the Northern Railroad Causeway and to flow through the porous causeway, which has been sealed to some degree by fine sediment.

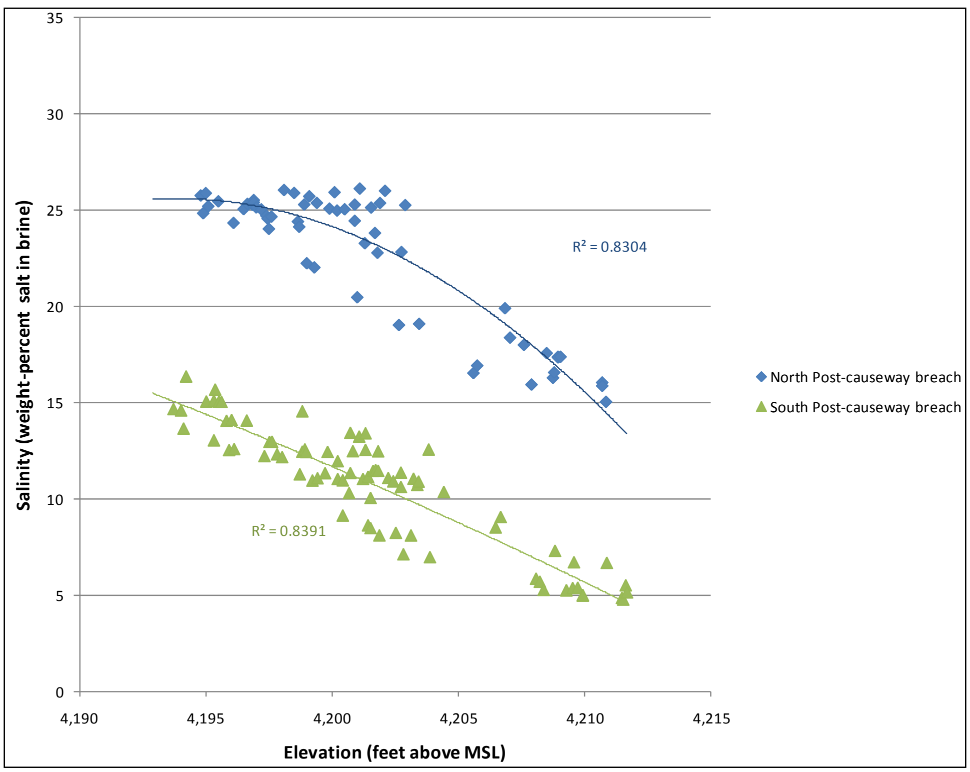


Figure 2.10. Relationship between lake level and salinity in Gilbert Bay (South Arm) and Gunnison Bay (North Arm) since 1984 (Gwynn 2007; UGS 2011).

2.3.3.4.4 Gunnison Bay

The salinity of the North Arm also exhibits an inverse relationship with lake level, and since 1984, it has fluctuated from a high of 26% in 2007 to a low of approximately 15% in 1987 (UGS 2011c). Salinity in the North Arm stays relatively constant, at saturation (Gwynn 2002), especially when lake elevations are below 4,203 feet. This is because the North Arm receives insignificant quantities of fresh surface-water inflow and large quantities of salty water inflow from the South Arm. Evaporation from the surface of the North Arm is sufficient to maintain the North Arm salinity at a high concentration.

2.3.4 Water Quality

Because of the lake's high salinity and unique aquatic biology, some contaminants that are of great concern in fresher water systems may not be as problematic in GSL, and some may even help support the aquatic ecosystem. Others may be rendered harmless by the lake water's high salinity, but may become more bioavailable when lake water freshens. GSL's unique and complex nature, biogeochemistry, and hydrology have made assessing and establishing water quality criteria difficult. However, several pollutants of concern (primarily selenium, mercury, and nutrients) have been the focus of water quality studies from 2000 to present. More monitoring and assessment is needed to address pollutant impacts to the lake and to identify those that could be affecting the beneficial uses of the lake. Additional water quality concerns will continue to emerge and be evaluated in the future. For example, pharmaceuticals and personal care products are an emerging water quality concern around the country (Kolpin et al. 2002). Although the risks to aquatic organisms and humans are still largely unknown, pharmaceuticals and other endocrine-disrupting compounds can cause biological effects at very low concentrations (USGS 2011c).

2.3.4.1 GREAT SALT LAKE WATER QUALITY MANAGEMENT

DWQ and the Utah Water Quality Board have been charged by the Utah State Legislature to "protect, maintain and enhance the quality of Utah's surface and underground waters for appropriate beneficial uses; and to protect the public health through eliminating and preventing water related health hazards which can occur as a result of improper disposal of human, animal or industrial wastes while giving reasonable consideration to the economic impact" (DWQ 2010a). The statutory authorities of the board and division are located in UTAH CODE § 19-5.

The CWA established the institutional structure for the EPA to regulate discharges of pollutants into waters of the U.S., establish water quality standards, conduct planning studies, and provide funding for specific grant projects. The EPA has provided most states with the authority to administer many of the provisions of the CWA. Accordingly, the DWQ has assigned appropriate beneficial uses for waters of the state (Utah Administrative Code [UTAH ADMIN. CODE] R317-2) and protects those uses through the development and enforcement of water quality standards (40 Code of Federal Regulations § 131.11). The beneficial use classes are as follows:

- **Class 1:** Protected for use as a raw water source for domestic water systems
- **Class 2:** Protected for in-stream and recreational use and aesthetics
- **Class 3:** Protected for in-stream use by aquatic wildlife
- **Class 4:** Protected for agriculture uses including irrigation of crops and stock watering
- **Class 5:** Great Salt Lake

Most of these main classes are divided into subclasses, which address more beneficial uses and the water quality standards assigned to protect those uses. The State of Utah reclassified the designated uses of GSL (Class 5) in 2008 into five subclasses (use Classes 5A, 5B, 5C, 5D, and 5E) that more accurately reflect different salinity and hydrologic regimes and the unique ecosystems associated with each of the four major bays (Gilbert, Gunnison, Bear River, and Farmington) and the transitional water, as described in Table 2.10 (UTAH ADMIN. CODE R317-2-6). An elevation of 4,208 feet and below was assigned as the elevation in each bay that is protected for its assigned beneficial use.

Table 2.10. *Beneficial Uses Designated to Great Salt Lake*

Class	Geographical Boundary	Beneficial Uses
Class 5A: Gilbert Bay	All open waters at or below an approximately 4,208-foot elevation south of the Southern Railroad Causeway, excluding all of Farmington Bay south of the Antelope Island Causeway* and salt evaporation ponds.	Protected for frequent primary and secondary contact recreation, waterfowl, shorebirds and other water-oriented wildlife, including their necessary food chain.
Class 5B: Gunnison Bay	All open waters at or below an approximately 4,208-foot elevation north of the Southern Railroad Causeway and west of the Promontory Mountains, excluding salt evaporation ponds.	Protected for infrequent primary and secondary contact recreation, waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain.
Class 5C: Bear River Bay	All open waters at or below an approximately 4,208-foot elevation north of the Southern Railroad Causeway and east of the Promontory Mountains, excluding salt evaporation ponds.	Protected for infrequent primary and secondary contact recreation, waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain.
Class 5D: Farmington Bay	All open waters at or below an approximately 4,208-foot elevation east of Antelope Island and south of the Antelope Island Causeway*, excluding salt evaporation ponds.	Protected for infrequent primary and secondary contact recreation, waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain.
Class 5E: Transitional waters along the shoreline of GSL	All waters below an approximately 4,208-foot elevation to the current lake level of the open water of GSL receiving their source water from naturally occurring springs and streams, impounded wetlands, or facilities requiring a Utah Pollution Discharge Elimination System permit. The geographical areas of these transitional waters change corresponding to the fluctuation of open water elevation.	Protected for infrequent primary and secondary contact recreation, waterfowl, shorebirds, and other water-oriented wildlife including their necessary food chain.

* Referred to as the Davis County Causeway in this plan.

Under the CWA, states are required to develop water quality standards for their surface waters, including wetlands. The EPA has established numeric standards (toxicity thresholds) for many toxic pollutants; these standards are refined and used by the states in conjunction with assessments of the beneficial uses for the various types of waterbodies. The application of national freshwater or marine quality criteria to GSL may not be applicable because 1) the lake has unique biogeochemical processes that alter the fate and transport of pollutants and 2) the lake supports unique species different from those on which national criteria are based. To date, DWQ has established a single numeric water quality criterion for selenium, which is applicable to Class 5A, Gilbert Bay (UTAH ADMIN. CODE R317-2-14).

Until numeric criteria can be developed, the beneficial uses of GSL are protected with the following narrative criterion (UTAH ADMIN. CODE R317-2-7.2):

> It shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum or other nuisances such as color, odor or taste; or cause conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other

desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in accordance with standard procedures.

The CWA and UTAH ADMIN. CODE R317-2-3 also provide antidegradation policy and procedures to protect and maintain existing high-quality waters. Utah's antidegradation policy does not prohibit degradation of water quality, unless the Water Quality Board has previously considered the water to be of exceptional recreational or ecological significance (Category 1 or Category 2 waters). Instead the policy creates a series of rules that together ensure that when degradation of water quality is necessary for social and economic development, every feasible option to minimize degradation is explored. Also, the policy requires that alternative management options and the environmental and socioeconomic benefits of proposed projects are made available to concerned stakeholders.

2.3.4.2 GREAT SALT LAKE WATER QUALITY ASSESSMENT

DWQ is striving to develop water quality assessments and applicable water quality criteria for GSL that measure beneficial use support to determine water quality goals and to evaluate management actions. The unique biogeochemical properties, hydrology, and history of GSL have complicated the establishment of numeric water quality criteria. Scientific research from other aquatic systems, freshwater and marine, may not be applicable to GSL, and the lack of comparable reference sites makes it difficult to establish expected natural conditions (DWQ 2010a). Despite these difficulties, DWQ is committed to establishing numeric criteria and associated assessment methods for this ecologically and economically unique ecosystem (DWQ 2010a).

In the absence of numeric criteria, DWQ's strategy to protect the beneficial uses is to create assessment frameworks based on biological, physical, and chemical parameters and to use these frameworks to document if and how the beneficial uses are protected using the narrative standard (DWQ 2010a). Assessment frameworks have been developed for mercury and nutrients in the open waters of GSL and are provided in DWQ's 2008 305(b) integrated reports. In addition, a preliminary Multimetric Index for GSL impounded wetlands was also developed, which uses multiple lines of evidence to quantify the physical, chemical, and biological condition of these waters (see section 2.4 [Wetlands]).

2.3.4.3 GREAT SALT LAKE WATER QUALITY MONITORING

Numerous local, state, and federal agencies and academic researchers have and are currently collecting water quality and chemistry data from GSL. The key state agencies monitoring the open waters of GSL are the Great Salt Lake Ecosystem Program (DWR), UGS, and DWQ. Key federal agencies include USGS, USFWS, and EPA. Continued collaboration and coordination among the various agencies that have management responsibilities, conduct research, and monitor the condition of GSL are essential to maximize the exchange of knowledge, data, and resources.

2.3.4.3.1 Future Monitoring and Assessment

For water quality monitoring of GSL, DWQ has instituted a strategic monitoring plan designed to address what the overall condition of the water quality is in the open waters of GSL. More specifically, the monitoring plan is designed to identify the potential contaminants of concern, the concentration of those contaminants in the water, and how those concentrations vary spatially, seasonally, and annually. Constituents that are being measured include total selenium and total mercury in the water, brine shrimp and bird eggs, trace metals in the water, nutrients, dissolved oxygen, pH, temperature, conductivity, Secchi depth, water depth, and depth to the DBL in the water.

2.3.4.4 PERMITTING DISCHARGE TO GREAT SALT LAKE

Facilities in Utah that produce, treat, dispose of, or otherwise discharge wastewater must obtain a Utah Pollution Discharge Elimination System (UPDES) discharge permit from DWQ. UPDES permits are required for all industrial, municipal, and federal facilities, except those located on Native American lands. After a discharge application is received, a wasteload evaluation is developed to determine specific discharge limitations, required treatment, and monitoring. Each permit includes effluent limitations and requirements for monitoring, reporting, and sludge use or disposal requirements. Permit duration is usually five years or fewer, with a provision for renewal. The most recent permits are available for public review on DWQ’s website (http://www.waterquality.utah.gov/UPDES/CurrentPermits/index.htm).

Permitted discharges to GSL include municipal wastewater treatment facility discharges, stormwater discharges, mineral extraction facility discharges, and other industrial facility discharges (Table 2.11). Wastewater treatment facilities improve water quality by treating sewage that historically was discharged directly to the lake. Nonetheless, discharge from wastewater treatment plants includes organic material, nutrients, and sediment. Stormwater discharges to the lake include pollutants that wash off of streets and other urban landscapes as well as pollutants that originate at the SLCIA. These include petroleum products, deicing fluids, solvents, lubricants, and antifreeze. Mineral (salt) extraction industries produce bitterns (residual) water from their solar evaporation ponds. These facilities withdraw water from GSL and then use solar evaporation to precipitate various salts from this water. Specific effluent guidelines and standards are applicable to discharges from salt extraction industries. The requirement is that the effluent contain only materials originally present in the intake water. Industrial discharges include effluent from copper concentration and smelting operations and from oil refineries located in the North Salt Lake area. The copper mining results in heavy metals and total and suspended solids discharges. Discharges from oil refineries have limitations on mass biological oxygen demand, total suspended solids, oil and grease, phenolic compounds, ammonia, sulfide, and chromium. A list of existing permits for discharges directly to GSL is provided in Table 2.11. Discharge permits in the GSL Basin that have an indirect effect on GSL are listed in Appendix C. The receiving waters in the GSL Basin have assigned beneficial uses independent of their influence on GSL (UTAH ADMIN. CODE R317-2). Many of the permit locations are shown on Map 2.6.

Table 2.11. *UDPDES Permits that Discharge to Great Salt Lake*

UPDES ID No.	Permit Name	Permitted Design Flow (million gallons per day)	Receiving Waters
UT0025755	ATI Titanium	1.0	Gilbert Bay
UT0000639	Cargill Salt	No discharge to GSL	Gilbert Bay
UT0020974	Central Davis County Sewer District	8.86	Bear Creek
UT0000175	Chevron U.S.A., Inc.	1.2	Oil Drain Canal to Farmington Bay
UT0000647	GSL Minerals	20.76	Bear River Bay
UT0000051	Kennecott Utah Copper, LLC	Monitoring only	004 Gilbert Bay
			008 Gilbert Bay
			012 Gilbert Bay*
			011 Ritter-Utah Salt Lake Canals
UT0020231	Lake Point Improvement District	0.164	Ditch to GSL
UT0000523	Morton Salt Inc.	10.9	GSL
UT0021741	North Davis Sewer District	23.2	Ditch to Farmington Bay
UT0021148	Perry City	0.84	Bear River National Wildlife Refuge
UT0021326	Plain City Corporation	0.81	Drain to GSL
UT0021725	SLC Water Reclamation Facility	35.2	Oil Drain Canal Then To GSL

Map 2.6. Permitted discharges to Great Salt Lake.

With the proximity of large industrial, transportation, and sewage treatment facilities to GSL, accidental, unpermitted discharges to the lake and the lake environs have occurred in the past and are likely to occur in the future. Emergency spill reporting and response is handled by several agencies with different jurisdictional responsibilities. The unpermitted release of any substance that may pollute surface or groundwater must be reported immediately to DWQ, followed by a written report summarizing the incident and remedial actions taken to respond. These include releases greater than 25 gallons of used oil, damaged radiation sources, lost or stolen radioactive materials spills, releases of radioactive materials to the environment, or other events causing significant human exposure or property damage. This reporting is required by both state and federal statutes. If an incident involves potential health or environmental effects that require immediate action by local authorities, the local emergency response access number should also be called. Some spills also may require notification of the National Response Center, depending on the type and amount of the release. In addition, spills, leaks, fires, and other events at oil or gas drilling or production facilities must be reported to DOGM within 24 hours, followed by a written report.

DEQ and the Utah Department Public Safety require that releases of substances or wastes that could be hazardous to human health or the environment must be cleaned up and the wastes disposed of, in accordance with applicable standards. This requirement includes releases that are below thresholds requiring notification to local, state, or federal authorities. The conduct of response and cleanup of spills is governed by contingency plans developed cooperatively among the affected resource management agencies and depends on the type, extent, and location of the spill. Federal and state agencies respond on-site and consult with the on-scene coordinator.

2.3.4.5 WATER QUALITY CONCERNS

2.3.4.5.1 Selenium

To better understand concerns associated with selenium in GSL, DWQ undertook a four-year research process in 2004 led by a Selenium Steering Committee comprising prominent stakeholders who were advised by an international scientific panel of selenium experts. The program culminated in the development of a water quality standard for selenium in GSL in 2008. The results of this work are available in a comprehensive report (DWQ 2008) and are summarized in the sections that follow.

Selenium Dynamics in Great Salt Lake

Selenium in lake water is mostly present in the dissolved phase; however, selenium concentrations can be higher in the particulate fraction of the DBL. Volatilization (i.e., conversion of selenium to a gaseous state) from surface waters is a major loss process for selenium from the water column and probably accounts for a net loss of selenium more than four-fold greater than that attributed to sediment burial. Sediment burial or permanent sedimentation follows as the second most important mechanism for selenium removal, estimated to be 285–960 kilograms (kg) per year (Oliver et al. 2009). Other mechanisms include shallow zone particulate sedimentation, DBL dissolution and resuspension, and brine shrimp cyst removal. Combined volatilization and sedimentation fluxes out of GSL total approximately 2,628 kg per year based on the geometric means (Johnson et al. 2008). However, when the estimates of selenium input fluxes were compared with loss fluxes, more selenium was estimated to be lost than was added to the lake. Naftz et al. (2008b) postulate that the most likely reasons for the discrepancy are unmeasured loads of selenium to the lake and/or that fluxes from the water column are overestimated.

Three primary components to selenium cycling in the open waters of GSL are 1) selenium in the upper food web, 2) selenium in the lower food web, and 3) selenium in the water and sediment. Selenium bioaccumulates in the food web, resulting in exposures to organisms at the top of the food web. Selenium in GSL generally originates from selenium in the water and sediment and moves up through the lower food web and into the upper food web. The lower food web consists primarily of algae and invertebrates (e.g., brine shrimp). The upper food web consists of resident and migratory birds. Invertebrates are the most likely food web link for selenium to resident and migratory birds. Some birds (e.g., gulls) are opportunistic and will eat whatever is available. Other birds (e.g., common goldeneye [*Bucephala clangula*] have very specific prey such as brine fly larvae; others (e.g., grebes) feed specifically on brine shrimp. During the study, to determine the selenium water quality standards, elevated concentrations of selenium and mercury were found in bird blood and livers. Selenium counteracts the toxic effects of mercury and may play a role in mercury detoxification for individuals with high mercury levels (Santolo and Ohlendorf 2008).

Sources

The estimated selenium load to GSL, based on measured and simulated loads from May 2006 through March 2008, is 1,560 kg per year. Six sources have been identified. These are the Goggin Drain (22%), KUCC Drain (24%), Bear River (25%), Farmington Bay (20%), Lee Creek (8.5%), and the Weber River (0.6%). However, other unmeasured sources of selenium could account for at least an additional 1,900 kg to Gilbert Bay during the same period (Naftz et al. 2008b). In addition, the Jordan Valley Water Conservancy District has proposed and implemented the development and construction of a groundwater extraction and treatment project with groundwater remedial functions that may result in an additional 224 kg per year of selenium (UDEQ 2011). However, because the current (unknown) sources of selenium to the bay likely include the groundwater plume being treated, the load of approximately 1,900 kg per year may decrease over time as a result of withdrawal and treatment of that water (Naftz et al. 2008b).

Most of the influent selenium occurs in its dissolved phase as selenate. There is the possibility that dry and wet atmospheric deposition could contribute a significant load of selenium to GSL, but so far, data have not been available to determine this. However, estimates of atmospheric load are as high as 596 kg per year based on deposition rates (DWQ 2008) and could therefore be greater than any single tributary. There is also a flow of selenium from the South Arm to the northern bays, estimated to be 880 kg per year (Naftz et al. 2008b), at the Northern Railroad Causeway separating the North and South arms of the lake. Additional sources of selenium could include unmeasured surface flows, submarine groundwater discharges, lake sediment pore water diffusion into the overlying water column, and wind-blown dust that is deposited directly on the lake surface.

Thresholds, Standards, and Current Conditions

Selenium is a naturally occurring element that is nutritionally essential. However, excessive concentrations of selenium are toxic to aquatic life, with aquatic-dependent birds often being the most vulnerable. Bird reproduction is affected (e.g., reduced hatchability, embryo malformations) at lower water concentrations than those that would adversely affect algae or brine shrimp. Although some selenium is taken up directly from the water, most of the exposure for birds comes from diet. Although selenium accumulates in aquatic organisms, it is not significantly biomagnified. That is, unlike mercury or polychlorinated biphenyls, concentrations of selenium do not increase significantly in animals at each level of the food web going from prey to predator.

Due to the unique geochemistry of GSL (see section 2.3.3), existing water quality criteria for selenium are not applicable. To address this data gap, DWQ convened a Science Panel in 2004 to study selenium in the open waters of GSL. Based on the recommendations of the Science Panel, the Utah Water Quality Board promulgated a selenium standard for Gilbert Bay in November 2008. The selenium standard, GSL's first numeric criterion, is 12.5 milligrams (mg) per kg dry weight in bird eggs (UTAH ADMIN. CODE R317-2-14). This standard is intended to be protective for all species of birds and aquatic life in Gilbert Bay.

EPA is required to review and approve or disapprove all Utah water quality standards as part of Utah's authorization to implement the CWA. On December 12, 2011, EPA approved the selenium standard for Gilbert Bay (EPA 2011). Unless changed by the Water Quality Board, the standard remains valid from a state perspective.

In addition to the 12.5 mg/kg standard for bird eggs, lower selenium concentrations were adopted as triggers for additional action. The first trigger is at 5.0 mg/kg and requires a review of existing sampling procedures to determine if collection methods are sufficient. At a selenium concentration of 6.4 mg/kg, an Antidegradation Level II review (UTAH ADMIN. CODE R317-2-14) will take place for all new permits and renewals to GSL. At a concentration of 9.8 mg/kg, an initiation of a preliminary total daily maximum load study to evaluate the relative contribution of selenium sources to GSL will take place. Mean concentrations greater than 12.5 mg/kg would result in Gilbert Bay being impaired and would require the finalization and implementation of the preliminary total daily maximum load.

GSL is of vital importance to resident and migratory birds (see section 2.7.8), and birds are sensitive to selenium exposure. As previously mentioned, birds are exposed to selenium in GSL mainly through their diet (brine shrimp and/or brine flies). Successful reproduction (egg hatchability) is the most sensitive endpoint for evaluating bird exposures to selenium. Table 2.12 summarizes the impacts to hatchability as a result of increased consumption of selenium in a bird's diet.

Table 2.12. *Summary of Reduced Hatchability for Mallards (*Anas platyrhynchos*) Associated with Increased Consumption of Selenium in Birds*

Diet Selenium (mg/kg)	Reduction in Hatchability (%)	Egg Selenium (mg/kg)	Reduction in Hatchability (%)
3.6	3	6.4	2
4.9	10	12	10
5.7	18	16	21

Source: DWQ (2008).

DWQ intends to annually collect and analyze bird eggs collected from Gilbert Bay for selenium. The concentration of selenium in shorebird eggs collected from the Lee Drain close to where it enters GSL averaged 4.32 mg/kg in June 2010, which is below the water quality standard (Cavitt et al. 2010).

2.3.4.5.2 Mercury

Mercury Dynamics in Great Salt Lake

Mercury is a naturally occurring element in the Earth's crust, and because it is an element, it cannot be destroyed, degraded, or combusted. It can be released to the environment by natural (e.g., volcanic, geothermal, erosion, or forest fires) or anthropogenic means (e.g., coal fire power plants, incineration facilities) and is released in the elemental or inorganic nontoxic form. Once it is released, it circulates in and out of the atmosphere until it is deposited in the waterbody. In the waterbody, sulfur-reducing bacteria in the sediments can convert the elemental or inorganic mercury to the organic toxic form of methylmercury. Methylmercury is a neurotoxin that has a strong affinity for lipids, and it has the ability to pass through the barrier between brain tissues and circulating blood and systems that serve to protect the central nervous system. Methylmercury can be stored in muscle tissue of aquatic organisms and is not easily eliminated. Methylmercury bioaccumulates along the food web causing high concentrations in organisms at the top of the food web. As with selenium, methylmercury in GSL generally originates in the water and sediment and can move up through the lower food web (algae, brine shrimp, and brine flies) and into the upper food web (birds).

The process of how mercury is methylated in the water and sediments of GSL has not yet been researched, yet the geochemical conditions in the DBL are conducive to the methylation of mercury because of the high sulfate concentration and reducing (as opposed to oxidizing) conditions. When the shallow brine mixes with the deep brine during storm and wind events, methylmercury can become available in the biologically active shallow layer.

Sources

The greatest source of inorganic mercury to aquatic ecosystems is through atmospheric deposition (see section 2.5.4). Atmospheric deposition is the process whereby pollutants are transported from a ground source, and through atmospheric processes, they are deposited on a distant land or water surface. High concentrations of chlorine and bromine in GSL may enhance atmospheric deposition of mercury to the lake surface (Jones et al. 2009).

USGS-modeled, annual total mercury load from six riverine input sources was 6 kg (with almost 50% of the annual total mercury load from Farmington Bay outflow to GSL), whereas the combined annual wet and dry atmospheric deposition of mercury to GSL was between 30 kg and 49 kg, exceeding riverine inputs by a ratio of at least five to one (DWQ 2010b; Lisonbee 2010). For GSL, there are many potential local sources of atmospheric mercury deposition that could contribute to the mercury values in GSL (Naftz et al. 2005). Source studies are currently underway at the University Of Utah Department Of Atmospheric Sciences to determine whether the atmospheric sources are local, regional, or international (Perry 2011).

Thresholds, Standards, and Current Conditions

In 2003, water column measurements conducted by the USGS reported elevated methylmercury concentrations exceeding 33 nanograms (ng)/L in the DBL. Although these are some of the highest recorded methylmercury levels in the United States (Naftz et al. 2008a), these high levels occurred in the DBL and were not being expressed in the shallow layer of water where most GSL organisms reside. In addition, the DBL represents a small fraction (typically less than 5%) of the total lake volume. Also, low concentrations of total mercury in brine shrimp cysts in the main body of the lake indicate that mercury is not absorbed or retained by the cysts that are harvested from the lake for commercial use. In 2005 and 2006, waterfowl breast muscle tissue was analyzed for total mercury because of the potential for methylmercury to accumulate in the GSL food web, from algae, plants, and invertebrates to waterfowl and local hunters. Testing from three of ten waterfowl species showed mean total mercury concentrations in the waterfowl breast muscle tissue above the EPA screening value of 0.3 parts per million (ppm) total mercury (EPA 2000). In response, the Utah Department of Health (2005, 2006) issued the first United States waterfowl consumption advisory for the three species of waterfowl (cinnamon teal [*Anas cyanoptera*], northern shoveler [*Anas clypeata*], and common goldeneye). In a follow-up study on wintering waterfowl, Vest et al. (2008) report elevated levels of total mercury in common goldeneye and northern shoveler. These elevated mercury concentrations in the DBL and in wintering waterfowl were the impetus for additional investigations into possible toxic exposures to the biota of GSL and to people who hunt waterfowl.

Through funding provided by an EPA Regional Geographic Initiative Grant and a one-time state appropriation from the Utah legislature, a comprehensive effort to compile data for mercury concentrations in the GSL ecosystem began in 2008. The objective of this effort was to 1) provide baseline information on the timing and extent of mercury concentrations in the GSL ecosystem, including the water column, sediments, waterfowl, and the waterfowl food chain biota both lake-wide and in the adjacent wetlands, and 2) compare these concentrations to known literary benchmarks for toxicity to birds and their food chain.

The DWQ *2008 GSL Mercury Ecosystem Assessment* report summarizes the mercury data by providing an overview of the average mercury concentrations in the biota in the open waters and wetlands compared to the benchmarks of mercury toxicity chosen from the published literature (Table 2.13) (DWQ 2010b). Most of the aquatic benchmarks for mercury concentrations in the water column, sediment, and biota were developed in freshwater or marine systems and may not be applicable. However, the benchmarks chosen were based on the extensive research that was conducted to formulate them and were evaluated for applicability by USFWS and EPA scientists.

Key findings of the *2008 GSL Mercury Ecosystem Assessment* include the following:

- The mean total mercury water concentration in the DBL (46.6 ng/L) was extremely high. However, the mean concentration of total mercury in the shallow brine layer (5.31 ng/L) was well below the EPA aquatic life criteria for salt water (12 ng/L).
- The mean total mercury breast muscle tissue concentrations in two waterfowl species (cinnamon teal and northern shoveler) was below the EPA screening value of 0.3 ppm used to calculate consumption advisories.
- The mean methylmercury concentrations in liver tissue for both northern shoveler and cinnamon teal were below the lowest observed adverse effect level for reproductive health.
- At all wetland locations, the mean methylmercury concentration in cinnamon teal eggs was less than the lowest observed adverse effect level of 0.5 ppm wet weight for reproductive effects.
- The mean total mercury concentrations increase with life stage for both brine flies (larvae to pupae to adults) and brine shrimp (cysts and nauplii to adults). Although, early life stages for both brine flies (larvae) and brine shrimp (cysts/nauplii) were well below the lowest observed effect level for mercury concentrations in dietary items for birds.
- Total mercury concentrations in wetlands vary diurnally; this needs to be considered when using water concentrations as a surrogate for estimating exposure.

Many of the results from the *2008 GSL Mercury Ecosystem Assessment* report are contrary to earlier assessments. Mercury concentrations in the breast muscle tissue of both species of waterfowl were much lower than found in earlier studies that triggered the waterfowl consumption advisories. The mean mercury liver concentrations were below the lowest observed adverse effect level for reproductive health as opposed to the earlier study that saw liver mercury concentrations in the high risk category. The total mean mercury concentration in the DBL was higher than reported in 2003; however, the shallow brine layer mercury concentration was low and below the EPA aquatic life criteria. Further research is needed to rectify the differences in mercury concentrations in the water column and biota between the 2008 assessment and earlier studies, specifically the following:

- A laboratory round robin to confirm and compare results from previous studies to the *2008 GSL Mercury Ecosystem Assessment*
- Research of mercury concentrations in the parts of the GSL food web (e.g., phytoplankton in the open waters and vegetation and macroinvertebrates in the wetlands) that were not part of the *2008 GSL Mercury Ecosystem Assessment* or other assessments
- More information on those bird species that feed primarily on brine flies or on brine shrimp
- More information on whether bird species are exposed to mercury at the GSL or elsewhere
- Research on the relationship between selenium and mercury in bird species

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Table 2.13. *Summary of the Conceptual Model Results from the Division of Water Quality Collaborative Study Comparing Ecological Receptors and Exposure Pathways with Benchmarks of Mercury Toxicity chosen from Published Literature in the Division of Water Quality Study*

Ecological Receptors and Exposure Routes		Potential Benchmarks for Mercury Impairment	Open Waters of GSL	Bear River Bay Wetlands	Ogden Bay Wetlands	Farmington Bay Wetlands (Farmington Bay WMA)
Water	Water	EPA Aquatic Life Standard: 12 ng/L	n/a	2.93 ng/L	7.04 ng/L	7.43 ng/L
	DBL*	EPA Aquatic Life Standard: 12 ng/L	46.6 ng/L	n/a	n/a	n/a
	Shallow brine layer	EPA Aquatic Life Standard: 12 ng/L	5.31 ng/L	n/a	n/a	n/a
Sediment	Sediment	Washington State Marine Sediment THg Standard: 410 ng/g	182 THg/g dw	17.38 ng/g	141 ng/g	47.6 ng/g
Brine fly[†]	Larvae	Evers Low Risk in Diet: <0.05 meHg ppm	0.0265 THg ppm ww	n/a	n/a	n/a
	Pupae	Evers Moderate Risk in Diet: 0.05-0.15 meHg ppm	0.0720 THg ppm ww	n/a	n/a	n/a
	Adult	Evers High Risk in Diet: 0.15-0.30 meHg ppm	0.152 THg ppm ww	n/a	n/a	n/a
Brine shrimp[†]	Nauplii	Evers Low Risk in Diet: <0.05 meHg ppm	0.0071 THg ppm ww	n/a	n/a	n/a
	Adults	Evers Moderate Risk in Diet: 0.05-0.15 meHg ppm	0.0594 THg ppm ww	n/a	n/a	n/a
	Cysts	Evers Low Risk in Diet: <0.05 meHg ppm	0.0071 THg ppm ww	n/a	n/a	n/a
Birds	Northern shoveler liver	Low Risk in Liver: <0.89 ppm meHg ww	0.662 meHg ppm ww	n/a	n/a	n/a
	Cinnamon teal liver	Low Risk in Liver: <0.89 ppm meHg ww	n/a	0.205 meHg ppm ww	0.497 meHg ppm ww	0.452 meHg ppm ww
	Cinnamon teal eggs	Low Risk in Eggs: <0.5 ppm ww	n/a	0.133 meHg ppm ww	0.246 meHg ppm ww	0.135 meHg ppm ww

Source: DWQ (2010b).

Note: The mean mercury concentration is based from samples collected over all seasons and locations in 2008. Numbers in red are measurements that exceeded the EPA Aquatic Life Standard or are at high risk.

ng/L = nanograms per liter; meHg = methylmercury; ww = wet weight THg = total mercury; dw = dry weight.

*The DBL changes annually and represents a small proportion of total lake volume (typically less than 5%).

[†] Data from Evers et al. (2004).

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2.3.4.5.3 Nutrients

Nitrogen and phosphorous (nutrients) are essential for plant and animal growth, maintenance, and reproduction. However, elevated nutrient concentrations can contribute to eutrophication or excessive growth of algae (phytoplankton and periphyton) in most surface waters. General concerns associated with excessive algal growth include nuisance scums, low dissolved oxygen, elevated pH, and toxins produced by cyanobacteria (blue-green algae). In the South Arm of GSL, algae are the primary source of food for brine shrimp and brine flies that support the GSL food chain. In Farmington Bay and Bear River Bay where salinities are lower and brine shrimp and brine flies are not grazing on the algae, elevated nutrients that lead to excessive algal growth may cause the problems associated with elevated nutrients in most surface waters.

Nutrient Dynamics in Great Salt Lake

The biological productivity of GSL is largely determined by the concentrations of nutrients in the water. Most often, nitrogen, phosphorous, or combinations of these two nutrients control plant growth in aquatic systems. Nitrogen concentrations are the most frequent limiting factor for phytoplankton growth in the South Arm (Belovsky et al. 2011; Stephens and Gillespie 1976). There is a particularly large difference between nitrogen concentrations in shallow and deep waters of GSL, although a similar but smaller difference also occurs for phosphorus (Figure 2.11). The concentrations of nutrients in the water column of the lake fluctuate with depth, season, and lake level and are controlled primarily by releases of in-lake pools of nitrogen (stored in deep waters). Nutrients from the watershed, from atmospheric deposition, and from biological processes (dead algae, brine shrimp excrement, etc.) accumulate in the deepest sections of GSL (Belovsky et al. 2011; Figure 4.11). When the lake mixes, nutrients are released into the water column and are used by phytoplankton. Shallow areas of the lake mix as a result of wind and wave action. Deeper areas of the lake are thermally stratified and only mix during fall and spring turnover, or if wind and wave action is exceptionally great (Belovsky et al. 2011).

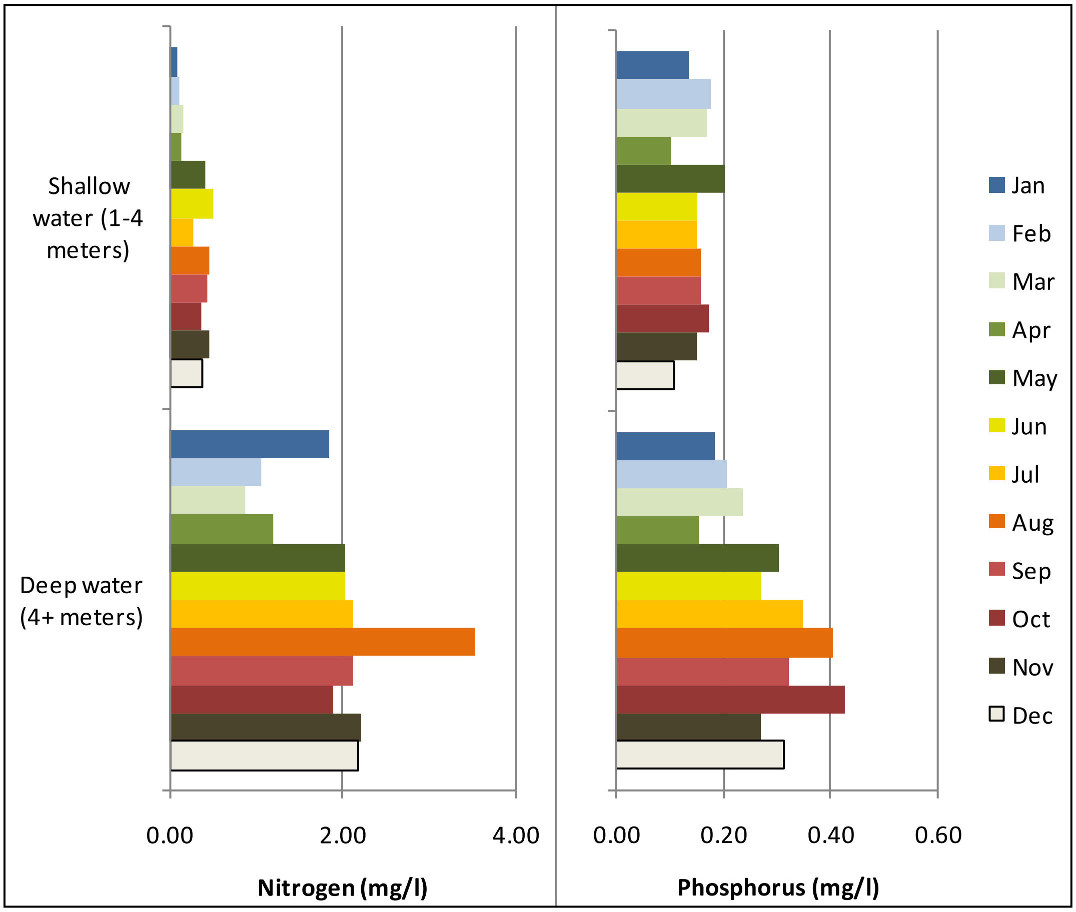


Figure 2.11. Average monthly nutrient concentrations in shallow and deep portions of Great Salt Lake between 1994 and 2006 (Belovsky et al. 2011).

Concentrations of nitrogen in shallow waters tend to be highest in the summer and fall when brine shrimp are present, and lowest during the winter months. This is attributed to nutrient processing by brine shrimp. Phosphorus concentrations remain relatively constant in the shallow parts of GSL.

In the late 1980s, phosphate, ammonia, and total nitrogen and phosphorus concentrations in the DBL in the South Arm were 10–100 times higher than the overlying, less-saline water (Wurtsbaugh and Berry 1990). However, it is not clear to what extent this difference was due to sedimentation of nutrients from the overlying water and how much was due to the bidirectional flow transporting nutrients back from the North Arm. More recent data also indicate that concentrations of nutrients are higher in deeper portions of GSL than in the shallow areas (Belovsky et al. 2011; see Figure 2.11).

Salinity plays an important role in nutrient dynamics in both Gilbert Bay and Farmington Bay. Salinities in Farmington Bay range from less than 1% to 6% depending on freshwater inflows, mixing, and evaporation. When dense underflow of highly saline water occurs, this layer does not mix readily with the overlying layer. Sedimentation of phytoplankton and zooplankton carries nutrients into the DBL, thus removing them for months to years from the biological cycle. In both the South Arm and in Farmington Bay, the nutrient that controls algal growth is mediated by the salinity. At salinities below approximately 5%, cyanobacteria compensate for nitrogen deficiency by fixing atmospheric nitrogen. Under these circumstances, the lake is limited by phosphorus. At higher salinities, cyanobacteria cannot fix atmospheric nitrogen, and nitrogen is limiting (Marcarelli et al. 2006; Stephens and Gillespie 1976; Wurtsbaugh 1988).

There are also important nutrient dynamics between the various bays in GSL. An investigation was conducted in 2006 to evaluate nutrient fluxes between the bays and the impact of nutrients on brine shrimp populations in the lake (Wurtsbaugh et al. 2006). Farmington Bay and Bear River Bay receive the largest loads of nutrients from inflowing rivers. Nutrient fluxes from Bear River Bay to the South Arm primarily occurred during the spring runoff period and were substantially larger than the fluxes from the more eutrophic Farmington Bay. During the summer period, nutrient loads from Bear River Bay to the South Arm decreased but increased from Farmington Bay. Over the study period, Farmington Bay contributed 45% of the nutrient load to the South Arm and Bear River Bay contributed 55%. This loading contributes to anoxic conditions in the DBLs throughout the lake, which provide a reducing environment for the formation of methylmercury. However, nutrient loading also fuels phytoplankton growth, which stimulates brine shrimp populations in the South Arm. The researchers estimate that approximately 12% of the phytoplankton consumed by brine shrimp in the South Arm is generated in Farmington Bay during the summer (Wurtsbaugh et al. 2006).

Sources

The primary sources of nutrients to Farmington Bay are from the Jordan River and from wastewater treatment plant discharges to the bay. Sources of nutrients to the Jordan River include wastewater treatment discharges from cities in Salt Lake Valley, stormwater runoff, agricultural return flow, and other nonpoint sources. The primary sources of nutrients in the Bear River and Weber River basins are from agricultural return flow and other nonpoint sources.

Anthropogenic factors undoubtedly have a large influence on the total pool of nutrients in GSL; however, the largest driver of nutrient concentrations in the water column is the release of nutrients from in-lake stores/pools (Belovsky et al. 2011). When tributary waters pass through wetlands prior to entering the lake, substantial portions of the nutrients may be removed (Horne and Goldman 1994).

Thresholds, Standards, and Current Conditions

Nutrient Concentrations

No numeric criteria have been established for nutrients in GSL. Generally, a phosphate concentration of 0.01 mg/L will support plankton, whereas concentrations of 0.03–0.10 mg/L phosphate will typically trigger blooms (EPA 1986; Dunne and Leopold 1978). However, these thresholds are typical of freshwater systems and are applicable only to the inlets of Farmington Bay and Bear River Bay. Additional research is necessary to identify appropriate nutrient criteria for each of the unique bays in GSL.

Average monthly phosphorus concentrations collected between 1994 and 2006 in GSL ranged from 0.05 to 0.84 mg/L (Belovsky et al. 2011). Concentrations of total dissolved phosphorus in deep and shallow areas of GSL average 0.59 and 0.31 mg/L, respectively (Belovsky et al. 2011). "In Farmington Bay mean total phosphorus from May-Nov was 0.67 mg P/L" (Wurtsbaugh and Marcarelli 2006b). Average monthly phosphorus concentrations collected between 1994 and 2006 in GSL ranged from 0.05 to 0.84 mg/L (Belovsky et al. 2011). Concentrations of phosphorus in deep and shallow areas of GSL average 0.59 and 0.31 mg/L, respectively (Belovsky et al. 2011). In Farmington Bay, total phosphorus in October 2005 was 0.12 mg/L (Wurtsbaugh and Marcarelli 2006). Sediment cores collected in Farmington Bay show that sediment phosphorus concentration are on a gradient from higher concentrations near the eastern shore to lower concentrations further west. Core data suggest that total phosphorus is relatively constant in the sediment down to a depth of at least 20 inches. Only a few sites show elevated sediment phosphorus concentrations in the top 5 inches of sediment (Myers et al. 2006).

Average monthly nitrogen concentrations collected between 1994 and 2006 in GSL ranged from 0.02 to 8.1 mg/L (Belovsky et al. 2011). Concentrations of nitrogen in deep and shallow areas of GSL average 3.96 mg/L and 0.66 mg/L, respectively (Belovsky et al. 2011). In Farmington Bay, total nitrogen peaked at 7.4 mg/L in 2005 (Wurtsbaugh and Marcarelli 2006).

Collaboration between EPA and DWQ resulted in a nutrient assessment framework for Farmington Bay that was part of the GSL appendix in the 2008 *Integrated Report* (DWQ 2010a). Paleolimnological research is underway to evaluate changes in key water quality parameters and biological assemblages over the last 200 years. The results of this study will provide preliminary conclusions of nutrient impacts to Farmington Bay (DWQ 2010a).

Nuisance Algae

Nuisance aquatic growth consisting of both algae (phytoplankton or water column algae and periphyton or attached algae) and rooted plants (macrophytes) can adversely affect aquatic life and recreational water uses. Algal blooms occur where nutrient concentrations (nitrogen and phosphorus) are sufficient to support growth. Available nutrient concentrations, circulation of water temperatures, and penetration of sunlight in the water column are all factors that influence algae (and macrophyte) growth. When conditions are appropriate and nutrient concentrations exceed the quantities needed to support algal growth, excessive blooms may develop. Commonly, these blooms appear as extensive layers or algal mats on the surface of the water.

Chlorophyll *a* concentrations are a common surrogate measure of algal growth and density. Chlorophyll *a* is the green pigment in plants associated with photosynthesis (the process whereby plants combine light energy, nutrients, and carbon to grow). A measure of chlorophyll is representative of the amount of photosynthesizing algae that are in the water column. The World Health Organization has a set of criteria for moderate to high probabilities of public health risk from nuisance algae when chlorophyll *a* concentrations exceed 50 micrograms (µg)/L (World Health Organization 2003); however, concentrations above 40 µg/L are generally considered to be a nuisance to recreation users (Heiskary and Walker 1995; Walmsey 1984; Raschke 1994). In the South Arm of GSL between 1994 and 2006, 24% of chlorophyll *a* concentrations (average monthly) exceeded 40 µg/L and 8% exceeded 100 µg/L (Belovsky et al. 2011). However, at other times, summer chlorophyll has been below 5 µg/L because brine shrimp readily graze the algae to low concentrations. The balance of nutrients, algae concentrations, the density of brine shrimp, and the benefits of dense brine shrimp populations to waterfowl and shorebirds and other GSL waterbirds requires further research to determine the presence and/or extent of nutrient-related concerns in GSL.

Algal blooms in Farmington Bay are more frequent and extensive than the rest of GSL. Thick mats of *Cladophora* filamentous algae have been observed in southern portions of Farmington Bay (T. Miller 2011), which is an area that receives high bird usage. In addition, a localized surface mat occurred in 2005 and lasted for three days (T. Miller 2011). The effects of algal mats (both positive and negative) on the thousands of staging shorebirds in Farmington Bay require more study. In 2005, chlorophyll *a* concentrations in Farmington Bay exceeded 100 µg/L (Wurtsbaugh and Macarrelli 2006). Algal blooms may also be contributing to the decline of submerged aquatic vegetation in the freshwater impoundments associated with the Farmington Bay area (Miller and Hoven 2007; Hoven and Miller 2009). However, more recent research points to other factors (including sediment chemistry) that are more likely to contribute to submerged aquatic vegetation decline (T. Miller 2011).

Anoxia

Excessive algal growth can also result in diurnal fluctuations in dissolved oxygen. Algae release oxygen during photosynthesis during the day and consume oxygen during respiration at night. Oxygen released during the day is offset by continuous oxygen consumption through respiration by and decomposition of aquatic plants. Further, both photosynthesis and respiration rates are higher in high light environments, with greater impacts on dissolved oxygen than algae in shaded sites.

On a seasonal basis, when algae die, they sink to the bottom of the water column and collect on the bottom sediments. The biochemical processes that occur as the algae decompose remove oxygen from the surrounding water. Because most of the decomposition occurs in the lower levels of the water column, dissolved oxygen concentrations near the bottom of lakes and reservoirs can be substantially depleted by a large algal bloom. The DBL resulting from density-stratification in Farmington Bay contributes to anoxia in Farmington Bay. The DBL in Farmington Bay traps organic matter and produces hydrogen sulfide through anoxic (reducing) conditions. During wind mixing events, the anoxia from the DBL can cause the entire bay to be anoxic for up to two days (Wurtsbaugh and Marcarelli 2004), which could kill phytoplankton and zooplankton.

Dissolved oxygen sondes were deployed in Farmington Bay in 2005 to evaluate whether algal growth resulted in diurnal swings of dissolved oxygen in water quality. During this time, extreme variation was recorded in oxygen levels, with nighttime oxygen concentrations reaching anoxic conditions and supersaturation of oxygen during the day (Wurtsbaugh and Marcarelli 2004). In addition to diurnal fluctuations in oxygen, there were also extended periods of anoxia recorded in August 2005. Anoxic conditions can also contribute to increased mercury methylation rates.

Harmful Algal Blooms

The relative composition of phytoplankton taxa varies in GSL with salinity, water temperature, and competition (Belovsky et al. 2011). Of all the species in the lake, blue-green algae are concerning because they can produce toxins that can be harmful to humans and wildlife. Overgrowth of blue-green algae is a public health and safety concern in recreational waters. Skin contact can result in irritation, rashes, and hives, whereas swallowing water can lead to severe gastroenteritis and organ toxicity in humans (Center for Disease Control 2008). The Center for Disease Control (2006) advises against recreating in water that is potentially contaminated with blue-green algae.

Blue-green algal blooms are an area of concern for Farmington Bay, though potential impacts to recreational users are still being researched. *Nodularia spumigena*, a toxic blue-green algal species, has been found in Farmington Bay especially at low salinity (Wurtsbaugh and Marcarelli 2004). Typical of blue-green algae, *N. spumigena* fixes nitrogen from the atmosphere and thereby contributes to nitrogen loading to Farmington Bay. This species is rarely seen at the higher salinities typical of Gilbert Bay. Nitrogen fixation appears to stop at salinities of greater than 5%, resulting in sharp reductions in blue-green algal species at higher salinities. Nodularin, the cyanotoxin produced by *N. spumigena*, is a skin and eye irritant, a hepatotoxin, and promotes tumors in mammals. It has caused mortalities in waterfowl, dogs, and livestock. Additional research is required to determine whether the cyanotoxins produced by *N. spumigena* in GSL are causing harm to humans or wildlife. Its chemical structure is similar to another well-studied toxin, microcystin. The World Health Organization has set a threshold of 100,000 cyanobacteria cells/mL or chlorophyll *a* concentrations of 50 µg/L to determine a moderate probability of adverse health effects in recreational waters (World Health Organization 2003; Wurtsbaugh and Marcalleli 2004). In addition, the World Health Organization has a guideline for recreation users of 20 µg microcystin/L, assuming a person swallows 100–200 mL/day of the tainted water. These standards were developed by taking the highest no-observed-effect level in multiple studies and then reducing it by an uncertainty factor of 1,000. Therefore, these thresholds are very protective of human health. Concentrations of cyanobacteria cells in Farmington Bay exceeded 200,000 cells/mL for most of the summer in 2007 and exceeded 600,000 cells/mL in the spring (Wurtsbaugh and Marcarelli 2006; unpublished data). Cyanotoxin concentrations in Farmington Bay were measured at 54 ug/L in May 2007 and 663 ug/L in October 2009 (Wurtsbaugh 2011; unpublished data). Monthly average cyanophyte concentrations in Gilbert Bay have reached concentrations as high as 117 µg/L in GSL, and total chlorophyll *a* concentrations have reached 228 µg/L. However, the average monthly concentration of cyanophytes and chlorophyll *a* in GSL is 14 and 32 µg/L, respectively (Belovsky et al. 2011). Additional research is underway to determine the frequency and extent of blue-green algal blooms in Farmington Bay and to ascertain whether these blooms typically include toxic varieties of blue-green algae. These additional data are necessary to determine whether blue-green algae pose a risk to recreation users of Farmington Bay.

2.3.4.5.4 Lake Level Effects on Water Quality

The relationship between lake level and water quality is complex and not yet well understood for GSL. There are no clear lake level thresholds that relate directly to water quality. However, there are a number of lake processes that are likely to be influenced by changes in lake level and indirectly through changes in salinity.

The most obvious effect of lake level on water quality is through dilution. The higher the lake level, the more dilution there is for pollutants and the lower their concentration. The opposite can be said for lower lake levels, less dilution, and more concentration of water quality parameters. Because there is no outlet from the lake, dilution plays an important role in water quality in the lake for parameters that are either processed and released in gaseous form or are semipermanently trapped in lake sediments or other ecosystem components.

Connectivity of the lake is also heavily influenced by lake level. Mixing between the North Arm and the South Arm occurs between lake elevations of 4,199 and 4,205 feet. There is partial mixing between Farmington Bay and the South Arm between lake elevations of 4,205 and 4,207 feet. There is full mixing between 4,208 feet and above 4,213 feet. When a bay is isolated from the main lake body, the water quality conditions in that bay can change without affecting the main lake. As with the conservative major ions, nutrients are transported to Bear River Bay and Farmington Bay, reducing the availability of nutrients to algae in the South Arm. Although limited measurements of nutrients have been made in the North Arm, the limited available data (Sturm 1980) show that nutrients in the North Arm were often double the concentration of those in the South Arm.

Due to the salinity gradients and head differences between bays separated by the Northern Railroad Causeway or Davis County Causeway, bidirectional flow occurs at causeway openings, breaches, and culverts. This bidirectional flow becomes more substantial as lake level goes up and results in the establishment of brine stratification in GSL. The DBL is the lower part of this stratification and is generally hypersaline and anoxic. Because the DBL facilitates the transformation of mercury into methylmercury, increases in the extent and thickness of the DBL could accelerate the process of mercury methylation. This would occur as lake levels increase up to the point at which the bays are fully connected and the causeways are overtopped.

As lake levels increase above 4,205 feet, there is partial and full mixing between Farmington Bay and the South Arm. High salinity concentrations from the South Arm flow into Farmington Bay, causing salinity concentrations in Farmington Bay to increase. When salinity concentrations are below 5% in Farmington Bay, a large portion of the algal biomass is often composed of harmful blue-green algae. It has been demonstrated that the cyanobacterium, *N. spumegina,* often found in Farmington Bay, survived poorly and stopped fixing nitrogen at salinities above 5% and will not survive at all at 8% salinity (Wurtsbaugh and Marcarelli 2006).

As the lake level goes down, a larger proportion of the lake mixes, and more nutrients are released into the water column. As the DBL is reduced due to increased salinity, mixing occurs more easily, and nutrients become mixed into the water column and available for algae in the upper portions of the lake where there is sufficient light for them to grow. Further, as the lake is reduced, nutrients are concentrated into a smaller pool of water and concentrations increase (Belovsky et al. 2011).

2.4 Wetlands

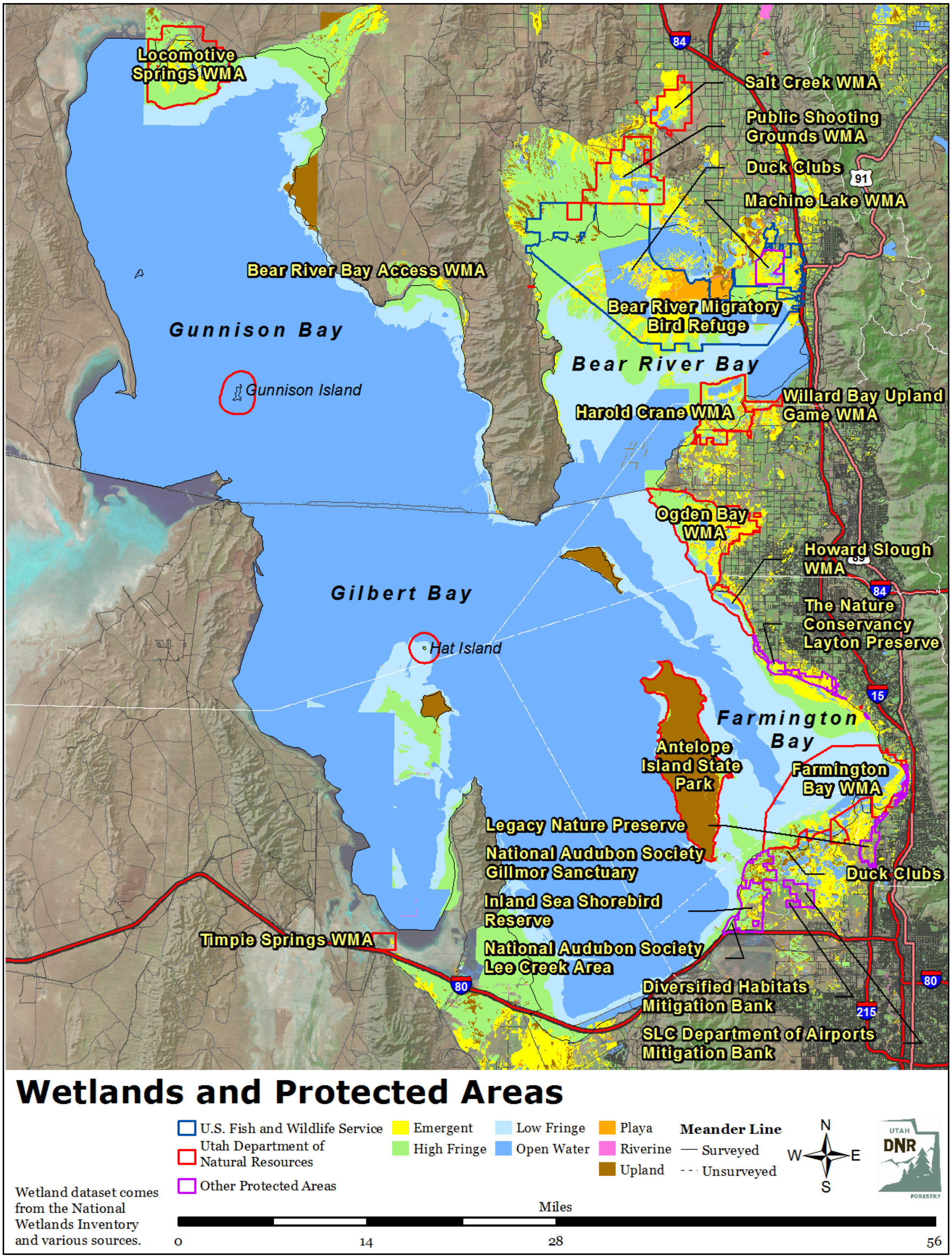
The wetlands surrounding GSL are of international importance, and they are acknowledged for supporting large populations of migratory birds. As a zone of transition between uplands and the open water of GSL, they also provide other functions. These include flood control, water quality improvement, and biogeochemical processing. There are approximately 360,000 acres of wetlands below the GSL meander line, in addition to 546,697 acres of open water and 3,540 acres of upland (Map 2.7). Wetlands represent 26% of the 1.37 million acres below the meander line.

2.4.1 Wetland Classification

Many wetland classification systems exist to describe different wetland types. These may be based on vegetation communities such as wet meadows or emergent marsh, or they may be based on hydrogeomorphic setting such as slope or depressional wetlands. Wetland classes typically apply to a specific purpose (e.g., wildlife management) where it is useful to have a common definition or description based on structural or functional characteristics. Cowardin et al. (1979) identify four objectives of a classification system:

- To describe ecological units that have certain homogenous natural attributes
- To arrange these units in a unified framework for the characterization and description of wetland that will aid decisions about resource management
- To identify classification units for inventory and mapping
- To provide uniformity in concepts and terminology

In their classification system, Cowardin et al. (1979) outline a hierarchical system of classes that characterizes wetlands based on hydrology, substrate, and vegetation. The USFWS has applied the Cowardin et al. (1979) classification system to a widely used mapping tool, the National Wetland Inventory. Alternatively, the hydrogeomorphic classification approach (Brinson 1993) emphasizes hydrologic and geomorphic controls, which maintain many functional aspects of wetland ecosystems. Used by the USACE, it is adaptable for regulatory and planning purposes such as the development of functional assessment methods. In addition, Table 2.14 describes the recent UGS effort to consolidate current National Wetland Inventory data into five classes that account for geomorphic position, vegetation, hydrology, and water chemistry. Approximate acreages for each wetland class below the meander line are included, and descriptions of each class follow Table 2.14.



Map 2.7. Wetlands and protected areas surrounding Great Salt Lake.

Table 2.14. *Utah Geological Survey Wetland Classes and Acreage Below the Meander Line of Great Salt Lake*

Wetland Class	Acreage
Emergent	37,006
High fringe	94,980
Low fringe	219,323
Playa	6,703
Riverine	1,362
Total	**359,374**

These wetland classes are described, as follows:

- **Emergent**: Emergent wetlands have permanent to semipermanent standing fresh water or saturated soils that support emergent macrophytes such as cattail (*Typha* spp.), bulrush (*Schoenoplectus* spp.), and/or wet meadow species such as grasses, rushes, and sedges.
- **High Fringe**: High fringe wetlands are irregularly inundated and contain standing water only when lake levels are high. The soils of high fringe wetlands may remain saturated near the surface over a wide range of lake levels, and develop a crust of bare mineral soil in summer. During extended periods of low lake level and thus, drier conditions, high fringe wetlands may be colonized by halophytic (salt-loving) vegetation.
- **Low Fringe**: Low fringe wetlands remain inundated over multiple years and can be considered transitional between open water portions of GSL and regularly exposed high fringe wetlands. These wetlands are almost always devoid of rooted vegetation due to yearly inundation by high salinity water. When inundated by fresh water, reeds, rushes, and other plants may establish small colonies or create an indistinct boundary between emergent and high fringe wetlands.
- **Playa**: Playas are shallow enclosed basins that accumulate soluble salts often with little or no vegetation or vegetation that is tolerant of saline conditions.
- **Riverine**: Riverine wetlands are perennial streams (including canals and ditches) and associated riparian areas that are regularly flooded by overbank flow.

Finally, for the process of developing wetland water quality standards and assessment methods, DWQ (2009) uses an additional class of wetland termed *impounded* wetlands. These form where dikes, berms, ditches, and culverts have been constructed to control or constrict the inflow into or outflow of water from the wetlands.

2.4.2 Wetland Mapping

Although there are maps illustrating wetlands in various areas around GSL, few are comprehensive. The 2000 GSL CMP uses a DWR publication (Jensen 1974) to quantify wetland habitat adjacent to GSL. Subsequent wetland maps or mapping tools include Ducks Unlimited's *Great Salt Lake Wetlands Assessment Project* (2007) and the USFWS's National Wetland Inventory (2008), which includes the Wetland Mapper found at http://www.fws.gov/wetlands/Data/Mapper.html. The *Great Salt Lake Shorebird Management Plan* (Paul et al. 2012 [in press]) uses the former to estimate acreage of migratory bird habitat. The latter is an interactive mapping tool based on multiple data sources that allows users to identify the location and extent of wetlands.

Additional tools that were financially prohibitive in the past are also being applied in Utah to map wetlands; these tools are based on remote sensing technology and the interpretation of satellite and infrared images. By analyzing the spectral signatures that reflect off certain vegetation communities or land surfaces, it is possible to identify and map wetlands by type, such as wet meadow, emergent marsh, mudflat, and open water. This technology has been applied to two special area management plans (SAMP) along GSL in northern Tooele and Salt Lake counties and to the Machine Lake Mitigation Bank in Box Elder County. Similarly, the distinct signature of *Phragmites* allows for mapping the establishment and spread of this invasive plant. Dr. Christopher Neale at USU has conducted this type of remote sensing analysis on the Bear River Migratory Bird Refuge.

2.4.3 Wetland Reference Network

Beginning in early 2000s, DWR established a wetland reference network with which to calibrate a wetland functional assessment tool. This reference network includes approximately 80 sites of different wetland classes along a continuum of anthropogenic disturbance. DWQ and UGS continue to amend and improve on this wetland reference tool. As work continues on local and National Wetlands Assessment methods, the reference wetlands surrounding GSL will be useful to define condition and provide baseline information for mitigation.

2.4.4 Development and Use of Assessment Methods

Recent initiatives at the national level and the 2008 Wetland Mitigation Rule that emphasize the use of science-based assessment procedures have resulted in the development of various methods to assess the condition of wetland resources. The Utah Wetlands Assessment Group, comprising federal and state agencies and private wetland consultants, evaluated five wetland assessment methods to assist in the ultimate development of a Utah model. The effort resulted in a white paper titled *Utah Wetlands Assessment Group Review and Evaluation of Five Wetland Assessment Models* (Defreese 2005). These methods range from UDOT's rapid assessment method (Johnson 2007) to a hydrogeomorphic model developed for slope wetlands in the Great Basin (Jones et al. 2003); both seek to quantify or qualify the condition of ecological or functional variables associated with wetlands.

To date, the lessons learned from the Utah Wetlands Assessment Group evaluation and other wetland programs at the national level were incorporated into the Utah Wetland Ambient Assessment Method by Dr. Heidi Hoven of The Watershed Institute. It is the intention of DWQ and UGS to apply the United States Rapid Assessment Method as part of the National Wetlands Assessment program. This method was developed by the EPA, and the National Condition Assessment program can be found at http://water.epa.gov/type/wetlands/assessment/survey/index.cfm. Relative to sovereign lands in Utah, the objectives of this method are to help states implement wetland monitoring and assessment programs to guide policy development and project decision making.

2.4.5 Groundwater Withdrawal Effects on Wetlands

UGS research indicates that wetlands and springs along the eastern and southern shore and Locomotive Springs along the north shore of GSL are sustained by shallow, unconfined aquifers, which are connected to deep basin fill aquifers (Burk et al. 2005; Bishop et al. 2009; Yidana et al. 2010). Shallow groundwater levels are affected by drought, GSL levels, groundwater pumping, and a shift in water use from agriculture to municipal. Modeling the water budget of fringe wetlands in Salt Lake, Tooele, and Davis counties suggests that subsurface inflow is most affected by long-term drought (20-year). Municipal and industrial pumping would further exacerbate the reduction in subsurface inflow during long periods of drought. Water budgets in acre-feet for these wetland systems are illustrated in Table 2.15.

Table 2.15. *Select Great Salt Lake Wetland Water Budgets*

Wetland System	Subsurface Inflow (acre-feet)	Other Inflow (acre-feet)	Total (acre-feet)
Salt Lake Valley	27,800	24,620	52,420
Farmington Bay	16,000	22,000	38,000
Tooele Valley	98,000	6,600	104,600

Sources: Burk et al. (2005); Bishop et al. (2009); and Yidana et al. (2010).

2.4.6 Water Quality in Wetlands

During the 2000 CMP process, the Scientific Review Committee identified the lack of a comprehensive database on GSL as a significant impediment to management decisions protective of the lake's resources. Since then, DWQ has embarked on a GSL Wetlands Monitoring, Assessment, and Water Quality Standards Program.

Numeric water quality standards were adopted for the state WMAs and the Bear River Migratory Bird Refuge for aquatic wildlife beneficial uses. However, DWQ found that applying existing water quality standards to these wetlands was problematic for two reasons:

- The standards that are specifically applied to wetlands are based on the geographical location of the aquatic resource rather than their ecological characteristics. Numerous wetland classes are located within WMAs and the Bear River Migratory Bird Refuge, and each class has its own biota and distinct ecosystem processes. The ecologically distinct character of each of those wetland classes needs to be considered when developing defensible standards, assessment methods, and protection practices. Also, the wetland areas described in current standards represent just a subset of the wetlands around GSL. The quality of some wetlands outside of the described areas may actually be more at risk because they are not actively managed for wildlife conservation.
- The identification of those criteria that best reflect or characteristic ecosystem/wetland condition is problematic. For example, the water quality standards for the WMAs had numeric criteria for dissolved oxygen and pH. Although water quality conditions can exceed the desired criteria within many "impoundment" class wetlands, including the most pristine, there is evidence suggesting that most of these wetlands continue to support their designated uses. Wetland biota have adapted to environmental conditions with wide fluctuations in dissolved oxygen and pH. These measures are not robust indicators of wetland condition.

To address these issues and in response to stakeholder concerns of excessive algae in GSL impounded wetlands, DWQ and its partners have expended considerable time and resources to build an ecological understanding of this wetland class. Research by Gray, L.J. (2005, 2009), CH2M Hill (2008, 2009), Miller and Hoven, (2007), and Rushforth and Rushforth (2006a–d) has advanced the understanding of the biogeochemical processes of this wetland class. These findings will inform the development of more appropriate water quality standards for impounded wetlands for parameters such as dissolved oxygen, pH, and nutrients and will contribute to a Multimetric Index to measure ecological integrity in these wetland systems.

In December 2009, DWQ developed a preliminary Multimetric Index for GSL impounded wetlands that includes quantitative indicators of water chemistry, submerged aquatic vegetation, surface mats, and benthic macroinvertebrates. These indicators provide multiple lines of evidence that together quantify the relative condition of GSL's impounded wetlands. Ongoing data collection and research will focus on improving and validating the preliminary assessment framework.

Finally, because of the unique biochemistry of the GSL ecosystem, it is likely that numeric criteria for the protection of biota will have to be applied based on wetland class. Much of the existing research is limited to impounded wetlands, and the next step is to extend wetland monitoring and assessment to the fringe (sheet flow) wetlands class.

2.4.7 Regulatory and Jurisdictional Issues

As per State of Utah v. United States 1971, the bed of the lake below the meander line is considered Utah Sovereign Lands, and FFSL is authorized to manage them. Additional jurisdictional layers also apply. For example, GSL is considered a traditional navigable water under Section 404 of the CWA, and as such, the discharge of dredge and fill material is regulated by both the USACE and the EPA. At this time, the USACE regulates those lands below 4,205 feet, whereas potential waters of the U.S. above this elevation are considered on a case-by-case basis pending the findings of a delineation and jurisdictional determination process.

Waters of the U.S. are generally defined as a) those waters that are currently used in interstate or foreign commerce, b) those waters that were used in the past in interstate or foreign commerce, or c) those waters that may be susceptible to use in interstate or foreign commerce. In the context of the current regulatory landscape articulated by the Supreme Court in the Rapanos decision, potential waters of the U.S. between 4,205 feet and the meander line include streams, playas, mudflats, and both adjacent and abutting wetlands. No mitigation guidance for impacts to sovereign lands that are also considered waters of the U.S. exists beyond what is required by the USACE.

UDNR agencies generally enforce only USACE permit requirements when issuing land-use authorizations that affect wetlands. UDNR is considering establishing a policy that goes beyond USACE requirements. This could include actions such as mitigation requirements, grazing, burning, and herbicide and pesticide application in jurisdictional and nonjurisdictional wetlands.

FFSL's statutory mandate also includes defining the lake's floodplain, and legislative policy maintains the lake's floodplain as a hazard zone. UDNR considers the floodplain to extend to the 4,217-foot elevation. This is based on high lake levels in the 1980s of roughly 4,212 feet, plus 3 feet for wind tide and 2 feet for wave action.

UDNR has no regulatory authority over land they do not own in the lake's floodplain. The regulatory framework is provided by local government planning and zoning, FEMA, and USACE. FEMA has mapped the floodplain to determine when flood insurance is required and has determined that the 100-year floodplain generally lies at 4,217 feet. Adherence to FEMA's demarcation is required if local communities want to participate in the National Flood Insurance Program. UDNR satisfies the legislative mandate and policy by defining the floodplain for planning purposes as lands below 4,217 feet and discouraging development below that level. If a wetland lies within the floodplain, as determined by USACE, an additional criterion is added to the permit decision-making process. Agencies do not always agree on the extent of the floodplain.

2.4.8 Royalty/Fee Sources and their Potential to Fund Wetland Conservation

FFSL reserves the right to recoup a fee or royalties stemming from leases, bioprospecting (UTAH CODE §§ 65A-14-201 and 202), and other activities conducted on state lands. At present, all revenue including fees and royalties goes into the "Restricted Fund" to be allocated by the state legislature (see section 2.14.4 for discussion of recent royalty contributions to the Restricted Fund). No provision in the state code directs money specifically to GSL wetlands conservation or protection. Through the GSL Technical Team, grant applications are accepted to fund wetland-related research and projects, as funding is available through FFSL.

2.4.9 Existing Wetland Management Areas

Map 2.7 illustrates that the approximately 260,000 acres of wetlands or wetland-upland-open water mosaics are under some form of management or protection by federal, state, municipal, or private organizations (Table 2.16). Although some of these protected areas fall below the meander line, many extend above or are adjacent to this jurisdictional boundary. Most are managed specifically for waterfowl or shorebird habitat, whereas a few function as mitigation areas to offset prior impacts to wetlands authorized by the CWA. Federal and state properties have management plans that are revised periodically (e.g., Locomotive Springs, Bear River Access, Public Shooting Grounds, and Harold Crane WMAs were revised in January 2010) and that address habitat condition and maintenance. State plans receive a Resources Development Coordinating Committee project number and are reviewed by the DWR Habitat Council and regional advisory councils.

Table 2.16. *Managed or Protected Wetland Areas Above and Below the Meander Line*

Management Area	Acreage
Federal	**71,491**
Bear River Migratory Bird Refuge	70,400
Wetland Reserve Program easement (Natural Resources Conservation Service), Box Elder	1,091
DWR (state)	**90,012**
Locomotive Springs WMA	18,000
Bear River Access WMA	5
Salt Creek WMA	5,254
Public Shooting Grounds WMA	11,800
Harold Crane WMA	11,303
Willard Bay Upland Game Management Area	2,000
Ogden Bay WMA	20,000
Howard Slough WMA	3,210
Farmington Bay WMA	17,000
Timpie Springs WMA	1,440
DSPR	**7,259**
Antelope Island State Park	7,259

Table 2.16. *Managed or Protected Wetland Areas Above and Below the Meander Line*

Management Area	Acreage
FFSL	**26,632**
GSL Lake bed (not subject to lease; includes Hat and Gunnison islands)	26,632
UDOT	**2,072**
Legacy Nature Preserve	2,072
Municipal	**250**
Salt Lake City Department of Airports Mitigation Site	250
Private Conservation	**56,631**
Diversified Habitats Mitigation Bank	123
The Nature Conservancy Layton Preserve	4,498
National Audubon Society Gillmor Sanctuary	2,433
National Audubon Society Lee Creek Area	305
Inland Sea Shorebird Reserve	3,670
GSL Duck Clubs*	42,707
Machine Lake Mitigation Bank	2,895
Total	**254,347**

* Includes Bear River, Chesapeake, Canada Goose, and South Shore duck clubs.

2.4.10 Additional Acreage Brought into Conservation or Protection Status

Since the 2000 GSL CMP, new areas have been brought under conservation and protection as preserves (e.g., Legacy Nature Preserve [Davis County]) or as mitigation (e.g., Machine Lake Mitigation Bank [Box Elder County]). In collaborating to produce the *Great Salt Lake Shorebird Management Plan*, the USFWS estimates that approximately 26,600 acres of lake bed are not subject to lease and are therefore protected, 90,500 acres are state WMAs, and 70,400 acres are federally managed as refuge. The *Great Salt Lake Shorebird Conservation Strategy Plan* (Paul et al. 2012 [in press]) provides an updated and comprehensive review of these properties.

2.4.11 Lake Level Effects

Although little work has been done to quantify the change in location and extent of wetlands relative to GSL elevation, the dynamic process associated with changes in lake level is generally well understood because hydrology and lake level vary from year to year. As lake levels rise, mudflats become shallow open water, whereas freshwater wetlands become increasingly saline or contiguous waters of GSL (DWQ 2009). It is estimated that for every 1-foot increase or decrease in lake level, approximately 44,000 acres of mudflats are inundated or exposed (Aldrich and Paul 2002). As water levels decline, the length of the open water/mudflat interface decreases, reducing the amount of shorebird habitat. During high water, salt coming out of solution is deposited in sediments, which are flushed back into the lake by freshwater tributaries when surface-water levels drop (DWQ 2009). Due to this exposure, channels with perennial or intermittent flow that are covered during high water now have the potential to support vegetation. Ultimately, increases and decreases in soil and water salinity drive the establishment of vegetation communities as they adapt to these changing conditions.

UGS groundwater models (Yidana et al. 2010; Bishop et al. 2009; Burk et al. 2005) indicate that flow from basin-filled aquifers to shallow, unconfined aquifers sustains wetlands and springs adjacent to GSL. Drought and associated declines in lake level have a significant effect on this pathway and therefore the greatest impact on wetland ecosystems. According to UGS models, impacts can be exacerbated by groundwater withdrawals. Interagency consideration of the future allocation of groundwater resources should consider lake level.

Management of wetlands at various lake levels should consider how changes in water chemistry and how contributions from both surface and groundwater affect vegetation communities. For example, different plants may tolerate various levels of salinity, depth to groundwater, and depth/duration of surface-water inundation. In addition, natural disturbance (e.g., variation in lake level) allows for the establishment of invasive plant species such as *Phragmites* if not actively managed. Questions remain with regard to whether extensive/intensive groundwater pumping near the lake could result in intrusion of highly saline GSL water into shallow aquifers.

As illustrated in the GSL Lake Level Matrix, fringe (unimpounded) wetlands and impounded wetlands are affected by changes in lake level. Most are subject to inundation at high lake levels, the amount of which varies with base elevation. Similarly, most are subject to desiccation at low lake levels and the potential encroachment of invasive species. The magnitude of these effects is dependent on the specific management goals and infrastructure of each wetland area. For example, high lake levels can cause erosion of dikes, which is integral to waterfowl management (as seen during the floods in the 1980s). Conversely, high salinity in a management area can eradicate *Phragmites*. Low lake levels and drought conditions require that water is actively moved through wetland management areas. In some years, the USFWS must prioritize those units that receive water on the Bear River Migratory Bird Refuge. This management decision is based on factors such as the capacity to support waterfowl and the capacity to control avian botulism.

2.4.12 Wetlands Surveys and Research

A significant local effort for research on GSL wetlands has been the 1995 National Audubon Society's *Feasibility Study for the South Shore Wetlands Ecological Reserve of the Great Salt Lake*. This investigation has led to restoration of the natural inflow of fresh water to the prehistoric river channel and delta of the Jordan River. The results of this ecosystem restoration effort have been successful in providing migration and nesting areas for birds along the south shore of GSL (Sorensen 2010). This is one example of an effort focusing on improving habitat for waterfowl, shorebirds, and other waterbirds.

Studies of wetland habitats include the following efforts:

- Threats to wetlands posed by groundwater development and drought, northern Salt Lake County (Yidana et al. 2010)
- Threats to wetlands posed by groundwater development and drought, Tooele Valley (Bishop et al. 2009)
- Threats to wetlands posed by groundwater development and drought, Farmington Bay Area (Burk et al. 2005; UGS 2005)
- GSL Wetlands Mapping and Assessment (Ducks Unlimited)
- Revision of National Wetlands Inventory data layer (USFWS and UGS)
- Preliminary Multimetric Index for GSL for impounded wetlands (DWQ and other researchers)
- Macroinvertebrates in GSL Wetlands (Gray 2005, 2009)

- Using multispectral imagery for wetland mapping and assessment (USU, Frontier Corp. and SWCA Environmental Consultants)
- WMA management revisions (DWR)
- Comparison of two rapid methods to assess wetland condition in Bear River Bay (UGS)

2.5 Air Quality

Air quality is an important consideration for the quality of life of residents of the Wasatch Front and for the protection of the GSL ecosystem. Planners and resource managers have recognized the importance of air quality and pollutant transport along the Wasatch Front. This section describes current air quality concerns along the Wasatch Front and the contribution to these issues from industries dependent on the GSL ecosystem.

2.5.1 Current Air Quality Concerns

Air quality in Utah is of greatest concern in valley areas that experience temperature inversions associated with topography. Temperature inversions severely limit the transport and dispersion of pollutants emitted into the lower layers of the atmosphere (Wasatch Front Regional Council 1980). During inversions, the Wasatch Front often records the worst air quality in the country. Despite the challenges associated with topography, Utah has significantly cleaner air today compared to 25 years ago (DAQ 2011). Reductions in emissions since the 1980s, primarily in motor vehicle and industrial emissions, have resulted in improved air quality and visibility throughout the state.

The Clean Air Act Amendments of 1990 provide the policies regarding areas not currently meeting federal health standards for certain criteria pollutants. It also requires that comprehensive state air quality plans be developed that will reduce pollutant concentrations to a safe level. The maximum allowable concentrations set by EPA for the criteria pollutants are known as the National Ambient Air Quality Standards (NAAQS). Areas failing to comply with these standards are considered nonattainment areas and can be classified as marginal, moderate, serious, severe, or extreme. An area with a marginal rating will have less time to reach attainment than an extreme classification.

Although air quality has improved since the 1980s, the NAAQS have become more protective over time, challenging states to make further improvements. Currently, Utah has or is in the process of writing SIPs for several nonattainment areas, including counties and municipalities along the Wasatch Front. These areas are exceeding or have recently exceeded the following current NAAQS:

- Particulate matter (PM_{10}): Salt Lake and Utah counties and the City of Ogden.
- Particulate matter ($PM_{2.5}$): Weber, Davis, Salt Lake, and Utah counties and portions of Box Elder and Tooele counties based on proximity to other counties in nonattainment.
- Sulfur dioxide (SO_2): Salt Lake County.
- Ozone (O_3): Salt Lake and Davis counties have only recently attained the NAAQS for O_3 and are being monitored to ensure that compliance is maintained (designated maintenance status).
- Carbon monoxide (CO): Ogden, Salt Lake City, and Provo have recently come into compliance with CO standards and are currently operating under a maintenance plan to ensure continued compliance.

Each state is responsible for developing plans to demonstrate how those standards will be achieved, maintained, and enforced to protect public health, according to the Clean Air Act (42 United States Code [U.S.C.] § 7401) requirements. These requirements set limits for maximum levels of pollutants in outdoor air. The SIPs and associated rules are enforced by the state and are subject to federal approval and compliance. The plans break down specific emission contributions from vehicles, industrial sources, and human activities and also provide the framework for each state's program to protect air quality.

Twenty-five monitoring stations are strategically located across the state and collect representative data to determine how much of each pollutant is in the air. Air pollutant concentration models are used to assess area pollution levels and provide information for maintaining air quality standards (DAQ 2011).

2.5.2 Emissions from Industries Dependent on Great Salt Lake

The confining terrain, diurnal wind circulation, and high inversion frequency requires that industrial sites be very carefully considered along the Wasatch Front (Wasatch Front Regional Council 1980). The impact of a given industry will depend on the transport properties of its emissions and the dispersion characteristic of the locality. There are many industrial, mobile, area, and other emissions that contribute to air quality concerns along the Wasatch Front. However, in this section, the focus is on the emissions from industries that are directly reliant on GSL and/or are permitted by FFSL.

Four mineral production companies that operate facilities to extract minerals and salts from GSL emit pollutants. These facilities emit pollutants such as CO, nitrous oxides, PM_{10}, $PM_{2.5}$, SO_2, volatile organic compounds (VOC), and hazardous air pollutants (HAP). Because the lake is critical to their operations, changes in operations related to lake management and lake level could change emissions of air pollutants from these facilities.

O_3 is generally not emitted directly, but forms from a chemical reaction between emissions of VOCs and nitrogen oxides (NOx) in the presence of heat and sunlight. CO is an odorless, invisible gas usually formed as the result of incomplete combustion of organic substances. GSL industries emit approximately 2% and 0.3% of the total NOx and VOC emissions in the five counties surrounding GSL, and therefore contribute a small amount to O_3 formation along the Wasatch Front. The largest contributors of NOx along the Wasatch Front are mobile vehicles. VOCs are primarily emitted from biogenic sources (e.g., livestock and vegetation), area sources, and other point sources (e.g., industries other than those dependent on GSL).

CO is an odorless, invisible gas usually formed as the result of incomplete combustion of organic substances. SO_2 is formed during the combustion of sulfur-bearing materials, such as the sulfur in metal ores or fossil fuels. GSL industries are not large sources of CO or SO_2 emissions in the counties surrounding GSL, accounting for only 0.1% and 0.5% of the total emissions, respectively. Most CO emissions are from mobile vehicles, whereas most SO_2 emissions are from commercial and industrial point sources.

PM refers to dust and other particles in the air and is measured either as PM that is 10 micrometers and smaller (PM_{10}) or fine PM that is 2.5 micrometers in diameter and smaller ($PM_{2.5}$). $PM_{2.5}$ is a subset of PM_{10}. During periods of temperature inversion, especially during the winter months, $PM_{2.5}$ reaches unhealthy concentrations. GSL industries contribute 2%–4% of PM emissions in counties that surround GSL. Mobile sources represent the largest source of particulate emissions in the area. Nearly half of the emission for PM_{10} in the five counties comes from area sources.

HAPs are those pollutants listed in the Clean Air Act that are known or suspected to cause cancer and other serious health problems. There are hundreds of HAPs monitored and controlled by DAQ. US Magnesium, one of the four GSL industries, is a significant contributor of HAPs in GSL counties and accounts for nearly half of the total HAPs emitted. The HAPs emitted by US Magnesium in greatest quantity are chlorine and hydrochloric acid. US Magnesium emitted approximately 580 tons of chlorine in 2008. Although this is still the largest emitter of chlorine in the state, it is a 99% reduction from historic emissions that totaled 44,300 tons in 1988 (FFSL 1999). Other HAPs emitted by GSL industries are dioxins, lead, polychorlinated biphenyls, acrolein, cadmium, formaldehyde, and polycyclic aromatic hydrocarbons (a summary for 2008 is shown in Table 2.17).

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Table 2.17. *Summary of 2008 Air Emissions from Facilities with Forestry, Fire & State Lands Great Salt Lake Leases Compared to Total Emissions in Counties around Great Salt Lake*

Facility	County	CO (tons per year)	NOx (tons per year)	PM_{10} (tons per year)	$PM_{2.5}$ (tons per year)	SOx (tons per year)	VOC (tons per year)	HAPS*	
								Total Emissions (tons per year)	HAPs Emitted
US Magnesium	Tooele	320.4	1,079.3	347.4	226.4	25.5	416.5	1,380.2	Chlorine, dioxins, hydrochloric acid (hydrogen chloride), lead, and polychlorinated biphenyls (aroclors)
Cargill Salt	Tooele	17.3	48.6	47.4	47.4	3.6	3.2	0.02	Acrolein, cadmium, formaldehyde, lead, polycyclic aromatic hydrocarbons
Morton Salt	Tooele	21.64	36.08	33.88	n/a	4.09	5.78	0	None
GSL Minerals	Weber	50.64	84.1	205.43	38.57	6.25	7.72	0	Lead
HAFB	Davis	90.69	142.33	21.14	7.65	2.08	215.96	47.57	†
HAFB: Utah Test and Training Range	Tooele	50.34	11.13	46.35	23.61	0.01	4.34	0.85	‡
Total industrial emissions from GSL mineral operators	–	551.01	1,401.54	701.6	343.63	41.53	653.5	1,428.64	–
Total counties around GSL	Box Elder, Davis, Salt Lake, Tooele, and Weber	363,782.50	57,815.60	38,227.10	8,661.60	7,988.70	156,996.90	2,738	–
County Totals from GSL Industries (%)	–	0.15%	2.42%	1.84%	3.97%	0.52%	0.42%	52.18%	–

* HAPs are those pollutants listed in the Clean Air Act that are known or suspected to cause cancer and other serious health problems.

† HAPS on HAFB Main Base: 1,2-epoxybutane; 2,2,4-trimethylpentane; 4,4-methylenedianiline; acetaldehyde; acrolein; benzene; diethylene glycol monobutylether A; dimethyl formamide; ethyl benzene; ethylene glycol; formaldehyde; hexane; methanol; hexone; dichloromethane; MDI; phenol; toluene; xylenes.

‡ HAPS on HAFB Testing and Training Range:1,1,2,2-tetrachloroethane; 1,3-butadiene; 2,2,4-trimethylpentane; acetaldehyde; acetonitrile; acrolein; acrylonitrile; arsenic; benzene; benzo(a)anthracene; benzo(a)pyrene; cadmium; chromium compounds; chrysene; cobalt; cumene; cyanide; dibenzo(a,h)anthracn; diethylene glycol monobutylether a; diethylene glycol monoethyl ether; ethylbenzene; ethyl chloride; ethylene glycol; ethylene oxide; ethylidene dichloride; fluroranthene; formaldehyde; hexane; hydrazine; hydrogen cyanide; hydrogen fluoride; indeno pyre; lead; manganese compounds; mercury compounds; methanol; methyl isobutyl ketone; methyl ter-butyl ether; methylene chloride; naphthalene; nickel; tetrachloroethylene; toluene; trichloroethylene; vinyl chloride; xylenes.

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2.5.3 Mercury Deposition on Great Salt Lake

GSL sediments and some deep water areas have some of the highest recorded concentrations of mercury in the country. However, mercury concentrations in the water column and in brine shrimp are generally below the EPA aquatic life standards. The implications of mercury to the GSL ecosystem are discussed further in section 2.3.5.2. Because GSL is a terminal lake, it acts as a mercury sink by accumulating mercury in lake sediments. According to a study completed in 2010, atmospheric deposition of mercury accounts for 89% of the total mercury influx to GSL each year (Lisonbee 2010). Mercury is deposited to the lake in three forms: gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate mercury (PBN). Dry deposition of GEM from global background is the largest identified source (50% of the total influx to the lake), followed by wet deposition (29%), and dry deposition of GOM, PBN, and local sources of GEM (10%) (Figure 2.12). In 2009–2010, deposition of GEM peaked during the winter months.

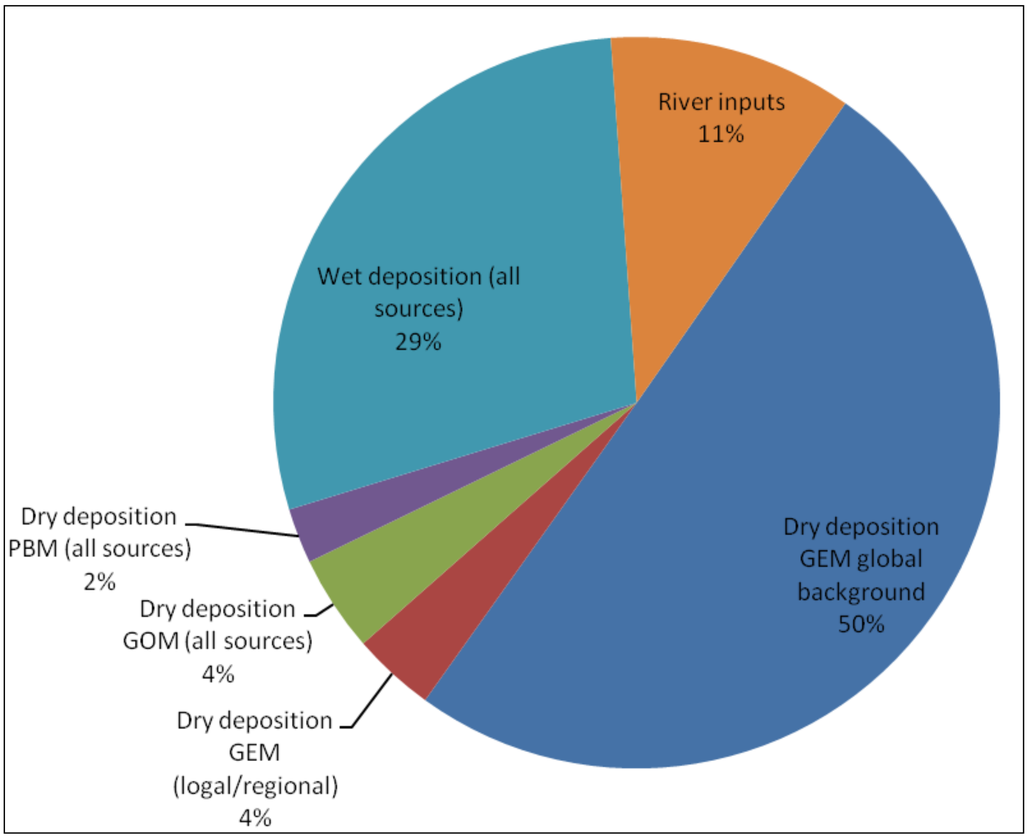

Figure 2.12. Summary of quantified mercury sources to Great Salt Lake, including wet and dry deposition.[5]

2.5.4 Lake Level Effects

Approximately 41% of PM emissions in GSL counties comes from diffuse area sources (Figure 2.13), including windblown dust from exposed lake beds. As the elevation of GSL declines, a large amount of lake bed becomes exposed, possibly becoming 1) an additional area source of PM_{10} emissions and 2)

[5] There may be additional sources that have not yet been quantified, such as coarse particulate mercury.

potential sediment-bound contaminants such as mercury. The amount of dust emitted per acre of lake bed playa exposed is unknown. The characteristics of exposed lake bed are highly variable, and numerous factors including hydrology (lake level and precipitation), sediment composition, wind direction, and wind patterns affect the amount of dust emitted as a result of wind erosion (Reynolds et al. 2007). In general, undisturbed dry playas emit less dust than salt-rich wet playas. *Undisturbed dry playas* are defined as playas in which the groundwater table is less than 5 m deep (Reynolds et al. 2007). The exposed playas around GSL are generally salt-rich, wet playas that are susceptible to wind erosion.

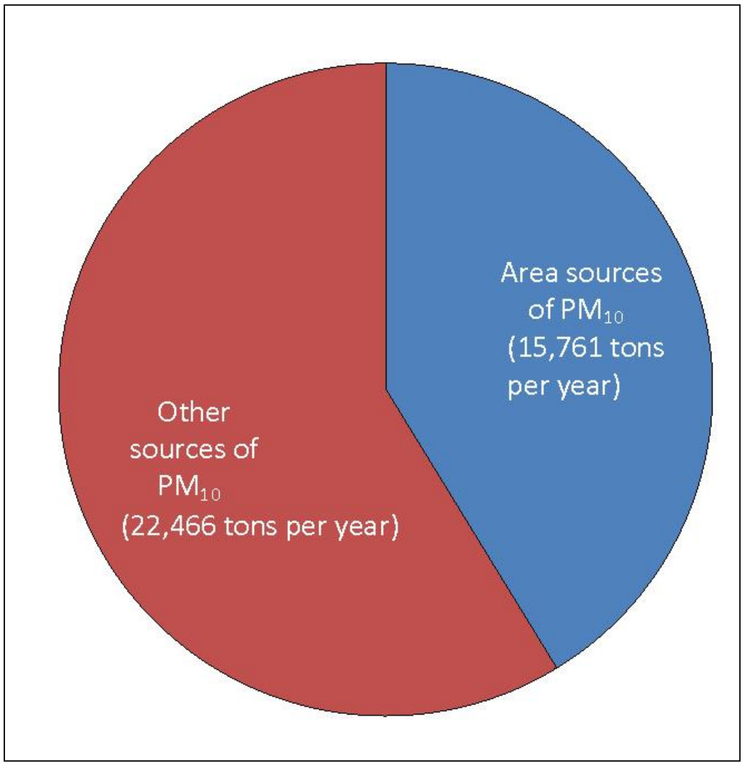

Figure 2.13. 2008 summary of PM_{10} emissions for Box Elder, Davis, Weber, Tooele, and Salt Lake counties.

Figure 2.14 illustrates the amount of lake bed exposed under each lake level category. Because of the relatively shallow depth of the lake, the amount of area exposed increases greatly in response to minor changes in lake level.

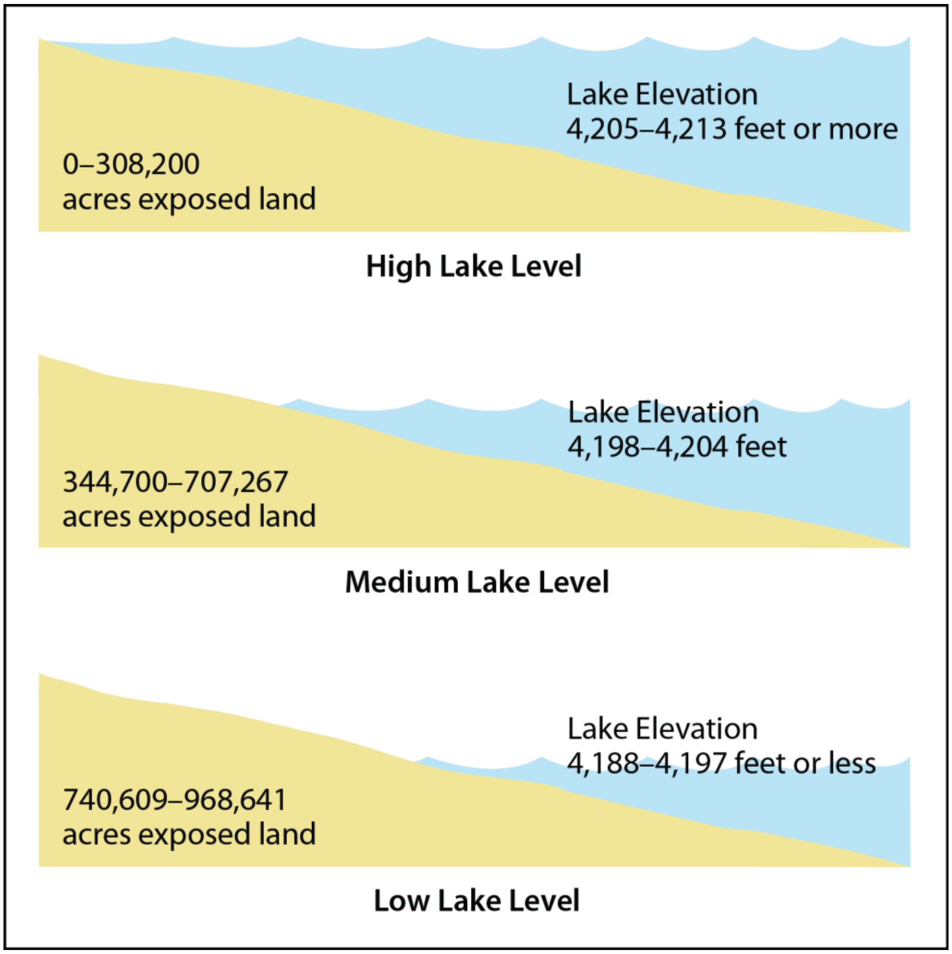

Figure 2.14. Lake surface exposed at elevation thresholds.

2.6 Climate

2.6.1 Global and Regional Climate Change

According to the *Climate Change Synthesis Report* published by the Intergovernmental Panel on Climate Change in 2006 (IPCC 2006), the years 1995–2006 rank among the eleven warmest years since 1850. The report also provides evidence from all continents that many natural systems are being affected by climate changes, particularly temperature increases. Hydrologically, there is high confidence that the following effects on hydrological systems are occurring in many river basins: increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers, and warming of lakes and rivers in many regions. The effects of climate change impact the thermal structure and water quality of hydrologic systems (IPCC 2006).

The United States Global Research Program (USGRP) found that climate change is already impacting the United States, and these impacts are expected to intensify in the future (USGRP 2009). In many areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring, and flows will be lower in late summer. Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between). Precipitation and runoff are likely to decrease in the West, especially the Southwest, in spring and summer (USGRP 2009).

Specific impacts of climate change in Utah were summarized by the Science Panel of the Governor's Blue-Ribbon Advisory Council on Climate Change in 2007 (Steenburgh et al. 2007). The report states that Utah is "projected to warm more than the average for the entire globe and more than coastal regions of the contiguous United States. The expected consequences of this warming are fewer frost days, longer growing seasons, and more heat waves" (Steenburgh et al. 2007:2). These effects have already been detected in the temperature data. Temperatures in Utah between 1997 and 2007 were more than 2^{o}F higher than the 100-year average. The report also reports that if greenhouse gas emissions remain at or above 2007 levels, it is likely that Utah's mountain snowpack will decline, and severe and prolonged episodic droughts could result. However, the report clearly states that there is no clear linkage between recent global warming and precipitation within the GSL Basin. Although mountain snowpack declines have been observed in the Pacific Northwest and California, there is no evidence yet of clear long-term trends in mountain snowpack or streamflows in Utah.

Ocean acidification is another well-documented climate change–related concern resulting from the increase in atmospheric carbon dioxide (CO_2). Increased CO_2 in the atmosphere is correlated with the absorption of CO_2 by the oceans. Dissolved CO_2 reacts with water to create carbonic acid that reduces ocean pH and causes the ocean to become more acidic. Since 1990, there has been a clear decline in ocean pH that is well correlated with CO_2 concentrations in the atmosphere and ocean water (Feely et al. 2009). As oceans become more acidic, it becomes more difficult for many marine organisms such as corals and mollusks to build shells and skeletons. USGS's Dr. David Naftz recently began exploring whether a similar effect could occur in GSL. Preliminary analysis indicates that if dissolved CO_2 in GSL were to increase, bioherms could begin to dissolve. More research is needed to quantify the magnitude of this threat and the specific biogeochemical pathways between lake pH and bioherm formation. The USGS is currently developing methods to measure the thickness of bioherm material in GSL in part to be able to monitor the growth and/or dissolution of these biogenic carbonates in the future (Naftz 2011).

2.6.2 Lake Effects on Local Climate

The size of GSL and its salinity play a role in the locate climate of the Wasatch Front. A variety of dynamic feedback mechanisms exists between weather and climate systems and any large lake. The *lake effect* occurs when relatively warm lake water enhances the moisture content of storm systems. The salinity of GSL prevents the lake from freezing, keeping the lake surface exposed for water vapor and energy transfer to the atmosphere even during winter months. This produces heavy precipitation, which is deposited on the leeward side of the lake in the Wasatch Mountain range. However, many storms in the Wasatch Mountains are characterized by orographic precipitation, which occurs when air masses move over topographic barriers such as mountain ranges and cool due to increasing elevation. Exceptional skiing conditions in the Wasatch Mountains can be attributed to the geographic coincidence of a large lake located upwind of a steep mountain front. The lake effect plays a role on snow fall in the Wasatch Mountains, accounting for approximately 10% of the annual snowfall (Steenburgh et al. 2000; Steenburgh 2011).

2.6.3 Lake Level Effects of Global Climate Change and on Local Climate

The watershed of GSL responds to global and regional climatic variability (annual precipitation, streamflow, temperature, and other hydrologic processes). Understanding the relationship between local precipitation and stream hydrology and global climatic drivers is important to understanding changes in lake volume and salinity. Runoff to the GSL Basin is driven by mountain snowpack and melt. The effect of climate change on this process in the GSL Basin cannot be predicted due to variation in current climate conditions and the lack of measurable trends in snowpack as of 2007 (Steenburgh et al. 2007). However, the Science Panel of the Governor's Blue-Ribbon Advisory Council on Climate Change found that as temperature increases, "expected declines in mountain snowpack will likely lead to lower average [GSL] lake levels and increased average salinity unless winter precipitation increases" (Steenburgh et al. 2007:18–19). The report notes that the timeframe of these changes is unknown.

The size and salinity of the lake influence lake effect storms. As lake level decreases, the salinity of the lake increases, and high salinity levels can significantly retard the amount of water that evaporates from the lake's surface. Therefore, a smaller lake could reduce the contribution of lake effect snow to the Wasatch Mountains. However, because there is high variability in winter precipitation and the lake only accounts for approximately 10% of this snowfall, lake levels are unlikely to result in a detectable change to snowpack.

2.7 Biology

The GSL ecosystem comprises a large, hypersaline, terminal lake surrounded by a mosaic of wetlands, uplands, and drainage systems. The GSL Basin encompasses approximately 3,011 square miles between the Wasatch Range and the western desert. The lake is fed by four large drainage systems (the Jordan, Ogden, Weber, and Bear rivers) and numerous smaller drainages. This Great Basin cold-desert ecosystem occurs from lake level (4,200 feet) to approximately 4,500 feet in elevation in surrounding wetlands and uplands. GSL receives an average of 15 inches of precipitation near the Wasatch Front, less than 10 inches of precipitation on the west side of the lake, and has annual average maximum temperatures of 65.5 degrees Fahrenheit (°F) and annual average minimum temperatures of 38.1°F. The surrounding drainages contribute approximately 3,684,500 acre-feet of fresh water to the lake, with wetland habitats located primarily along the river channels and deltas and smaller and more isolated wetland complexes located near drains, small tributaries, and groundwater discharge areas. Precipitation contributes an additional 1,000,000 acre-feet of fresh water to the lake annually. Sodium and chlorine form the major components of the lake's chemistry, and surrounding uplands are dominated by saline and alkaline soils.

GSL is of regional and hemispheric biological importance due to its role as a major North American migratory bird flyway, as vital shorebird breeding habitat, and due to its enormous size and influence on the climate and ecology of the area. Because the chemistry of the GSL ecosystem is dominated by sodium and chlorine, the vegetation communities that are associated with GSL habitats are primarily halophytic and contain plant species that are uniquely adapted to hypersaline conditions in the lake (e.g., algae) and saline and alkaline conditions in surrounding wetlands and uplands (e.g., submergent, emergent, and upland plants). Halophytic algae serve as the primary food for the brine flies and brine shrimp that support the GSL food chain (see Figure 2.2). The very flat gradient of the lake bottom causes dramatic fluctuations in the shoreline of approximately 460 feet per foot of lake level change (up to 880 yards seasonally) and results in a diversity of shoreline habitats, including ephemeral pools, mudflats, vegetated playas, and sand bars. The transitory nature of GSL water levels and shorelines are a fundamental component of the biological productivity of the lake and its value to migratory shorebirds and the brine shrimp industry.

The GSL ecosystem supports a diverse assemblage of plant and animal species in a unique mosaic of uplands, wetlands, mudflats, river deltas, ephemeral ponds, brackish and freshwater marshes, and other habitat types. Approximately 250 species of birds, 64 species and subspecies of mammals, 23 species and subspecies of fish (primarily in impounded freshwater inflow areas), 19 species of reptiles, and eight species of amphibians have been documented in the GSL environs. These species include the federally protected peregrine falcon (*Falco peregrinus*), the federally protected bald eagle (*Haliaeetus leucocephalus*), and 16 Utah state sensitive species, including the American white pelican (*Pelecanus erthrorhynchos*) and the long-billed curlew (*Numenius americanus*). The abundance and diversity of species associated with GSL varies across habitat types and seasons.

At least five uniquely productive aquatic environments exist in the GSL ecosystem. They provide abundant and diverse habitat for the numerous wildlife species that use the lake system. They are as follows:

- Open-water environments of varying salinities from freshwater to hypersaline water
- Freshwater lacustrine wetlands associated with river and stream deltas
- Brackish-water areas of freshwater and saline-water interface
- Spring-fed isolated wetlands
- Mudflat/playa environments

The wetlands around the lake are unique in North America because they cover a large expanse of inland, alkaline, and saline wetlands located in a cold desert. Approximately 400,000 acres of wetlands exist near the shores of GSL, which represent almost 75% of all wetlands in Utah. Although the focus of this section is on aquatic habitats and associated wildlife, adjacent upland habitats are also discussed due to their importance as foraging and breeding habitats for wildlife, and due to their role as corridors between wetland and other habitat types that contribute to the high productivity of the GSL ecosystem. These upland habitats are as follows:

- Uplands (shrublands, grasslands, agricultural lands, and barren areas)
- Dunes and sandbars
- Islands
- Dikes, levees, and other human-made structures

Upland areas provide an extraordinary amount of food and opportunities for cover and buffer wetlands from expanding urban and industrial developments around the south and east sides of the lake. In addition, the lake is tied to the Wasatch Mountains by ribbons of riparian habitat, which, in the desert west, are critical migratory and breeding habitats for a variety of wildlife, especially neotropical migrant songbirds, raptors, and riverine mammals. The latitude of the lake makes it a significant wintering migratory stopover area for a number of species.

The GSL ecosystem is a complex mosaic of aquatic and terrestrial habitats that support a diversity of species that often depend on the interaction between upland and wetland systems. Aquatic and terrestrial vegetation communities are described under their respective systems (aquatic and terrestrial); however, many groups of organisms, particularly water-associated birds, do not fit neatly under either aquatic or terrestrial biology. To simplify the presentation of information in this section, bacteria and algae, brine shrimp, brine flies, corixids, fish, and birds are discussed in section 2.7.1 (Aquatic Biology); plants, reptiles and amphibians, and mammals are discussed in sections 2.7.9–2.7.12.

2.7.1 Aquatic Biology

The salinity of GSL varies with geographic location, hydrology, geology, disturbance history, and the presence of human-made structures that increase or decrease the influx of fresh water into the lake (Table 2.18). A variety of plants and invertebrates depends on particular levels of salinity associated with different aquatic habitats. The range of salinity levels in GSL aquatic habitats provides a diversity of habitats for plant and animal species. Specifically, halophilic brine shrimp play a significant role in GSL ecosystems and, along with brine flies, are the keystone species supporting many of the water and shorebird species that frequent the lake. The abundance of brine shrimp varies in response to the abundance of the algal prey and predatory corixids in lake habitats. Salinity and nutrient levels as well as seasonal water temperature fluctuations determine the abundance of brine shrimp and their influence on predator and prey abundance (Belovsky et al. 2011). A primary reason for the hemispherically important bird numbers at GSL is the lake’s capacity to produce millions of pounds of this easily accessible protein source at the appropriate times for seasonal bird migrations.

The salinity of the North Arm (Gunnison Bay) is significantly higher than other areas of the lake. This is because of limited inflows and the Northern Railroad Causeway between Promontory Point and Lakeside that effectively separated the North Arm from the South Arm (Gilbert Bay). In their 1979 study, Felix and Rushforth found significant changes to the phytoplankton flora of GSL as a result of the construction of the Northern Railroad Causeway due to reduced salinity in the southern areas of the lake. Gunnison Bay only supports brine shrimp when GSL is at very high elevations (and lower salinities) and is limited to six phytoplankton species (compared to 20–30 phytoplankton species reported in the South Arm). Brine shrimp and cysts are washed into the North Arm from the South Arm and may persist where there are favorable low saline areas produced by freshwater springs or during periods of high lake levels; however, brine shrimp generally do not persist in the North Arm due to high water salinity. The productivity of the South Arm is considerably higher due to lower salinities and greater nutrient and freshwater inputs from the GSL watershed. Nutrient inputs in the South Arm and Farmington and Bear River bays are used by a diverse assemblage of algae and bacteria, which in turn support a rich microfauna of benthic invertebrates and macroinvertebrates. The lake bed is covered with approximately 23% algal bioherms (Wurtsbaugh 2009). These rock-like structures develop as a result of the precipitation of carbonates by algae and are an important source of algal production and habitat for brine flies. The west and south shores of the lake are moderately saline and support brine shrimp at high to average lake levels. The northeast, east, and southeast portions of the lake are less saline and support brine shrimp and other invertebrates during average and lower lake level years. The east shore of the lake is highly productive due to nutrient and freshwater inputs from the Jordan, Weber, and Bear rivers and numerous smaller Wasatch Front streams. Gilbert Bay supports higher densities of brine shrimp than the eastern portions of the lake (i.e., Farmington Bay and shallow, near-shore parts of Ogden Bay).

In addition to natural fluctuations in ecological conditions in GSL, active management of water depth, temperature, dispersion, and control of nutrient flows in managed wetlands has also produced highly productive aquatic habitats. Managed wetlands in the GSL ecosystem possess high-quality aquatic habitats in association with dikes, levies, headgate systems, and diversion structures. Ongoing management of these created wetland habitats in the GSL ecosystem facilitates high-quality seasonal habitats for tens of thousands of migrating and breeding shorebirds and waterfowl.

Table 2.18. *Ecological Components of Great Salt Lake*

Bay	Source of Inflow	Estimated Salinity Range Determined at 4,198 Feet and 4,208 Feet Post 1987 (%)	Periphyton and Phytoplankton	Brine Shrimp	Brine Flies	Freshwater Species	Bird Endpoints
Gunnison	Springs, creeks, groundwater, Gilbert Bay bidirectional flow	16%–27%	Halophylic archaea and bacteria, Chlorophyta *(Dunaliella salina)*	Mostly at Northern Railroad Causeway, reproduction at elevations of 4,208–4,212 feet	In littoral zone	n/a	n/a
Gilbert	Jordan River (Goggin Drain, North Point), Kennecott Outfall, Lee Creek, Weber River, Howard Slough, Bear River bidirectional flow, Farmington Bay bidirectional flow	7%–15%	Chlorophyta (*Dunaliella viridis),* Cyanophyta (*Nodularia spumigena, A. halophytical*), Pyrrophyta, diatoms	Main population consisting of cysts, nauplii, juveniles, and adults	Main population consisting of brine fly larvae, pupae, and adults	n/a	Reproductive success and body condition
Farmington	Jordan River, Surplus Canal, Salt Lake Sewage Canal, Central Davis Sewer District Outflow, Gilbert Bay bidirectional flow, Creeks (Kays, Holmes, Farmington, Crystal, Spring)	2%–6%	*Nitzschia* spp, Chlorophyta (*Dunaliella viridis),* Cyanophyta (*Nodularia spumigena*), diatoms	n/a	–	Corixids, chironomids, fish near sources of inflow, emergent and submergent vegetation	Reproductive success and body condition
Bear River	Bear River, Gilbert Bay bidirectional flow	1%–6%	–	n/a	–	Corixids, chironomids, fish from 4,200 feet upward, freshwater invertebrates, emergent and submergent vegetation	Reproductive success and body condition

2.7.1.1 LAKE LEVEL EFFECTS

The effect of different lake levels on the aquatic biology of GSL varies across different habitat types and for different species. One of the most important effects of fluctuating lake levels is the distribution and extent of mudflats and wetland habitats surrounding GSL. Fluctuations in lake levels also cause significant changes to salinity levels and other chemical aspects of the lake and associated species composition and productivity. In addition, significant changes in lake levels strongly influence the connectivity between islands and the mainland and the extent and distribution of both wetland and upland habitats in the GSL ecosystem. The impacts of different lake levels on specific aquatic habitat types are discussed in detail in section 2.7.2. The impacts of different lake levels on terrestrial habitat types are discussed in general in section 2.7.9 and in detail in section 2.7.10.

2.7.2 Aquatic Habitats

Aquatic habitats associated with the GSL ecosystem consist of open water, mudflats and playas, hemi-marsh, and emergent wetlands (Paul et al. 2012 [in press]). These habitat types generally occur as a mosaic around the shoreline of GSL. The aquatic habitats associated with GSL occur as fringe wetlands along the lakeshore and as impounded wetlands within embankments and bermed areas in and adjacent to the lake. These aquatic habitats are often highly variable in species composition, total plant cover, and community structure in response to water level fluctuations and across elevational gradients; however, habitat composition and structure can also be strongly influenced by biotic interactions. Invasive plant species are also discussed in this section due to their potential to disproportionately affect aquatic habitats. Aggressive invasive plants can alter vegetation community structure, ecological functioning, and the short- and long-term suitability of a habitat for foraging, nesting, and breeding wildlife. Invasive animal species are discussed in section 2.7.10 (Terrestrial Habitats). However, it should be noted that invasive animal species also affect aquatic communities through high levels of predation on nesting and brooding shorebirds and waterfowl and by exerting top-down effects on the GSL food chain.

2.7.2.1 EMERGENT WETLANDS

Emergent wetland habitats comprise large, shallow wetlands, seasonal wetlands, and wet meadow and palustrine wetlands. These wetlands contain 75% or greater emergent vegetation that may include cattail species (*Typha latifolia*, *T. domingensis*, *T.* x *glauca*), *Phragmites*, alkali bulrush (*Schoenoplectus maritimus*), hardstem bulrush (*Schoenoplectus acutus*), rushes (*Juncus* spp.), sedges (*Carex* spp.), and other emergent plant species.

2.7.2.2 FRINGE WETLANDS

Fringe wetlands fall under two categories: high fringe and low fringe wetlands. Natural fluctuations in lake level dictate the presence and location of fringe wetlands. High fringe wetlands are irregularly inundated and contain standing water only when lake levels are high. The soils of high fringe wetlands may remain saturated near the surface over a wide range of lake levels and may develop a crust of bare mineral soil in summer. During extended periods of low lake level and thus, drier conditions, high fringe wetlands may be colonized by halophytic (salt-loving) vegetation.

Low fringe wetlands remain inundated over multiple years and can be considered transitional between open water portions of GSL and regularly exposed high fringe wetlands. These wetlands are almost always devoid of rooted vegetation due to yearly inundation by high salinity water. When inundated by fresh water, reeds, rushes, and other plants may establish small colonies or create an indistinct boundary between emergent and high fringe wetlands.

2.7.2.3 HEMI-MARSH

Hemi-marsh wetland habitats may be semipermanent due to their association with impoundments and/or management of water levels. These habitats are created by flooding with sediment-laden water or flooding benthic environments. Hemi-marsh wetlands contain 25%–50% emergent vegetation that may include cattails, alkali bulrush, hardstem bulrush, *Phragmites*, and other emergent plant species.

2.7.2.4 MUDFLATS AND PLAYAS

Mudflat and playa habitats are the most extensive aquatic habitat types in the GSL ecosystem and dominate the GSL shoreline. These habitat types may have no vegetation cover (mudflats) or vegetation cover from 5% to 25% (playas) and are created by temporary or seasonal water fluctuations associated with the lake. Mudflats and playas are further distinguished by characteristic accumulation of salt on the soil surface in playas and less so in mudflats. These habitats support freshwater and saltwater macroinvertebrates that provide seasonal food for tens of thousands of migratory shorebirds. Wetland playas support a community of halophytes that may include iodine bush (*Allenrolfea occidentalis*), pickleweed (*Salicornia* spp.), seepweed (*Suaeda* spp.), greasewood (*Sarcobatus vermiculatus*), saltgrass (*Distchlis spicata*), and saltbush (*Atriplex* spp.).

2.7.2.5 OPEN WATER

Open water habitats comprise extensive open water bays and ponds, often associated with other wetland types that contain 15% or less emergent vegetation. These systems have an unconsolidated bottom and are intermittently, semipermanently, or permanently flooded. They are often dominated by open water during the winter and early spring inundation periods and by a community of halophytes from late spring through November. Common plant species found in areas that are intermittently and/or semipermanently flooded may include duckweed (*Lemna* spp.), widgeongrass (*Ruppia maritima*), sago pondweed (*Stuckenia pectinata*), and Eurasian watermilfoil (*Myriophyllum spicatum*).

2.7.2.6 INVASIVE SPECIES

Plant species of particular concern for aquatic habitats in GSL are *Phragmites*, purple loosestrife (*Lythrum salicaria*), tamarisk (*Tamarix* spp), and Eurasian watermilfoil. Faunal species of particular concern in aquatic habitats are raccoon (*Procyon lotor*), common carp (*Cyprinus carpio*), bullfrog (*Rana catesbeiana*), and mosquitofish (*Gambusia affinis*). Invasive plant and animal species negatively impact aquatic communities in the GSL ecosystem in one or more ways, as follows:

- By reducing the availability of foraging, nesting, and/or breeding habitats
- By altering habitat structure and/or functioning in the short or long term
- By increasing competition for resources
- By increasing habitat disturbance associated with control and eradication efforts.

The specific impacts of several species of particular concern are described in detail below:

Phragmites occurs as both native and non-native strains in the GSL ecosystem. Historic records indicate that the native strain has been present in Utah wetlands since at least 1875 and that the non-native strain has a competitive advantage due to its ability to rapidly expand both aboveground and belowground biomass (Kulmatiski et al. 2010). The distribution of the non-native strain of *Phragmites* has expanded rapidly over the last 30–40 years, and it currently dominates at least 34% of wetlands surrounding GSL (Kulmatiski et al. 2010). In the GSL ecosystem, the current distribution of the non-native strain indicates a nearly 200% increase in areal cover over approximately 30 years, whereas the native strain has become confined to a handful of isolated wetlands.

Phragmites is of limited use as wildlife habitat due to its dense growth. In the GSL ecosystem, *Phragmites* displaces native emergent wetlands and their associated species (e.g., Franklin's gulls [*Larus pipixcan]*, waterfowl, etc.) by a) blocking sunlight to the soil surface and excluding plant species that are favorable for forage and nesting habitat and b) providing cover for non-native predators such as raccoons. This invasive species also alters hydrology by trapping sediments and reducing water movement through wetland ecosystems. Total eradication of the species is likely infeasible due to the extent of its current distribution and the difficulty of controlling existing stands. Management actions should target aggressive, monotypic stands of the non-native strain that threaten to displace other wetland communities and limit habitat diversity for water-associated birds. The native strain occurs naturally in GSL ecosystem and contributes to overall habitat diversity and could be reestablished once the non-native strain has been eradicated.

Eurasian watermilfoil is an aquatic macrophyte that is native to Europe, Asia, and northern Africa (Jacono and Richerson 2011). It can tolerate a variety of environmental conditions, which has contributed to its spread. The species was first reported in Utah from Fish Lake and Otter Creek Reservoir in 1993 (FFSL 1999). The species is primarily spread through movement of plant fragments, but can also reproduce by seed. Watermilfoil negatively affects native vegetation communities by forming dense, monotypic mats on the water surface that displace other aquatic plant species and reduce the availability of foraging and breeding habitats. Watermilfoil has little value as a food source and displaces aquatic invertebrates by excluding their host species.

2.7.2.7 LAKE LEVEL EFFECTS

The distribution, extent, composition, structure, and diversity of aquatic habitat vary considerably at low versus high lake levels. At high lake levels, existing emergent wetlands, fringe wetlands, hemi-marsh, and mudflats and playas are inundated, but new wetland habitats can be created where inundation persists. At low lake levels, the distribution and extent of emergent wetlands, hemi-marsh, and mudflats and playas are greatly reduced in areas that are not maintained by control weirs and have proportional effects of the associated wetland vegetation and aquatic biota. When low lake levels persist for longer periods of time, salt-tolerant vegetation such as salt grass and pickleweed (*Salicornia*) colonize the exposed lake bed until lake levels rise again.

The extent of open water habitats and the abundance of species associated with this habitat type is reduced at low water levels and increased at high water levels. However, changes to salinity and water chemistry associated with changes in lake levels can exert disproportionate effects on the biota associated with all aquatic habitat types. Relatively high or low salinity levels associated with low and high lake levels, respectively, can limit the potential habitat available to some plant and animal species. In addition, at low lake levels, invasive plant species, particularly *Phragmites*, can invade large areas of previously inundated habitat and significantly alter the structure, composition, and functioning of wetland habitats.

2.7.3 Phytoplankton (bacteria and algae)

The GSL ecosystem is a relatively simple trophic system, as follows:

- Nutrients enter the system by freshwater inputs and deposition of organic and inorganic materials.
- Nutrients are consumed by phytoplankton.
- Phytoplankton are consumed by zooplankton (brine shrimp and brine fly larvae, respectively).

- Brine shrimp and brine flies are consumed by waterbirds, small animals, and insects (see Figure 2.2; Belovsky et al. 2011).

This trophic system is highly productive despite the physiological difficulties posed by the extreme salinity of the GSL environment (Belovsky et al. 2011).

Phytoplankton (e.g., benthic algae, blue-green algae, green algae, and diatoms) are autotrophic primary producers in the GSL ecosystem. Phytoplankton are photosynthetically active year-round in the lake; however, their abundance is limited from early spring through late fall. This is due to shrimp grazing and reduced nutrient availability when the shrimp population is at its peak in the summer (Belovsky et al. 2011). The lake acquires a green hue in winter when green algae populations increase in the absence of brine shrimp. Areas of the lake that are dominated by diatoms or blue-green algae may acquire different hues at different times of the year, depending on nutrient availability and levels of predation. Belovsky et al. (1995–2003; 2011) found that chlorophyll *a* (an indicator of photosynthetic levels) was highest between November and April, with peaks in January and February.

Bacteria assist in the decomposition of dead phytoplankton, zooplankton, and organic wastes entering GSL via streamflow and by wind deposition and are addressed as part of the phytoplankton flora in this section. There are few species of bacteria that can survive in the hypersaline water of GSL, relative to the biota of a freshwater lake. Eleven species of saline-tolerant bacteria inhabit GSL (Flowers and Evans 1966) and can exist in enormous numbers and account for a significant portion of the lake's biomass under favorable conditions. The North Arm of the lake supports only two genera of halophilic archaea , *Halobacterium* and *Halococcus*, which occur in numbers from 1,000,000 to 100,000,000 bacteria per milliliter, and their abundance is evident in the pink to purple color of this part of the lake (Rushforth and Rushforth 2006).

Belovsky et al. (2011) identified more than 60 phytoplankton taxa in GSL, and the GSL Ecosystem Program (GSLEP) has identified approximately 140 species to date (Luft 2010). Both of these datasets indicate that there is a considerably more diverse phytoplankton flora than the approximately 20–30 taxa that have been reported previously (Felix and Rushforth 1979; Rushforth and Felix 1982; Wurtsbaugh and Marcarelli 2004; Table 2.19). Belovsky et al. (2011) did not find any within-year variation in phytoplankton species composition, only in the relative abundance of individual species. GSL has marked seasonal trends in the densities of both phytoplankton (and zooplankton), but little is known about the distribution of these trends (Wurtsbaugh and Marcarelli 2004). Fluctuations in the abundance of phytoplankton may be indicators of heavy nutrient loading that changes the abundance of edible phytoplankton (Wurtsbaugh and Marcarelli 2004); however, brine shrimp are the primary determinant of phytoplankton densities. When brine shrimp are absent during the winter, nutrient loads and salinity are the primary drivers of phytoplankton densities.

Table 2.19. *Phytoplankton Taxa in Great Salt Lake*

Species	Farmington	South Arm	North Arm	Reference
Bacillariophyta (diatoms)				
Acanthes exigua	X	–	–	Felix and Rushforth (1979)
Acanthes lanceolata	X	–	–	Felix and Rushforth (1979)
Amphiprora sp.	–	–	–	Larson and DWR CD
Amphora coffeaeformis	C	A	–	Felix and Rushforth (1979)
Amphora delicatissima	C	C	–	Felix and Rushforth (1979)
Amphora ovalis	–	X	–	Felix and Rushforth (1979)
Anomoeoneis sphaerophora	X	–	–	Felix and Rushforth (1979)
Biddulphia levis	R	C	–	Felix and Rushforth (1979)
Caloneis amphisbaena	–	X	–	Felix and Rushforth (1979)
Chaetocerous muelleri	C	–	–	Felix and Rushforth (1979)
Cyclotella oscellata	–	X	–	Phycotech 1/17/2006
Cyclotella meneghiniana	R	–	–	Felix and Rushforth (1979)
Cymatopleura solea	–	X	–	Felix and Rushforth (1979)
Cymbella minuta	X	–	–	Felix and Rushforth (1979)
Diatoma hiemale var. *mesodon*	X	–	–	Felix and Rushforth (1979)
Diatoma tenue var. *elongatum*	X	–	–	Felix and Rushforth (1979)
Diatoma vulgare	–	X	–	Felix and Rushforth (1979)
Entomoneis pulchra	R	C	–	Felix and Rushforth (1979)
Epithemia turgida	–	X	–	Felix and Rushforth (1979)
Eunotia incisa	X	–	–	Felix and Rushforth (1979)
Fragilaria brevistriata	–	X	–	Felix and Rushforth (1979)
Fragilaria construens	X	–	–	Felix and Rushforth (1979)

Table 2.19. *Phytoplankton Taxa in Great Salt Lake*

Species	Farmington	South Arm	North Arm	Reference
Fragilaria construens var. *venter*	X	X	–	Felix and Rushforth (1979)
Fragilaria vaucheriae	X	–	–	Felix and Rushforth (1979)
Gomphonema angustatum	–	X	–	Felix and Rushforth (1979)
Gomphonema olivaceum	–	X	–	Felix and Rushforth (1979)
Gyrosigma sp.	–	X	–	Felix and Rushforth (1979)
Melosira granulata var. *angustissima*	–	X	–	Felix and Rushforth (1979)
Navicula cryptocephala	–	X	–	Felix and Rushforth (1979)
Navicula graciloides	A	A	–	Felix and Rushforth (1979)
Navicula gregarica	X	X	–	Felix and Rushforth (1979)
Navicula lanceolata	R	R	–	Felix and Rushforth (1979)
Navicula pygmaea	–	X	–	Felix and Rushforth (1979)
Navicula rhynchocephala	–	X	–	Felix and Rushforth (1979)
Navicula tripunctata	A	A	–	Felix and Rushforth (1979)
Navicula tripunctata var. *schizonemoides*	R	R	–	Felix and Rushforth (1979)
Nedium iris	–	X	–	Felix and Rushforth (1979)
Nitzschia acicularis	A	–	–	Felix and Rushforth (1979)
Nitzschia epithemioides	C	C	–	Felix and Rushforth (1979)
Nitzschia fonticola	C	R	–	Felix and Rushforth (1979)
Nitzschia hungarica	–	X	–	Felix and Rushforth (1979)
Nitzschia kutzingiana	–	X	–	Felix and Rushforth (1979)
Nitzschia linearis	X	X	–	Felix and Rushforth (1979)
Nitzschia palea	C	C	–	Felix and Rushforth (1979)
Nitzschia sigma	–	X	–	Felix and Rushforth (1979)

Table 2.19. *Phytoplankton Taxa in Great Salt Lake*

Species	Farmington	South Arm	North Arm	Reference
Nitzschia vermicularis	–	X	–	Felix and Rushforth (1979)
Phaedactylum tricornutum	–	–	–	Larson and DWR CD
Pinnularia microstauron	–	X	–	Felix and Rushforth (1979)
Pinnularia microstauron var. *biundulata*	–	X	–	Felix and Rushforth (1979)
Pinnularia termitina	–	X	–	Felix and Rushforth (1979)
Rhoicosphenia curvata	X	–	–	Felix and Rushforth (1979)
Rhopolodia musculus	R	A	–	Felix and Rushforth (1979)
Ropalodia sp.	–	–	–	INVE list
Surirella minuta	–	X	–	Phycotech 1/17/2006
Surirella ovata	–	X	–	Felix and Rushforth (1979)
Surirella robusta var. *splendida*	–	X	–	Felix and Rushforth (1979)
Surirella striatula	R	R	–	Felix and Rushforth (1979)
Synedra acus	–	X	–	Felix and Rushforth (1979)
Synedra sp.	–	X	–	Felix and Rushforth (1979)
Synedra ulna	–	X	–	Felix and Rushforth (1979)
Chlorophyta (green algae)				
Ankistrodesmus sp.	–	–	–	Larson and DWR CD
Carteria sp.	C	–	–	Felix and Rushforth (1979)
Characium sp.	–	–	–	Larson and DWR CD
Chlorococcaceae sp	–	R	–	Phycotech 1/17/2006
Cladophora fracta	X	–	–	Felix and Rushforth (1979)
Cryptomonas sp.	X	–	–	Wurtsbaugh and Marcarelli (2005)

Table 2.19. *Phytoplankton Taxa in Great Salt Lake*

Species	Farmington	South Arm	North Arm	Reference
Dunaliella salina	–	R	A	Felix and Rushforth (1979)
Dunaliella viridis	C	A	R	Felix and Rushforth (1979)
Enteromorpha intestinalis	–	X	–	Felix and Rushforth (1979)
Oocystis parva	A	R	–	Felix and Rushforth (1979)
Pediastrum sp.	X	–	–	Wurtsbaugh and Marcarelli (2005)
Scenedesmus sp.	X	–	–	Wurtsbaugh and Marcarelli (2005)
Spermatzopsis exultans	C	–	–	Felix and Rushforth (1979)
Sphaerellopsis gloeocystiformis	C	–	–	Felix and Rushforth (1979)
Treubaria triappendiculata	A	–	–	Felix and Rushforth (1979)
Ulothrix sp.	–	X	–	INVE list
Quadrigula lacustris	–	X	–	Phycotech 1/17/2006
Cyanophyta (blue-green algae)				
Chroococcus sp.	–	–	–	Larson and DWR CD
Coccochloris elabens	–	C	–	Felix and Rushforth (1979)
Cocconeis pediculus	X	–	–	Felix and Rushforth (1979)
Cocconeis placentula	X	X	–	Felix and Rushforth (1979)
Cocconeis placentula var. *euglypta*	–	X	–	Felix and Rushforth (1979)
Microcoleus lyngbyaceus	C	R	–	Felix and Rushforth (1979)
Nodularia heterocyst	X	–	–	Wurtsbaugh and Marcarelli (2005)
Nodularia spumigena	A	R	–	Felix and Rushforth (1979)
Nodularia veg	X	X	–	Wurtsbaugh and Marcarelli (2005)
Oscillatoria princeps	–	X	–	Felix and Rushforth (1979)

Table 2.19. *Phytoplankton Taxa in Great Salt Lake*

Species	Farmington	South Arm	North Arm	Reference
Pseudoanabaena sp.	X	–	–	Wurtsbaugh and Marcarelli (2005)
Spirulina major	R	–	–	Felix and Rushforth (1979)
Syechococcus elongatus	–	C	–	Phycotech 1/17/2007
Synechocystis sp.	–	C	–	Rushforth and Rushforth 2006; Belovsky et al. (2011)
Pyrrophyta (dinoflagellates)				
Ceratium hirundinella	–	X	–	Felix and Rushforth (1979)
Glenodinium sp.	C	–	–	Felix and Rushforth (1979)

Notes: X = Present; A = Abundant; C = Common; R = Rare; species marked with X occurred at very low frequency, low abundance, or did not appear to be viable populations. These may be samples from freshwater inflows and not established species in GSL.

Source: Wurtsbaugh and Marcarelli (2004); Luft (2010).

Diatoms appear to be more abundant when salinity levels are lower and give the lake water a gold hue. Pennate diatoms are oblong in shape with a silica covering and are too large for brine shrimp nauplii to consume (Stephens 1998). Laboratory experiments at USU have shown that brine shrimp populations are reduced when the lake is dominated by diatoms with low concentrations of green algae (Belovsky 1998).

Recent research by Belovsky et al. (2011) found that salinity and nutrient availability were approximately equal determinants of phytoplankton densities, and that brine shrimp predation was the primary driver of phytoplankton densities in GSL. Phytoplankton-brine shrimp trophic interactions have a strong influence on the abundance of both groups of organisms and have a bottom-up control on corixid and waterbird densities. Therefore, it appears that brine shrimp densities are controlled by phytoplankton densities and vice-versa, but phytoplankton abundance is also determined at least in part by nutrient availability and salinity. Belovsky et al.'s (2011) research demonstrates the increase in importance of prey limitations in the GSL food chain from the lowest (primary producer) to the highest (secondary or tertiary consumer) levels.

2.7.3.1 LAKE LEVEL EFFECTS

As indicated in Figure 2.2, the food web of GSL is directly controlled by watershed inputs and the nutrient inflows associated with those inputs. Fluctuations in the abundance of phytoplankton may be the result of heavy nutrient loading that changes the abundance of edible phytoplankton, or that produces algal blooms and associated anoxic conditions that reduce the abundance of zooplankton species (Wurtsbaugh and Marcarelli 2004). Watershed inputs associated with variations in regional climate and resulting lake levels also strongly influence the diversity and productivity of the biota due to differing nutrient inputs.

2.7.4 Corixids

Corixids, one of the zooplankton fauna of GSL, are small, predatory, flying aquatic insects that live in and around the edges of GSL where water salinity is less than 6% (FFSL 1999). Their diet includes, but is not limited to, brine shrimp. Predation by corixids and copepods on brine shrimp has been reported to decrease shrimp population densities (Wurtsbaugh 1992). Gliwicz et al. (1995) suggest that salinity levels similar to those observed in Farmington Bay might allow corixids to decrease the brine shrimp population in the South Arm of the lake during periods of lower salinity. Recent research by Belovsky et al. (2011) finds that corixid predation did not reduce brine shrimp populations from March through October and that corixids have a weak but *significantly positive* impact on brine shrimp abundance ($r^2 = 0.09$, $n = 60$, $p < 0.02$). Belovsky and Mellison (1998) observed that the corixid predation rate was 1–2 orders of magnitude less than the brine shrimp population growth rate and had a negligible impact on the brine shrimp population in the South Arm. This supports Belovsky et al's (2011) recent observations; however, corixid densities are limited in the South Arm by high salinity levels. At lower salinity levels (high lake levels), corixids can reduce brine shrimp populations; however, corixid populations have been limited by the salinity levels in the lake during recent years (1994–2006; Belovsky et al. 2011).

At present salinity levels, the evidence indicates that corixids do not have a significantly negative effect, if any, on brine shrimp populations in GSL. However, at lower salinity levels, corixids could exert a top-down effect on brine shrimp populations. There is no evidence that current levels of commercial brine shrimp cyst harvesting reduce brine shrimp density the following year, but commercial harvesting does reduce brine shrimp cyst densities in spring, which reduces the number of shrimp initiating the population. As demonstrated by Belovsky et al.'s (2011) study, reduction in shrimp numbers will have both top-down (on phytoplankton) and bottom-up (on corixids, waterbirds, etc.) effects on the GSL food chain.

2.7.4.1 LAKE LEVEL EFFECTS

Because corixids require water salinity of less than 6% (Belovsky and Mellison 1998), low lake levels and associated increases in water salinity would be expected to greatly reduce their abundance. In contrast, corixid abundance would be expected to increase during periods of high lake levels and the associated increase in shoreline habitats and decrease in water salinity. The study by Gliwicz et al. (1995) suggests that low water salinity associated with high lake levels would increase corixid abundance and result in a decrease in the brine shrimp population from corixid predation.

2.7.5 Brine Shrimp

The brine shrimp is a keystone species in the GSL ecosystem due to its abundance and top-down influence on primary producers (phytoplankton) and bottom-up influence on secondary and tertiary consumers (corixids, waterbirds) (see Figure 2.2). Brine shrimp occur in all portions of GSL and are most abundant in saline lakes due to their broad ecological tolerance and the lack of aquatic predators. The brine shrimp is an anastrocan crustacean zooplankton that reproduces by two pathways: 1) by eggs that hatch within the adult female and are released as live young into the lake in spring and summer, or 2) by the release of diapausing cysts that overwinter in the lake in a semidehydrated state and hatch in spring. Brine shrimp can also reproduce by nondiapausic cysts during periods of extreme stress due to limited food availability or climatic conditions. Freshwater inflows from snowmelt and rain decrease lake water salinity, and increases in water temperatures initiate egg (cyst) hatching in late January or early February, with peak cyst hatching in March or early April. The decrease in lake water salinity associated with spring snowmelt causes the cyst shell to swell and crack and allows the young brine shrimp (nauplii) to emerge. The nauplii molt through as many as 12 different juvenile stages before maturing into reproductive adult brine shrimp. As many as four generations of shrimp may be produced in GSL during a single growing season. Late season declines in food availability, water temperature, and day length and increasing lake water salinity due to reduced inputs and evaporation trigger female brine shrimp to start producing cysts. Brine shrimp start to die when water temperatures drop below 42^{o}F, and no adult brine shrimp survive the winter. The brine shrimp population is restored each spring from hatching cysts that overwintered in the water column or washed up on the shoreline during the winter and washed back into the lake in spring runoff. Cysts deposited on the shoreline also serve as refugia for brine shrimp populations in isolated playa lakes (Belovsky et al. 2011).

Brine shrimp serve a vital role in the ecology of the GSL ecosystem by providing a mass of readily accessible protein to migrating waterbirds and shorebirds. The large numbers of migrating waterbirds that annually stop over at GSL rely on brine shrimp and brine fly larvae to provide energy for breeding and/or migration to/from other breeding grounds. For this reason, brine shrimp are a key conservation issue for the GSL ecosystem (Conover and Caudell 2009; Belovsky et al. 2011). GSL annually hosts up to 2.5 million eared grebes (*Podiceps nigricollis*), up to 50% of the North American population (Paul and Manning 2008). Waterbirds and shorebirds of hemispheric importance (e.g., eared grebe, American avocet (*Recurvirostra americana*), black-necked stilt (*Himantopus mexicanus*); see additional discussion in section 2.7 below) rely on brine shrimp as a primary food source for breeding and migration (Aldrich and Paul 2002). Eared grebes rely on GSL as one of two molting and staging areas used by the North American population (the other is Mono Lake, California) and feed on brine shrimp nearly exclusively during their 8- to 10-month stay, during which the birds undergo a flightless molting period (Paul and Manning 2008).

Commercial harvesting of brine shrimp began in 1952 by the Sanders Brine Shrimp Company for tropical fish food. Several years later, brine shrimp cyst harvesting was initiated because cysts can be dried, packaged, and stored for long periods of time and hatched as needed. Commercial harvest of brine shrimp cysts is used by the aquaculture industry as feed for fish, shrimp, and other crustaceans, which are then used for human consumption. Presently, only cysts are targeted by the harvest operations, but there is a small market for the adult brine shrimp bycatch. Nevertheless, as discussed in the sections above, there is no evidence that current levels of commercial brine shrimp cyst harvesting reduce brine shrimp densities the following year. Commercial harvesting does reduce brine shrimp cyst densities in spring, but the Utah DWR manages the brine shrimp population and requires that a target level of brine shrimp cysts per liter of lake water are retained for restarting the population. As demonstrated by Belovsky et al.'s (2011) study, reduction in shrimp numbers will have both top-down (on phytoplankton) and bottom-up (on corixids, waterbirds) effects on the GSL food chain.

2.7.5.1 LAKE LEVEL EFFECTS

Because the brine shrimp population is restored each spring from overwintering cysts on the lake's surface or shorelines, periods of reduced watershed runoff and associated lake levels would be expected to reduce the abundance and productivity of the brine shrimp population. In addition, the algae upon which brine shrimp feed on require low to moderately saline water conditions and do not thrive in high saline water during low lake levels. Freshwater inputs from the surrounding watershed also provide significant nutrient inputs that result in algal growth and the highly productive brine shrimp population of GSL during average water years. During periods of high lake levels, brine shrimp population could be negatively affected if salinities are reduced below the species' tolerances.

In addition, changes in lake levels also affect lake temperatures and diurnal heating and cooling of lake water. At low lake levels, seasonal and diurnal lake water temperatures would be expected to fluctuate more with faster heating during the day and cooling at night. Brine shrimp have limited tolerance to temperatures above 85°F and below 40°F and would be negatively affected during low lake level conditions that cause water temperatures to approach the brine shrimp's high and low temperature tolerance levels.

2.7.6 Brine Flies

There are at least two documented species of brine flies in GSL. Of these, the most common are *Ephydra gracilis*, which is smaller and most abundant, and *Ephydra hians*, the alkali fly, a larger and less abundant species. Brine flies play an essential role in converting organic material entering the lake into food for wildlife living along the lake's shoreline. Brine flies are produced in enormous numbers each spring in GSL, with reportedly over 370 million flies per mile of sandy beach, for a total of over 110 billion flies plus 10 billion pupae on approximately 300 miles of beaches around GSL per year (Oldroyd 1964). Brine fly abundance is variable from year to year and depends on changes in water chemistry and other environmental conditions, particularly temperature. Rises in lake level create inundated shorelines where brine flies pupate. Wind direction and velocity and lake currents and substrata seem to have a direct effect on their distribution. Brine fly populations begin to increase rapidly around the first week of June, peak during July and August, and then decrease as temperatures begin to drop (Vorhies 1917).

By removing over 120,000 tons of organic matter each year from GSL, brine flies consume great quantities of algae, bacteria, and organic refuse from brine shrimp and their own life processes. It would require a 78,000,000-gallon-per-day wastewater treatment facility about the size of the Salt Lake City municipal treatment plant to remove this much organic waste from the lake.

Brine flies are vital to the ecology of the GSL food chain, but their trophic interactions are only weakly linked to those of the brine shrimp (see Figure 2.2). Brine fly larvae consume benthic algae, and adult brine flies serve as important prey for spiders, corixids, small mammals, reptiles, and birds living near the shores of the lake. Adult and larval brine flies are also consumed by waterbirds. Brine flies serve as an important food source for many migratory bird species, including the Wilson's phalarope (*Phalaropus* *tricolor*), eared grebe, and common goldeneye. See section 2.7.8 for additional discussion of bird use of brine flies on GSL.

The life cycle of the brine fly consists of four stages: egg, larva, pupa, and adult. Each female lays approximately 75 eggs on the surface of the water or on floating debris consisting of brine fly pupal casings, dead brine shrimp, or cysts. The eggs sink to the bottom of the lake before they hatch into larvae. They obtain oxygen from the water by diffusion and feed on blue-green algae. They become free swimming after emergence, until they find suitable habitat such as algal bioherms or other stationary objects in shallow areas of the lake on which to pupate. Larvae and pupae have been found in water depths of between 1 and 20 feet and can obtain oxygen from the water by use of tracheal gills located in a long forked anal tube. During warm weather, the larval stage also may pupate on the surface of the lake on floating masses of algae. The pupal cases split open on the back and the flies emerge out of the cases and develop into adult flies. Flies emerging from the bottom of the lake float to the surface in a bubble of air. The life cycle can be completed in 21–30 days and may extend longer during cooler temperatures. Adult brine flies only live three to four days, and one or two generations of flies reach maturity each year. The flies survive the winter in immature stages.

2.7.6.1 LAKE LEVEL EFFECTS

Lake levels exert a strong influence on brine fly abundance from year to year due to the effects of water chemistry and other environmental conditions associated with differing water levels. During high lake level years, the increase in freshwater inputs and inundated shoreline habitats where brine flies pupate could decrease the brine fly population, whereas the opposite effect could occur during low lake level years. Figure 2.2 illustrates the importance of brine flies to the trophic ecology of GSL and suggests that fluctuations in lake levels could result in strong bottom-up impacts to corixids and other primary and secondary predators that directly or indirectly depend on brine flies. However, there are limited data regarding the effects of lake level on brine fly densities, and additional work is needed to better understand these dynamics.

2.7.7 Fish

Fish are of limited importance in the GSL ecosystem due to high salinity levels in both the North and South arms that exclude fishes. During the spring runoff period when shoreline salinity levels are low, fish may be carried out into Bear River Bay from adjacent freshwater marshes and waterways. In addition, strong south winds can push saline water from the south side of the causeway up into Bear River Bay and cause significant fish kills. In the shallow water areas near freshwater inflows, fish can be influential components of the food chain, and fish have been known to persist for years during periods of high lake level. However, there are few studies of fish in the wetlands and bays surrounding the lake. Species of fish that could be washed into GSL from its tributaries are brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), cutthroat trout (*Oncorhynchus clarkii*), rainbow trout (*Oncorhynchus mykiss*), bullhead catfish (*Ameiurus melas)*, channel catfish (*Ictalurus punctatus*), crappie (*Pomoxis nigromaculatus*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), whitefish (*Prosopium williamsoni*), and yellow perch (*Perca flavescens*). In addition, the non-native rainwater killifish (*Lucania parva*, likely introduced in contaminated stock in surrounding waterways; Sigler and Miller 1963) and invasive mosquitofish (introduced for mosquito control in Salt Lake City in 1932; Reese 1934) are known to occupy low salinity waters in wetlands and bays of the lake (Sigler and Sigler 1996; Billman et al. 2007). Carp and shad (*Doroshoma depedianum*) are known to escape from Willard Bay and are also found in wetlands and bays surrounding the lake. Carp can damage or destroy wetland habitats by scouring shorelines, removing emergent vegetation, and competing with native species for food and habitat (Sigler and Sigler 1996). Piscivorous bird species such as American white pelicans, western grebes (*Aechmophorus occidentalis*), and double-crested cormorants

(*Phalacrocorax auritus*) use the bays as foraging areas. Farmington Bay tends to be more saline than Bear River Bay. Its salinity is often at 3.5%, which is too saline to support freshwater species of fish. The margins of the bay adjacent to the freshwater marsh outflows are sometimes fresh enough to sustain temporary populations of fish and the birds that eat them. However, the winds frequently mix the water to the point that the fish cannot survive. Occasionally, some fish wash out of Farmington Bay through the Davis County Causeway into the main lake. This phenomenon is not as common as fish from Bear River Bay, because the populations of fish in Farmington Bay are rarely as abundant. The North Arm does not support a population of fish because of the salt concentrations.

2.7.7.1 LAKE LEVEL EFFECTS

The distribution and diversity of fish species in tributaries to GSL could be reduced during periods of low lake level due to reduced watershed inputs, concentrated nutrients and pollutants in contributing waters, and the reduced extent of freshwater wetland habitats and associated prey species. At high lake levels, the extent of freshwater wetland and other freshwater habitats would be increased with associated increases in native and non-native fish species.

2.7.8 Birds

2.7.8.1 INTERNATIONAL, HEMISPHERIC, AND NATIONAL SIGNIFICANCE OF GREAT SALT LAKE

GSL is highly regarded for its international significance to both migratory and resident birds, and it has been designated as a regionally and hemispherically important site in the Western Hemispheric Shorebird Reserve Network. Although nomination as a Wetland of International Significance for the Ramsar Convention designation was a topic of discussion during the 2000 GSL CMP process, no such designation is currently being considered. Many locations on GSL provide important habitat for multiple bird species. The description of GSL from Aldrich and Paul (2002) provides a well-stated assessment of GSL’s importance:

> GSL is one of several terminal lake systems in the Great Basin and is the fourth largest terminal lake in the world (Stephens, 1997). With its impressive size and extensive associated wetlands, the presence of GSL, in an otherwise xeric environment, underscores the “oasis” effect of the system. Consider the lake's position in the western hemisphere. There is a broad sweep of land that lies between the Cascade Mountains and the Mississippi River valley extending from the arctic rim to nearly Central America that receives less than 20 inches (50 cm) of precipitation annually. Except mountain environments, this is a vast arid region of the Americas. In this setting, productive sites for feeding, fattening and molting of large numbers of migratory birds are isolated and often vast distances apart. These sites are always the exception and not the dominant habitats. From breeding grounds in the arctic, many species of birds travel more than 1,860 miles (3,000 km) by the time they arrive at GSL. Some will need energy to travel farther south to reach their wintering grounds. An American avocet (*Recurvirostra americana*) travels approximately 1,300 miles (2,100 km) to winter on the west coast of Mexico at Marismas Nacionales. A Wilson’s phalarope (*Phalaropus tricolor*) doubles its weight on GSL brine flies (*Ephydra cinerea*) and brine shrimp (*Artemia fransiscana*) before flying nonstop, nearly 5,400 miles (8,800 km), to Laguna mar Chiquita in central Argentina. Other species migrate as near as the Salton Sea or as far as the Straits of Magellan from GSL.

Birds associated with the lake and its environs are abundant and diverse. Groups include waterbirds, shorebirds, waterfowl, diurnal raptors, owls, and marsh and upland-associated songbirds. Over 250 different bird species have been identified (Paul and Manning 2008). Several million birds use the lake area during the spring, summer, and fall migration. Some unique winter visitors occur in the area, including one of the largest concentrations of bald eagles in the 48 contiguous United States.

GSL is located on the eastern edge of the Pacific Flyway and on the western edge of the Central Flyway. These corridors are the major routes that populations of birds use when migrating north and south. These flyways were defined for administrative considerations primarily (not biological) and are used in the analysis of bird banding data. It was discovered that birds typically, although not exclusively, migrate in north-to-south corridors.

Three species identified in the Utah Partners in Flight Conservation Strategy rely on GSL for most phases of their life cycle: American avocet, black-necked stilt, and American white pelican (Parrish et al. 2002). In addition to these three species, many species of waterfowl, shorebirds, and waterbirds are associated with the habitats within and adjacent to GSL. These species include Brewer's sparrow (*Spizella breweri*), ferruginous hawk (*Buteo regalis*), grasshopper sparrow (*Ammodrammus savannarum*), greater sage-grouse (*Centrocercus urophasianus*), Lewis' woodpecker (*Melanerpes lewis*), long-billed curlew, sage sparrow (*Amphispiza belli*), and sharp-tailed grouse (*Tympanuchus phasianellus*) (Evans and Martinson 2008).

Salinity varies around the main body of the lake due to geographic location, geology, and the presence of human-made structures. A variety of plants and invertebrates depends on these differing saline habitats. Each species has an optimum range of preferred salinity levels, and this wide spectrum of salinities provides unique and critical habitat for wildlife. Brine shrimp play a significant role in GSL ecosystems and, along with brine flies, are a keystone species supporting many of the waterbird and shorebird species that frequent the lake. A primary reason for the hemispherically important bird numbers at GSL is the lake's capacity to produce millions of pounds of easily foraged protein at the appropriate times for staging and molting migratory birds.

Generally, the North Arm (Gunnison Bay) is extremely saline and only supports brine shrimp when GSL is at very high elevations. The west and south shores are moderately saline and support brine shrimp at high to average lake levels. The northeast, east, and southeast sides of the lake are less saline and support brine shrimp and other invertebrates during average and lower lake level years. These open lake and littoral zones are exceptionally important to phalaropes, common goldeneyes, Franklin's gulls, California gulls (*Larus californicus*), and eared grebes. The east shore of the lake has many productive habitats due to the freshwater deltas of the Jordan, Weber, and Bear rivers and numerous smaller Wasatch Front streams. The water from all these drainages has been totally or partially diverted through natural or managed wetlands adjacent to the lake. The historic Jordan River and the Weber River deltas have been abandoned and receive little or no natural flow. These are very productive areas for waterfowl, colonial nesters, and many shorebirds, including dowitchers (*Limnodromus* spp.), yellowlegs (*Tringa* spp.), godwits (*Limnosa* spp.), American avocets, and black-necked stilts.

Managed wetlands have created unique habitats with dikes, levies, headgate systems, and diversion structures. These systems enhance the opportunities for active management by changing water depths, temperature, and water dispersion patterns and by controlling nutrient flows over time. These managed wetland areas accommodate seasonal use and the needs of migrating and breeding aquatic birds. Significant waterfowl breeding also occurs in these areas.

The following discussion outlines the research that has been conducted on bird species associated with GSL since the 2000 GSL CMP was published. Most of the discussion provides recently discovered information on waterbirds, waterfowl, and shorebirds. This information includes research and data that have been collected on habitat relationships, breeding, and migration of each of these broad guilds of birds. References such as Paul (2010), Vest (2009), The Cadmus Group (2009), SWCA (2009), Jones and Stokes (2005), Paul and Manning (2008), and Aldrich and Paul (2002) provide a more detailed discussion of the bird populations that use GSL.

2.7.8.2 WATERFOWL

Many species of waterfowl have been documented on and around GSL. Over 75% of the western population of tundra swans (*Cygnus columbianus*) uses the lake as a stopover and foraging area during their migration. As many as 60,000 individuals have been observed at peak times. They use the large lake areas within state WMAs and the Bear River Migratory Bird Refuge. Sago pondweed grows in these units and is their preferred forage. Trumpeter swans (*C. buccinators*) also occasionally inhabit the area. As a means to broaden their wintering range across the west, USFWS and DWR have been transplanting trumpeter swans to GSL from areas where populations have exceeded the food source.

2.7.8.2.1 Habitat Relationships

Shallowly flooded ponds with water more than 1 foot deep and hemi-marshes characterized by approximately 50% emergent vegetation and 50% open water are the most commonly used habitat types for waterfowl (Aldrich and Paul 2002). Wintering waterfowl use any areas that are not covered by ice, which can be limited in mid-winter (Vest et al. 2009).

2.7.8.2.2 Breeding

Most waterfowl species breeding in the GSL area occupy marshes in the impounded areas adjacent to GSL. Many waterfowl species prefer to nest in upland sites, then lead their broods of ducklings to the marshes to rear them. Some of these areas are within the scope of this document, but many are managed by private and nonprofit organizations such as private duck clubs, The Nature Conservancy, and the National Audubon Society. Others are areas set aside, restored, or enhanced for mitigation purposes. The important aspect of the adjacency of these areas is the working partnerships that have been developed to deal with large-scale effects in land management practices. Table 2.20 provides estimated numbers for nesting waterfowl in the GSL ecosystem from Aldrich and Paul (2002).

Table 2.20. *Estimated Numbers for Nesting Waterfowl in the Great Salt Lake Ecosystem*

Common Name	Latin Name	Number of Breeding Pairs
Cinnamon teal	*Anas cyanoptera*	40,702
Gadwall	*Anas strepera*	59,994
Mallard	*Anas platyrhynchos*	48,099
Northern pintail	*Anas acuta*	9,436
Northern shoveler	*Anas clypeata*	26,510
Redhead	*Aythya americana*	29,642
Ruddy duck	*Oxyura jamaicensis*	16,389

Source: Aldrich and Paul (2002).

Note: The total number of individuals is double the breeding pair number.

2.7.8.2.3 Migration

Numerous waterfowl use the wetlands around GSL during migration and as wintering populations (Paul and Manning 2008). Duck populations on GSL observed as part of ground surveys conducted on state and federal management areas showed average peak populations of over 600,000 individual ducks during September for the years 1993–1998 (Aldrich and Paul 2002). Over 75% of the western population of tundra swans and 25% of the continental northern pintail population use the GSL area. The annual production of breeding waterfowl from the marshes adjacent to the lake is estimated to exceed 750,000 birds (DWR 2005).

Waterfowl that are produced elsewhere, typically north of Utah, use marshes and lakes as a stopover point during their migration. Up to 5 million waterfowl migrate through Utah each year. Large numbers of green-winged teal (*Anas crecca*) and northern pintail use GSL each summer as a key molting area. They fly from other areas and use the large open water portion of the lake for security and foraging. During the waterfowl molt, the birds are flightless for a three- to four-week period. Northern pintail numbers in late summer have reached approximately 1,000,000 birds. This is approximately 25% of the continental population of these birds. In the 1990s, northern pintail populations were approximately 250,000 on GSL. Green-wing teal numbers generally peak at 600,000 during the molting and staging period. Vest (2009) determined that GSL also hosted the largest inland concentration of wintering common goldeneye, with a peak winter population of 45,000 or 4% of the combined continental population of Barrow's (*Bucephala islandica*) and common goldeneye. Populations of species presented in Table 2.21 also use the lake during migration periods and peak in the late winter or early spring.

Table 2.21. *Peak Population Numbers of Waterfowl at Great Salt Lake*

Common Name	Latin Name	Peak Population
Canada goose	*Branta canadensis*	50,000
Canvasback	*Aythya americana*	50,000
Cinnamon teal	*Anas cyanoptera*	80,000
Common goldeneye	*Bucephala clangula*	45,000
Gadwall	*Anas strepera*	100,000
Mallard	*Anas platyrhynchos*	500,000
Northern shoveler	*Anas clypeata*	100,000
Redhead	*Aythya americana*	150,000
Ruddy duck	*Oxyura jamaicensis*	60,000

Note: 7,000–11,000 Canada geese annually molt along the west side of Bear River Bay.

2.7.8.2.4 Wintering

Wintering populations of waterfowl are dependent on habitat and climatic conditions, which change yearly. The amount of water that is not frozen and the availability of food are the primary factors governing abundance of birds during the winter. If the winter is severe, most of the marshes are frozen over, and relatively deep snow covers the ground, birds migrate south until more favorable conditions are encountered. Mid-winter numbers of ducks range from 10,000 to 150,000, depending on weather.

DWR participates with other states and USFWS in the management of migrating waterfowl. Management of birds that can move in one day from state to state or even between countries requires coordinated management. Utah conducts several bird surveys each year to determine population numbers. These counts are coordinated with other states so a continental population can be determined. For example, all states in wintering areas conduct mid-winter surveys between January 1 and 15 to establish wintering population data.

Vest et al. (2009) and Conover et al. (2009) looked at trace element concentrations in wintering waterfowl at GSL and determined that high levels of both selenium and mercury were found in common goldeneye, northern shoveler, and green-winged teal. These results were confirmed by Peterson and Gustin (2009). They suggest that further research is needed to determine what the effects of these elements are on GSL waterfowl and waterbirds. Johnson and Naftz (2010) have postulated that the combination of both selenium and mercury create a stable form of mercury selenate that limits the toxic effects of these elements on bird populations.

2.7.8.3 SHOREBIRDS

GSL has one of the largest shorebird concentrations in the world. Over 35 species of shorebirds are found in the Western Hemisphere (Sorensen 1997), and 28 of them have been observed using GSL habitats (Paul 2010). Many of these species visit GSL each year and commonly include American avocet, black-necked stilt, and killdeer (*Charadrius vociferous*).

Many of these birds undertake extraordinary migrations, with some birds traveling up to 6,000 miles. Over 50% of the world population of Wilson's phalaropes (500,000), the largest staging population in the world, depends on GSL. The largest population of American avocets (250,000) and black-necked stilts

(65,000) in the Pacific Flyway and over 10% of all red-necked phalaropes (*Phalaropus lobatus*) (240,000) stop over on GSL (Aldrich and Paul 2002; Luft and Niell 2011). The lake also hosts the world's largest assemblage of snowy plovers (*Charadrius alexandrinus*) (3,715) and the only staging area for marbled godwits (*Limosa fedoa*) (58,000) in the interior of the United States. Observations of over 30,000 dowitchers have been made on a single occasion (Aldrich and Paul 2002; Luft and Niell 2011).

The GSLEP is cooperating in the development of a *Great Salt Lake Shorebird Management Plan* (Paul et al. 2012 [in press]). When completed, this plan will be the basis for future shorebird management decisions involving the lake.

2.7.8.3.1 Habitat Relationships

The most significant aspect of GSL ecosystems is the diversity of habitats created from the integration or close association of freshwater and salt-water systems, which creates a fluctuating "mosaic" of landforms, vegetative cover, water, and salinity. Several microhabitats (natural and human-made) are important to each habitat. Management and conservation efforts must consider each habitat type and the species that frequent these areas.

Shorebirds use a variety of aquatic and terrestrial habitats for feeding, breeding, and resting in the GSL area. The most commonly used habitat types are shallowly flooded mudflats and marshes that are along the fringes of the GSL waterline each year (Paul et al. 2012 [in press]). Shorebirds typically like to nest in areas that have little or no vegetation, which are common in areas that have been inundated by GSL at one time or another (Cavitt 2010).

Freshwater and salt-water interfaces are created where flowing fresh water enters directly into the lake, such as the outflows of several small streams along the east shore. These areas provide important foraging areas for breeding, brooding, and staging. These areas also stay ice-free in the winter and provide habitat for waterfowl.

Salt playas, mudflats, and other lake interfaces occur at numerous locations throughout the extremely shallow, low gradient GSL Basin. These environments shift seasonally and with lake level fluctuations. These areas are critical to snowy plovers for nesting, and they provide foraging and staging areas for numerous shorebirds, including tens of thousands of avocets and stilts. The associated shoreline supports a robust population of brine flies, which are a significant bird food source. The transitory nature of the shoreline introduces a constant dynamic state; emergent vegetative stands are constantly shifting between early and late seral stages as water levels advance and recede. A rich mosaic pattern of habitat types results. Some examples include Farmington Bay, Howard Slough, areas west of existing WMAs, and The Nature Conservancy's GSL Shorelands Preserve (formerly known as the Layton Wetlands Preserve). There are numerous ephemeral pools that are associated with the mudflats and playas. They result from slight changes in topography and precipitation, overland flow (runoff), wind tides from the main lake, and receding lake levels. Small pools create critical habitats for waterfowl and shorebirds and create unique places for food production of invertebrates and vegetation species.

2.7.8.3.2 Breeding

Surveys conducted by Cavitt for nesting shorebirds from 2003 to 2010 determine that predation from ground-nest predators is one of the most significant limiting factors for success in nesting attempts (Cavitt 2010). Data collected as part of the Legacy Avian Noise Survey Project (UDOT 2009) and Cavitt (2010) indicate that sites with predator control practices have significantly higher rates of reproduction in shorebirds.

Black-necked stilts and American avocets nest on mudflats and playas around the lake and within fringe wetland associated with runoff from managed wetlands. These sites are adjacent to favored shallow water feeding areas. Snowy plovers select playas with little vegetation around the lake for nesting sites. Other shorebirds that have been observed nesting around GSL include Wilson's phalarope, willet (*Catoptrophorus semipalmatus*), and long-billed curlew, all of which typically nest in uplands adjacent to the lake. Limited data are available on the success of these nesting species, due to the cryptic nature of their nesting habits and difficulty in observing specific nest locations. More common species, such as killdeer and Wilson's snipe (*Gallinago delicata*), also use habitats adjacent to GSL extensively for nesting, foraging, and migration.

2.7.8.3.3 Migration

As discussed in the section on the international importance of GSL for bird species, millions of shorebirds have been observed using GSL on their spring and fall migrations (Aldrich and Paul 2002). Twenty-seven species of shorebirds are known to regularly use the wetlands, mudflats, and open waters of GSL for migration (Paul et al. 2012 [in press]). Table 2.22 provides some shorebird migration numbers in the wetlands and open waters of the GSL ecosystem.

Table 2.22. *Population Sizes of Great Salt Lake Ecosystem Species of Importance*

Common Name	Latin Name	Trend*	North America Population Size†	Rely‡	Intermountain West Joint Venture Population§	GSL Peak Count¶	North America Population at GSL (%)	Intermountain West Joint Venture Population at GSL (%)
Black-bellied plover	*Pluvialis squatarola*	3	50,000	2	15,000	3,383	7	23
Snowy plover	*Charadrius alexandrinus*	4	13,200	3	10,000	3,715#	28	37
Killdeer	*Charadrius vociferus*	5	1,000,000	2	50,000	3,020	<1	6
Black-necked stilt	*Himantopus mexicanus*	3	175,000	2	120,000	65,000**	37	54
American avocet	*Recurvirostra americana*	3	450,000	3	420,000	250,000**	56	60
Greater yellowlegs	*Tringa melanoleuca*	3	100,000	2	12,000	555	<1	5
Willet	*Catoptrophorus semipalmatus*	3	160,000	2	50,000	2,289	1	5
Lesser yellowlegs	*Tringa flavipes*	3	400,000	2	15,000	1,832	<1	12
Long-billed curlew	*Numenius americanus*	5	123,500	3	70,000	409	<1	1
Marbled godwit	*Limosa fedoa*	4	172,000	3	130,000	43,833	25	34
Sanderling	*Calidris alba*	5	300,000	2	15,000	8,477	3	57
Western sandpiper	*Calidris mauri*	3	3,500,000	4	500,000	194,536	6	39
Least sandpiper	*Calidris minutilla*	5	700,000	2	100,000	8,041	1	8
Baird's sandpiper	*Calidris bairdii*	3	300,000	3	35,000	1,130	<1	3
Long-billed dowitcher	*Limnodromus scolopaceus*	2	400,000	1	250,000	58,800	15	24
Wilson's phalarope	*Phalaropus tricolor*	5	1,500,000	2	750,000	533,000††	36	71
Red-necked phalarope	*Phalaropus lobatus*	4	2,500,000	1	350,000	240,000§§	10	69

* Population Trend: 5 = documented decline and/or ESA species, 4 = thought to have declined though no data to prove so, 3 = no information on population change, future risks are a concern, 2 = population is considered stable, 1 = population may be increasing above historic levels (Brown et al. 2000).

† North American population size (Morrison et al. 2006).

‡ Reliability of population estimate: 1= Poor, 2 = Low, 3 = Moderate, 4 = Good, 5 = High (Brown et al. 2000).

§ Intermountain West Joint Venture population size was derived from proportions of the American Central Flyway and Eastern Pacific Flyway shorebirds passing through the Intermountain West and further refined with site-specific count data.

¶ Data from GSL waterbird survey (Paul and Manning 2008) except where noted.

Data from Cavitt (2010)

** Data from Shuford et al. (1995).

†† Data from Jehl (1988).

§§ Data from Paul (1982).

2.7.8.4 WATERBIRDS

Waterbirds include species that are associated with the aquatic habitats of GSL, but that are not classified as waterfowl (ducks and geese) or shorebirds (sandpipers and other similar species). GSL has extensive populations of colonial waterbirds. These species can be found on the lands or marshes adjacent to the lake, or on the islands and dikes/causeways within the lake. There are three primary habitat types used by these birds for nesting locations: islands/dikes, emergent vegetation, and areas of woody vegetation.

2.7.8.4.1 Habitat Relationships

Birds that select the interface of open water areas and the beginning of the emergent vegetation (such as bulrush species) of the exterior marshes include white-faced ibis (*Plegadis chihi*), Franklin's gulls, and tern species (*Sterna* spp.), which are often found together in nesting colonies around the lake. Eared grebes also use this habitat type, although they do not necessarily nest alongside the species previously mentioned. As lake levels fluctuate, the location of the bulrush-open water interface constantly changes. The dynamic of the GSL shoreline helps maintain pioneering stages in emergent vegetation types, which are important in developing habitat edge and vegetation density. It allows for periodic open mudflats and playas important for certain bird species and breeding sites for invertebrates. Changing habitats are the key to wildlife diversity and abundance in GSL ecosystems.

There is another group of species that uses a relatively rare habitat type around the lake. This habitat is woody vegetation in the form of trees and large shrubs. These are usually found along the waterways entering the marshes or planted along dikes and uplands by wildlife managers. All of the trees below a lake elevation of 4,212 feet were killed by salt water and/or flooding in the mid-1980s. Some of the dead trees still persist, and new trees have been planted or have naturally reestablished. These woody plants are excellent nesting sites for such species as great blue herons (*Ardea herodias*), snowy egrets (*Egretta thula*), black-crowned night herons (*Nycticorax nycticorax*), and double-crested cormorants. Other species such as raptors use these trees as well.

The open or pelagic areas of the lake are very important to many waterbirds. These areas are primarily used for either foraging or resting. Eared grebes and red-necked phalaropes feed on brine shrimp in the open waters of the lake. Gulls are observed there as well. They feed on dead and live brine shrimp and brine flies that collect in windrows on open water.

Most of the waterbirds of GSL are associated with shallowly flooded marshes for feeding and hemi-marsh habitats for nesting. These birds include the waders (e.g., egrets, ibis, and herons) that use riparian areas and marshes, but also include other birds that use uplands, wetlands, and open water (e.g., gulls and terns) (Aldrich and Paul 2002; Intermountain West Joint Venture 2005).

2.7.8.4.2 Breeding

Waterbird breeding habitat in the GSL area is primarily provided by islands in GSL and marshes adjacent to GSL. Waterbird species are typically colonial nesters and require a source of fresh water for survival (Paul 1984). Colonies are deserted occasionally due to human intrusion or predation by small mammals (Aldrich and Paul 2002). Large colonies of white-faced ibis, Franklin's gulls, and American white pelicans have also been observed around GSL (DWR 2005).

One example of a waterbird nester is the California gull. It nests on islands in the lake and on dikes or causeways that transect the lake. Egg, Hat, and Gunnison islands and dikes at the GSL Minerals operation in Bear River Bay are sites for gull colonies. The world's largest breeding population of California gulls nests at GSL. One of the world's largest nesting colonies of American white pelicans occurs on Gunnison

Island. This extremely remote island provides security from disturbance and predators. The pelicans fly from the island to forage for fish in the freshwater marshes and reservoirs, then return to bring food to the colony. Adult pelicans leave the colony for anywhere between 18 and 72 hours.

Conover and Vest (2009) examined selenium and mercury in breeding California gulls on GSL and determined that they had high levels of these elements. However, they found no evidence that health or reproductive abilities were diminished by the presence of these elements. These results were confirmed by Peterson and Gustin (2009), again suggesting that the combination of these two elements may physically bind one to the other in mineral form and lower the chances of abnormalities in birds (Johnson and Naftz 2010). There is no direct evidence of a synergistic reduction of deleterious effects in GSL fauna, whereas the interaction of selenium and mercury has been demonstrated to cause increased mortality in mallard embryos (Heinz and Hoffman 1998). Darnall and Miles (2009) examined mercury and selenium in eared grebes on GSL and Mono Lake (California) in 2006 and found significantly elevated levels of methylmercury and selenium in grebe livers during a two-month period. Compared to levels of liver mercury from 1992 to 2000, there has been an increase in mean liver mercury concentrations in eared grebes during the past two decades (Darnall and Miles 2009). An increase in mercury levels has also been documented in brine shrimp, the primary food of eared grebes, from an average of 0.34 mg/kg to 1.02 mg/kg during the same time period (1992–2006; Darnall and Miles 2009). Nevertheless, there is currently no evidence of reduced body mass or reproduction in eared grebes due to concentrations of selenium or mercury in GSL (Conover et al. 2009).

2.7.8.4.3 Migration

Over 1 million eared grebes stage on GSL each autumn and primarily eat brine shrimp in the open water habitats. Conover and Caudell (2009) determined that grebe populations need to consume 26,500–29,600 adult brine shrimp per day during migratory staging on GSL. They suggest that "commercial brine shrimp harvest should be curtailed when cyst densities fall below 20,000 cysts/m^3 to ensure enough adult brine shrimp for grebes during the subsequent year" (Caudell and Conover 2009).

Conover and Vest (2009) found that selenium and mercury concentrations in staging grebes on GSL in 2006 were high, but were not inhibiting grebes from increasing or maintaining mass. These results were confirmed by Peterson and Gustin (2009). Johnson and Naftz (2010) have theorized that the presence of both selenium and mercury creates a unique condition where a mercury selenide mineral is created, therefore reducing the adverse impacts of both elements on the birds.

2.7.8.5 PATHOGENS (AVIAN BOTULISM AND AVIAN CHOLERA)

Pathogens such as avian botulism and avian cholera occur in outbreaks in the marshes along the south and east shores of GSL. Waterfowl losses in the hundreds of thousands have been documented from botulism in marshes in the Bear River delta before the establishment of water control infrastructure in the Bear River Migratory Bird Refuge (Gwynn 2002). Barras and Kadlec (2002) found that precipitation and summer streamflow were the strongest predictors of potential outbreaks of botulism. Avian cholera was first documented in Utah wetlands in 1944 and has occurred in recent years along the south and east shores of GSL (Gwynn 2002; Niell 2010). In some locations, the limited areas that are available for waterfowl foraging and resting have led to increases in the incidence of avian botulism and avian cholera (Kadlec 2002). Ongoing studies of avian botulism outbreaks will continue to provide essential information on how to limit these occurrences.

2.7.8.6 LAKE LEVEL EFFECTS

The effects of lake level on birds that use GSL habitats are highly variable and are based on the specific requirements of individual species. One very important aspect of GSL for migratory and nesting birds is the transitory nature of the shoreline. The flooding and drying of the mudflats and wetlands around GSL create conditions where new resources become available and foraging areas shift over time.

For this analysis, bird species are grouped into foraging and nesting guilds (Table 2.23). Further explanation of specific fixed elevation or transitory elevation changes and effects on birds is outlined in Table 2.24. In an effort to simplify the display of this information in the larger matrix, these guilds are combined based on similar life requirements. The effect of lake level is also different for each of the managed areas of GSL, therefore a place-based analysis of effects is detailed in the GSL Lake Level Matrix (see Appendix A).

The foraging guilds are based on the type of food and habitat bird species use most frequently. For example, many waders, waterfowl, and shorebirds use shallowly flooded wetlands or shoreline areas for foraging. These birds would all fall within the wetland foraging guild and are grouped to provide a more simple explanation for analysis of effects. Nesting guilds are grouped in a similar way, and both guild analyses have exceptions and some minor overlap in species due to the general habits of many of these bird species. Foraging guilds are based on habitat affinities (e.g., open water, wetlands, shorelines and shallow water, and mudflats). Some specific species forage in multiple habitat components, therefore future analysis could be refined to show additional detail.

Some foraging guilds, such as wetland foragers, have changing effects based on the transition of lake level, where a slow degradation of conditions occurs over a variable lake level range. An example is evident in the transitory shoreline that shifts constantly over time, changing the habitat at a specific location from flooded to completely dry. Other foraging guilds have no transition, such as fish eaters (piscivores), where there is a complete loss of the fishery at a certain elevation (approximately 4,200 feet). Further detail is provided in Table 2.24.

Nesting guilds also have some overlap among and between species, but some generalities can be stated. For example, island colonial nesters are found on a few of the islands in GSL. These islands are connected to the mainland at low lake levels, thus allowing land-based predators to access the nests, which are on the ground. For these species, high lake levels keep nesting areas isolated. *Artificial structure nesters* are defined as either colonial or noncolonial nesting birds that nest on human-made structures, which are typically dikes or levees. Most of these features are related to wildlife and WMAs or salt evaporation ponds. At certain lake levels, all of these dikes and levees are inundated and nesting areas are reduced.

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Table 2.23. *Foraging and Nesting Bird Guilds that use Great Salt Lake Habitats*

Elevation (feet)	Open Water Foragers (salt water)	Open Water Foragers (fresh water)	Wetland Foragers (vegetation and invertebrates)	Wetland Foragers (fish and invertebrates)	Shoreline and Shallow Water Foragers (fresh water)	Shoreline and Shallow Water Foragers (salt water)	Shoreline and Shallow Water Foragers (fresh and salt water)	Shoreline and Shallow Water Foragers (mudflats)	Island Colonial Nesters	Island Noncolonial Nesters	Artificial Structure (dikes and levees) Colonial Nesters	Artificial Structure (dikes and levees) Noncolonial Nesters	Rooted Emergent Over-water Nesters	Rooted Emergent and Submergent at Water Level Nesters	Mudflat Nesters	Shoreline/Shallow Water Nesters	Uplands Near Shorelines Nesters
4,213+	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
4,212	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
4,211	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
4,210	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Yellow
4,209	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green
4,208	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Green
4,207	Orange	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green
4,206	Orange	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green
4,205	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,204	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,203	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,202	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,201	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,200	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
4,199	Green	Green	Yellow	Orange	Yellow	Orange	Yellow	Orange	Green	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange
4,198	Green	Green	Yellow	Orange	Yellow	Orange	Yellow	Orange	Green	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange
4,197	Green	Orange	Yellow	Orange	Yellow	Orange	Yellow	Orange	Orange	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange
4,196	Green	Orange	Yellow	Orange	Yellow	Orange	Yellow	Orange	Orange	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange
4,195	Green	Orange – Low lake levels indicate drought	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
4,194	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
4,193	Green	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
4,192	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
4,191	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
4,190	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
4,189	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow
-4,188	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data

Note: Green = beneficial for resource; Yellow = transition; Orange= adverse for resource; Light yellow: incomplete data or information gap.

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Table 2.24. *Explanation of the Effects of Lake Levels on Birds with Fixed Elevation and Transitional Shifts in Habitat Conditions*

Nesting and Foraging Guilds	Open Water Foragers (salt water)	Open Water Foragers (fresh water)	Wetland Foragers (vegetation and invertebrates)	Wetland Foragers (fish and invertebrates)	Shoreline and Shallow Water Foragers (fresh water)	Shoreline and Shallow Water Foragers (salt water)	Shoreline and Shallow Water Foragers (fresh and salt water)	Shoreline and Shallow Water Foragers (mudflats)	Island Colonial Nesters	Island Noncolonial Nesters	Artificial Structure Colonial Nesters	Artificial Structure Noncolonial Nesters	Rooted Emergent Over-water Nesters	Rooted Emergent And Submergent at Water Level nesters	Mudflat Nesters	Shoreline/Shallow Water Nesters
Fixed point habitats									X	X						
Habitats with transition range	X	X	X	X	X	X	X	X			X	X	X	X	X	X
Transitional effect	Ecological shift in forage resources	Reduced number of ponds or area of open water	Loss or reduction in rooted emergent aquatic vegetation		Insufficient water to use all management systems in managed wetlands	Reduction in shoreline length	Loss of wetland/saltwater inter phase habitat at both high and low lake level	Inundation of mudflats at high lake			Inundation of nesting substrate with increasing water levels	Inundation of nesting substrate with increasing water levels	Loss or reduction in rooted emergent aquatic vegetation	Loss or reduction in rooted emergent aquatic vegetation	Increased distance from wetland edge at low lake	Nest loss with greater than average seasonal lake rise
	Reduced water volume and surface area	Loss of submergent vegetation and fishery	Reduction in aquatic invertebrates and fish		Reduction in freshwater pool size and subsequent shoreline	Ecological shift in forage resources					Increased access to site by predators with decreasing elevations	Increased access to site by predators with decreasing elevations	Loss of standing water around emergent vegetation	Loss of submergents used for nest platforms	Increased distance from nest site to fresh water	Nesting habitat reduction with increasing distance from wetland edge at low lake
						Increased distance from wetland edge at low lake							Increased predation	Loss of access water travel lanes to and from nests	Loss of nesting substrate at high lake	Increased predation as nesting nears dikes and other predator travel lanes

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2.7.9 Terrestrial Biology

The GSL ecosystem is floristically diverse due to the interface between freshwater deltas, saline marshes, alkaline and saline soils, and unique topography. The wetland flora of GSL is dominated by salt-tolerant emergents and halophytes, whereas the upland flora of the GSL ecosystem is dominated by halophytic, xeriphytic, and montane plant species. There is often a stark transition from saline wetland habitats to xeric upland habitats. Shoreline-associated wetlands, such as playas, quickly transition to upland sagebrush steppe and grassland communities. Human activities on the GSL shoreline have altered the historic distribution of upland and wetland habitats, with often abrupt transitions between dike uplands and emergent wetlands. Upland habitats are described here as *uplands*, which consist of both native and agricultural upland communities; *dunes* and *sandbars*, which are formed by windborn or waterborne oolitic sand; *islands*, which comprise a diversity of upland habitats; and *dikes*, *levees*, and *human-made structures*, which are raised constructions comprising soil, rock, or concrete that can support either upland or wetland vegetation. Invasive plant and animal species are also discussed in this section due to their potential to disproportionately affect terrestrial habitats relative to their abundance and distribution. Aggressive, invasive plants can alter vegetation community structure, ecological functioning, and the short- and long-term suitability of a habitat for wildlife. Invasive animal species affect terrestrial communities through high levels of predation on upland-nesting shorebirds and waterfowl and by exerting top-down effects on the GSL food chain.

2.7.9.1 LAKE LEVEL EFFECTS

The effect of different lake levels on the terrestrial biology of GSL is largely due to changes in the distribution and extent of island and mainland upland habitats. Significant changes in lake levels strongly influence the connectivity between islands and the mainland, and the extent and distribution of both wetland and upland habitats in the GSL ecosystem. The impacts of different lake levels on specific aquatic habitat types are discussed in section 2.7.2. The impacts of different lake levels on terrestrial habitat types are discussed in section 2.7.9 and section 2.7.10.

2.7.10 Terrestrial Habitats

2.7.10.1 UPLANDS

Upland habitats are found at slightly higher elevations than GSL wetlands and are characterized by dry ground and grasses, forbs, and shrubs that favor drier soil conditions. The uplands surrounding GSL are generally outside the GSL meander line and outside the GSL CMP management area boundary. However, the upland habitats play an important role in connectivity to other GSL-specific habitat types. The GSL uplands are dominated by shadscale (*Atriplex confertifolia*)-greasewood associations adjacent to sparsely vegetated shorelines (Aldrich and Paul 2002), but often occur as a mosaic of shrublands, grasslands, and barren areas. Upland habitats that are dominated by sagebrush (*Artemisia* spp.) and rabbitbrush (*Ericarmeria* spp.) serve as winter cover for wildlife and important winter forage for domestic sheep and deer.

Upland areas historically used for agricultural purposes tend to be dominated by grass species, including but not limited to, intermediate wheatgrass (*Thinopyrum intermedium*), foxtail barley (*Hordeum jubatum*), bluegrass (*Poa* spp.), and cheatgrass (*Bromus tectorum*). Grasslands and agricultural areas provide important upland wildlife habitat and serve as critical habitat when lake levels are high. Upland habitats also serve as important waterfowl and shorebird nesting habitats that provide dry cover for nesting sites close to wetlands and open water. One of the most important features of GSL uplands is the buffer they provide from human disturbances and development on adjacent lands (Aldrich and Paul 2002).

2.7.10.2 DUNES AND SAND BARS

Dunes and sand bars form along the eastern shore of the lake, along the shores of Antelope and Stansbury islands, and on the plains and foothills bordering the salt desert. Dunes near the lake are composed of white, calcareous oolitic sand formed around mineral particles and brine shrimp fecal material. Vegetation is usually restricted to the upper edges of the shoreline where waves and flooding are infrequent. However, in some areas, invasive species are populating sand dunes and altering their natural state. The floras of dunes and sandbars are distinct from surrounding playas and uplands in some areas, but may contain a mixture of upland-wetland species in others.

2.7.10.3 ISLANDS

Islands in GSL (specifically Antelope, Hat, Carrington, Egg, Fremont, Gunnison, Mud, Stansbury, Dolphin, Badger, and White Rock) provide valuable nesting and brooding habitats, as well as migratory resting locations, some of which are protected from land predators and human disturbance. Vegetation on GSL islands varies from no plant cover to a diversity of upland community types on Antelope and Stansbury islands. Some islands consist only of bare rock, whereas others possess soils and sparse vegetation or dense vegetation cover (Aldrich and Paul 2002).

2.7.10.4 DIKES, LEVEES, AND HUMAN-MADE STRUCTURES

Dikes, levees, and other human-made structures have strongly influenced the distribution of upland and wetland habitats on GSL, and they have become important nesting sites for waterfowl and shorebirds (Gwynn 2002). Vegetation on these structures varies from bare materials, to a mixture of wetland and upland species, to upland shrublands and grasslands. Gull populations, in particular, have apparently increased in response to increased availability of ‘artificial’ islands around GSL (Aldrich and Paul 2002). However, these structures also provide access routes between wetland habitats and isolated nesting sites for ground predators, which have negatively affected some species that lose large proportions of eggs and chicks due to predation.

2.7.10.5 INVASIVE SPECIES

Invasive non-native and noxious plant species are also increasingly found in upland sites. For example, Russian knapweed (*Rhaponticum repens*) is found at the Inland Sea Shorebird Reserve, Bailey’s Lake area, SLCIA wetland mitigation site, and the Legacy Nature Preserve. On the miles of dikes surrounding many managed areas of the south shore of GSL, upland floral invasive species include tall whitetop (*Cardaria draba*), poison hemlock (*Conium maculatum*), bittersweet nightshade (*Solanum dulcamara*), and several species of thistle (*Cirsium* spp.)

Low lake levels can create upland corridors between previously isolated wetlands and waterbird breeding habitats. The creation of these upland areas creates opportunities for both native and non-native predators to prey on breeding bird colonies and can significantly reduce the number of hatchlings and surviving offspring in a given year. Faunal species of particular concern in upland habitats are red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and feral domestic cats (*Felis catus*). The raccoon was historically rare in the area before the 1970s, but it is currently the primary predator of wetland bird nests in the GSL ecosystem (Aldrich and Paul 2002). Impacts to terrestrial communities in the GSL ecosystem associated with invasive weeds and non-native predators include, but are not limited to habitat reduction, short- and long-term habitat alteration, competition for resources, top-down impacts to the food chain and the resulting change in ecosystem structure and function, and increased disturbance associated with invasive species monitoring, control, and eradication efforts.

2.7.10.6 LAKE LEVEL EFFECTS

The distribution and extent of terrestrial habitats is considerably greater at low versus high lake levels. At high lake levels, dunes and sandbars and island habitats may be inundated. Island habitats in GSL are increasing isolated at higher lake levels. This increases the quality of these habitats for nesting birds due to the protection they provide from predation and other disturbance. At low lake levels, the distribution and extent of upland, dune and sandbar, and island habitats is increased, but the increased connectivity between these habitat types and mainland habitats can significantly reduce their value to nesting birds.

Islands are connected to the mainland at low lake levels, thus allowing land-based predators to access the nests, which are on the ground. For these species, high lake levels keep nesting areas isolated. At high lake levels, dikes, levees, and human-made structures are inundated, and ground-nesting areas are reduced; however, nests may be more productive due to reduced access by land-based predators.

2.7.11 Reptiles and Amphibians

Limited work has been done on the amphibians and reptiles in the GSL ecosystem. Historically, eight species of amphibians and 19 species of reptiles (two species of turtles, nine species of lizards, and eight species of snakes) were identified in *The Great Salt Lake Biotic System* biological resource inventory and study (Rawley et al. 1974). Currently, the Utah Conservation Data Center (DWR 2011b) database recognizes 11 species of amphibians (including two introduced frog species) and 21 species of reptiles (nine species of lizards and twelve species of snakes) in the GSL region (Table 2.25).

Table 2.25. *Reptiles and Amphibians of the Great Salt Lake Ecosystem*

Common Name	Latin Name	Conservation Status
Reptiles		
New Mexico whiptail	*Aspidoscelis neomexicana*	Not native to Utah
Tiger whiptail	*Aspidoscelis tigris*	None
Rubber boa	*Charina bottae*	None
Eastern racer	*Coluber constrictor*	None
Great Basin rattlesnake	*Crotalus oreganus lutosus*	None
Great Basin collared lizard	*Crotaphytus bicinctores*	None
Ring-necked snake	*Diadophis punctatus*	None
Western skink	*Eumeces skiltonianus*	None
Long-nose leopard lizard	*Gambelia wislizenii*	None
Nightsnake	*Hypsiglena torquata*	None
Sonoran Mountain kingsnake	*Lampropeltis pyromelana*	None
Milksnake	*Lampropeltis triangulum*	None
Striped whipsnake	*Masticophis taeniatus*	None
Smooth green snake	*Opheodrys vernalis*	Sensitive

Table 2.25. *Reptiles and Amphibians of the Great Salt Lake Ecosystem*

Common Name	Latin Name	Conservation Status
Reptiles		
Greater short-horned lizard	*Phrynosoma hernandesi*	None
Desert horned lizard	*Phrynosoma platyrhinos*	None
Gophersnake	*Pituophis catenifer*	None
Common sagebrush lizard	*Sceloporus graciosus*	None
Terrestrial gartersnake	*Thamnophis elegans*	None
Common gartersnake	*Thamnophis sirtalis*	None
Common sideblotched lizard	*Uta stansburiana*	None
Amphibians		
Tiger salamander	*Ambystoma tigrinum*	None
Western toad	*Bufo boreas*	SC
Great Plains toad	*Bufo cognatus*	SC
Woodhouse's toad	*Bufo woodhousii*	None
Pacific tree frog	*Pseudacris regilla*	None
Western chorus frog	*Pseudacris triseriata*	None
American bullfrog	*Rana catesbeiana*	Not native to Utah
Green frog	*Rana clamitans*	Not native to Utah
Columbia spotted frog	*Rana luteiventris*	CA
Northern leopard frog	*Rana pipiens*	None
Great Basin spadefoot toad	*Spea intermontana*	None

Notes: SC = Utah wildlife species of concern; CA = species under Conservation Agreement (Bosworth 2003; DWR 2010a; UCDC 2011).

2.7.11.1 LAKE LEVEL EFFECTS

In general, the distribution and extent of terrestrial habitats for reptiles would increase during periods of low lake levels and decrease during periods of high lake levels. Impacts to reptile species would be minimal due to the predominance of upland habitats in the landscape surrounding GSL. In contrast, the distribution and extent of amphibian upland habitats that are close to water would be reduced during periods of low lake levels. During high lake levels, some freshwater habitats may be created or expanded; however, inundation of existing freshwater habitats by saline waters from GSL could cause a reduction in available habitats for and populations of amphibians.

2.7.12 Mammals

Sixty-four species or subspecies of mammals (most of which are rodents) have been identified around the lake and on islands in the main body of the lake. Other species present include bats, rabbits, porcupines, coyotes, foxes, bobcats, mountain lions, deer, and feral cats. DSPR and DWR have established pronghorn (*Antilocapra americana*) and California bighorn sheep (*Ovis canadensis californiana*) on Antelope

Island. Locations and records of occurrence can be examined in *The Great Salt Lake Biotic System* (Rawley et al. 1974).

2.7.12.1 LAKE LEVEL EFFECTS

In general, the distribution and extent of terrestrial habitats for mammals would increase during periods of low lake levels and decrease during periods of high lake levels. Impacts to mammal species would be minimal due to the predominance of upland habitats in the landscape surrounding GSL. In addition, increased access to the nests of ground-nesting bird species on islands and other shoreline habitats during periods of low lake levels could increase the abundance of land-based predators, including invasive species such as the raccoon, striped skunk, red fox, and feral cat.

2.7.13 Biological Surveys and Research

In addition, there is an enormous amount of information and research (published and nonpublished) available on the flora and fauna of GSL. A complete literature search has been conducted and compiled by USU and GSLEP. The GSLEP program is also seeking research papers on brine shrimp in natural systems, limnology of saline lakes, bird ecology of hypersaline lakes in the Western Hemisphere, and research on GSL. A bibliography may be available in the future.

Ecological sampling has been conducted for 17 years in the South Arm (1990–2006; Belovsky et al. 2011), and this sampling may be one of the most extensive and long-term studies of a large hypersaline lake ever conducted.

GSL is the largest permanent saline lake in the United States and is a critical habitat area for birds. There are many bird surveys conducted on and around GSL to answer specific questions such as total numbers present, peak season use, species use, and habitat relationships. A waterbird survey coordinated by DWR GSLEP is the most extensive to date. It began in 1997 and is projected to continue. The count examines total number of waterbirds over time and relates these data to habitats.

The Utah Natural Heritage Program is a central repository for information about Utah's biodiversity, including animal and vegetation communities. This program was initiated by The Nature Conservancy in 1988. The program was transferred to the state in 1991 and is currently partially funded by DWR. The program's mission is to collect information about Utah species and vegetation communities in a standardized and easily retrievable way and to provide this information for natural resource management decision makers.

The Utah Regional Gap Analysis Project (ReGAP) analysis program comprises a geographic information system that includes map layers of habitat types, vegetation, wildlife distribution, and other resources. This information can be used to investigate spatial relationships of resources and to track changes or trends in wildlife distribution and habitat use.

Many master's theses and doctoral dissertations have been completed on the ecology of GSL and are kept at the universities where the research was originally funded. These publications are included in the bibliography prepared by DWR and USU. Recently completed and ongoing ecological and biological research can be found in Appendix D.

2.8 Minerals and Hydrocarbons

GSL brines contain chloride, sodium, sulfate, magnesium, potassium, and other ions that can be combined into valuable minerals or concentrated into useful brines through solar evaporation. Hydrocarbon (oil and gas) resources are also present at GSL, but are presently undeveloped. The state owns and administers the minerals located in the bed and waters of GSL below the meander line as Public Trust resources. The responsibility to manage the minerals of the lake and of all sovereign state lands has been assigned to the FFSL by statute. The division has specific management responsibilities for minerals of GSL pursuant to UTAH CODE § 65A-10-18. In 1996, FFSL developed the *Great Salt Lake Mineral Leasing Plan*. The MLP provides FFSL with guidance on the long-term management and leasing of GSL mineral resources. The 1996 MLP has been updated in concurrence with this 2013 GSL CMP revision. Please refer to the 2013 MLP for details on the management of GSL's mineral resources (FFSL 2012).

2.8.1 Mineral Resources and Industries

Although GSL is renowned for its "salt" (sodium chloride or table salt), the lake can be used to produce sodium, potassium, calcium, and magnesium salts. GSL salt content comes from a variety of sources. Rain and snow in the mountains leach sodium, potassium, magnesium, and other ions from soils and rocks carrying them in solution in streams that eventually flow into the lake (Hem 1989). The high salt content of GSL may be attributed to its location on the lake bed of Lake Bonneville, where the salt in the much larger Lake Bonneville has now been concentrated into GSL (Trimmer 1998). In addition, some believe that the lake's salts were leached from deposits of oceanic salt of Jurassic age that crop out within the GSL Basin. Others suggest that salt is brought by wind into the lake from the ocean (Eardley 1970). Although there is not one universally accepted means by which salt reaches GSL, it is agreed that once salt is delivered to the lake, it remains in the lake.

Due to the terminal nature of GSL, the only way for salt to be removed from GSL is through mineral extraction. The water entering the lake escapes by evaporation only. A notable exception occurred when the West Desert pumps moved water from the GSL lake bed to the West Desert to avoid infrastructure damage at high lake levels in the late 1980s. From April 1987 to June 1989, the pumps deposited 2.73 million acre-feet of brines (approximately 0.5 billion tons of salt or 14.2% of the GSL salt load) into the West Pond. GSL presently contains approximately 4.5–4.9 billion tons of salt in its system (UGS 2011b).

Salt extraction is one of Utah's oldest industries, and salt has been harvested from the waters of GSL for over 150 years (Gwynn 2002). Beginning in the 1960s, research and development have led to the economic production of potassium sulfate, magnesium metal, magnesium chloride products, nutritional supplements (Gwynn 2002), and other products.

Brine-derived products, including salt (sodium chloride), magnesium chloride, and potash, were the largest contributors to the value of industrial-mineral production in Utah in 2009 (Bon and Krahulec 2010). Currently, the largest operators on GSL are GSL Minerals (a subsidiary of Compass Minerals), Cargill Salt, Morton Salt, and US Magnesium LLC (Bon and Krahulec 2010). The companies involved in mineral extraction on GSL are listed in Table 2.26 and highlighted in Map 2.3. For information regarding the economic impacts of the extractive industries, please see section 2.14 (Economic and Sociological Trends).

Table 2.26. *Summary of Mineral Companies and Type of Mineral Production*

Company	Production
Compass Minerals Subsidiaries: GSL Minerals North American Salt Company	GSL Minerals Sulfate of potash, magnesium chloride brine and flake (bischofite). Magnesium chloride is also referred to as *Chlori-Mag* by GSL Minerals. Salt for snow and ice removal, animal nutrition, water conditioning, and swimming pools. North American Salt Company Packages, markets, and sells the salt products.
Cargill Salt	Salt and return bitterns (the concentrated brine that remains after sodium chloride has crystallized).
Morton Salt	Salt and return bitterns.
US Magnesium LLC	Magnesium metal is their primary product, but they also sell the following by-products: chlorine, calcium chloride (brine), magnesium chloride (brine), sodium chloride, ferrous chloride, ferric chloride.
North Shore Limited Partnership	Magnesium brine and salts are concentrated and then processed into nutritional supplements by Mineral Resources International.

The brine-derived products from GSL are almost exclusively produced from solar evaporation ponds. The industries either use salts that have precipitated from the ponds, or brines that have been concentrated as a result of evaporation. Depending on the product being produced, the salts or brine are used as-is or are subjected to further processing. Sodium chloride is precipitated in evaporation ponds and is sold primarily by Morton Salt, Cargill Salt, and North American Salt Company.

Potassium sulfate, also referred to as sulfate of potash, is produced by GSL Minerals for use as fertilizer. Potassium-bearing salts are produced by solar evaporation of brines, and the salts are purified and converted to potassium sulfate during processing. GSL Minerals is the only producer of sulfate of potash in North America and is currently in the permitting process for expansion of their operations. USACE is in the process of developing an EIS to assess the impacts of the proposed GSL Minerals expansion.

Magnesium chloride is produced and marketed by GSL Minerals in solid and liquid forms. Magnesium chloride is used in a number of applications, including road dust suppressant, road deicer, and fertilizer.

Concentrated magnesium-chloride brine is also used by US Magnesium to produce magnesium metal. Magnesium metal was the third-largest contributor to the value of base metals in Utah in 2009 (Bon and Krahulec 2010). Magnesium metal is produced from the concentrated brines by US Magnesium at its electrolytic plant at Rowley in Tooele County. This plant is the only active magnesium processing facility in the United States (Bon and Krahulec 2010) and provides 6% of the world's magnesium supply (USGS 2011d).

Chlorine is a co-product of magnesium metal production. The chlorine is sold as a liquid. Chlorine emissions from the magnesium plant have been a point of contention to air and water quality regulators (GSLEP 2011). However, US Magnesium has done much to reduce chlorine and other emissions in recent years. For example, they have significantly reduced chlorine emissions from historical levels using several innovative processes. The electrolyzers used in magnesium production were redesigned in the early 2000s, which realized significant increases in chlorine collection. In addition to this effort, the company has installed more efficient chlorine scrubbing equipment and a chlorine conversion unit to collect vaporized chlorine as hydrochloric acid. These activities have combined to reduce chlorine emissions by over 95% since the late 1980s (Gwynn 2011c).

A titanium sponge metal plant, operated by ATI Titanium LLC, began operating adjacent to US Magnesium in 2010. The plant is located next to US Magnesium on the west shore of GSL because magnesium metal is a critical processing component for the production of titanium metal. The start-up of a titanium sponge plant will add incremental demand for magnesium and begin a new era in metal processing in the state (Bon and Krahulec 2010).

Mirabilite (sodium sulfate) is a naturally occurring mineral that is precipitated from highly concentrated lake brines during the cold winter months. This salt is not stable and redissolves as the brine warms in the spring, except where it is enclosed in sediment at the bottom of the lake. Mirabilite-cemented oolite beds have been found at numerous places around the lake, including near the Northern Railroad Causeway, Saltair, the South Shore Marina, the Antelope-Island Marina, and the Morton Salt intake canal on the south end of Stansbury Island. At one time, IMC Kalium-Ogden Corp. produced anhydrous sodium sulfate or thenardite from winter-precipitated mirabilite; there is no current production of mirabilite.

Epsomite (magnesium sulfate) can be produced by the winter cooling of highly concentrated lake brines, such as those used by US Magnesium in the production of magnesium metal and chlorine (gas and liquid). Epsomite is not currently being produced from lake brines.

Oolitic sands are an unusual sediment type found in and around GSL at numerous locations. They are light-colored calcium carbonate grains that range in shape from nearly spherical to cylindrical. Their surfaces are usually smooth, like a miniature pearl. The size of oolites ranges from 0.015 to 1.5 millimeters, with the average size being approximately 0.31 millimeters. The chemical composition of the outer shell consists mainly of calcium carbonate, though some calcium-magnesium carbonate (dolomite) is also present. The nucleus or central core of the ooid is usually a mineral fragment or a brine-shrimp fecal pellet.

Some of the areas in which oolites are found include 1) the west side of Stansbury Island in Stansbury Bay; and the north end of the island extending northward past Badger Island, where beds up to 18 feet thick have been measured; 2) around Antelope Island and especially in the area of the Bridger Bay bathing beaches; and 3) the southern shores of the lake.

Oolites were used in the past to neutralize the acidic gases produced during the processing of melting magnesium chloride into magnesium metal. Oolites have also been used to produce calcium chloride, which is used in the brine-desulfation process and as an industrial chemical. Oolites are also used as flux in ore-smelting operations and could also be used in most applications where limestone is used. Small amounts of oolitic sand are used in drying flowers.

2.8.1.1 LAKE LEVEL EFFECTS

Changes in lake level have a relatively minor impact on GSL minerals themselves. Mineral extraction is impacted at high and low lake levels and is discussed in further detail in section 2.14.3.3. At high lake levels, the brines in GSL become more diluted. The low-lying, unimpounded beds of oolitic sands (around Antelope Island, for example) would be covered at approximately 4,204 feet. As the lake level drops, the brines become more concentrated. When the salinity in the North Arm reaches 27%, sodium chloride precipitates and falls to the bottom of GSL (Gwynn 2011c).

2.8.2 Oil and Gas

Other geological resources under and around the lake include oil and gas. Oil has been produced at Rozel and West Rozel Point oil fields, and natural gas has been produced at Farmington Bay and Bear River Bay; however, economically viable hydrocarbons have not yet been discovered. The oil field in the West Rozel has substantial quantities of oil in place, but its composition and the costs associated with its off-shore production are two limiting factors for production.

2.8.2.1 ROZEL POINT OIL FIELD

Naturally oozing tars have been produced from areas near Rozel Point, probably since pre-settlement times. Shallow wells drilled near surface oil seeps at Rozel Point beginning in the early 1900s produced a small amount of oil. The field area lies on mudflats at the edge of the lake and is submerged at times of high lake levels. There are currently no active wells in the Rozel Point oil field. Cumulative production (to 1993) is 2,665 barrels of oil (Kendell 1993a). The oil is thick with a high sulfur content (11%–12%) making it difficult to produce and refine. Previous research on the Rozel Point field is discussed by Heylmun (1961b), Eardley (1956, 1963a), and Kendell (1993a).

2.8.2.2 WEST ROZEL POINT OIL FIELD

Amoco Production Company drilled 15 wells in GSL, using a floating barge-mounted drill rig, from mid-1978 to 1981. The drilling resulted in the discovery of the West Rozel oil field, a seismically defined structural feature 3 miles west-southwest of the Rozel Point oil field. The structure is a faulted anticline approximately 3 miles long and more than 1 mile wide, covering approximately 2,300 acres. The discovery well produced two to five barrels of oil per hour during production testing from perforations located 2,280–2,410 feet below surface in Tertiary basalt. Cumulative production (to 1993) is 33,028 barrels of oil (Kendell 1993b). The oil is very thick and high in sulfur, making it difficult to produce and refine. Previous research on the West Rozel is discussed by Bortz (1983, 1987), Bortz et al. (1985), and Kendell (1993b).

2.8.2.3 FARMINGTON GAS FIELD

The Farmington gas field was discovered in 1891 near the shore of GSL approximately 3 miles southwest of Farmington. One well produced at a rate of 4.9 million cubic feet of gas per day from a depth of 850 feet. In 1895, a pipeline was built from the field to Salt Lake City and provided gas for 19 months until the gas was depleted or the wells sanded up (Richardson 1905). It is estimated that the field produced 150 million cubic feet of gas at a rate of 8.5 million cubic feet per month. The Farmington gas field is discussed by Heylmun (1961a).

2.8.2.4 BEAR RIVER GUN CLUB

Natural gas has often been encountered while drilling shallow water wells on the Bear River Delta. A water well drilled by the Bear River Gun Club was converted to gas production and provided natural gas for private use for many years until the well blew out. When attempts were made to plug the well, the gas flow cut away from the well bore and blew out through the soil. It took several days to control the flow, which was estimated to be as large as 1 million cubic feet a day. There has never been any attempt to commercially exploit the gas resource from the delta.

2.8.2.5 ADDITIONAL OIL SHOWS

Additional oil shows were found in samples collected by Amoco Production Company during drilling in the South Arm of the lake.

2.8.2.6 LAKE LEVEL EFFECTS

Fluctuating lake levels may have an impact on future oil and oil production by making it difficult to drill and produce. Floating, lake-based, or island-based facilities will be subject to flooding during high-water periods, and shore-based facilities may be subject to the same problems during high water. Low lake levels would not likely have impacts on oil production because construction and access to facilities during low water would not be problematic, and the presence of oil is unrelated to GSL lake levels.

2.9 Land Use

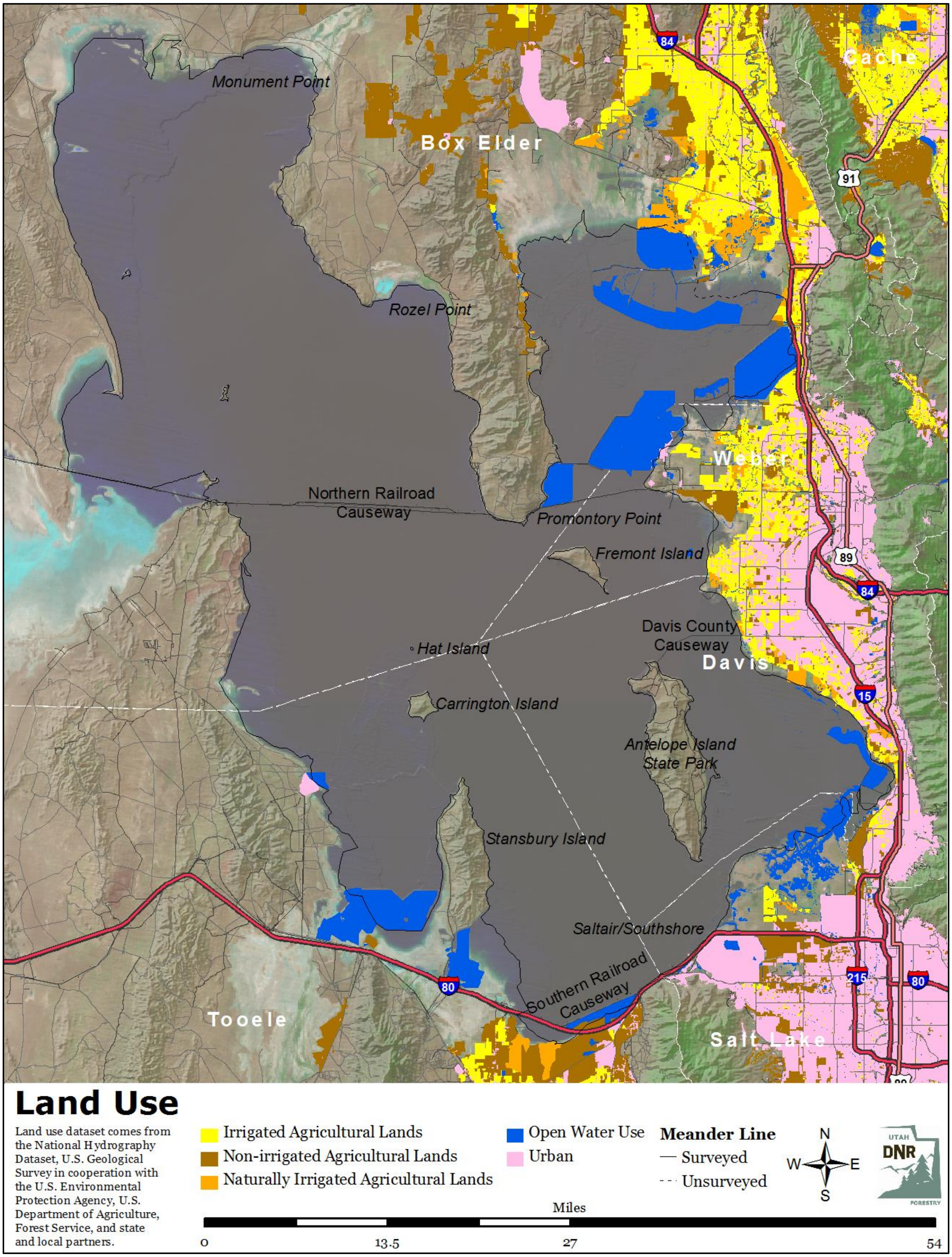
The state is responsible for the management of the GSL bed, pursuant to the Equal Footing doctrine as discussed in section 1.12. The boundary line of GSL is the “meander line,” a coarsely surveyed line established by court order in 1976. The meander line follows no particular topographic contour or elevation, but is generally located between 4,202 and 4,212 feet above sea level in most places around the lake. Lands within the meander line are referred to as *sovereign lands* in this plan. Sovereign lands also include the unsurveyed islands in GSL: Dolphin, Badger, Egg, and White Rock islands. Hat and Gunnison islands are owned by DWR. Stansbury, Fremont, Carrington, and Cub islands are federally and/or privately owned.

In addition to the sovereign lands owned by the state, UDNR has acquired lands in and around GSL, including Antelope Island (DSPR), wetlands and uplands associated with WMAs, and formerly private lands needed for the WDPP, all of which are managed for specific purposes.

The management of sovereign lands is the responsibility of FFSL. One of the challenges in managing sovereign lands is that the biological and physical systems of GSL do not observe property boundaries, and management decisions on sovereign lands affect and are affected by uses and activities on adjacent lands.

2.9.1 Land Uses Adjacent to the Great Salt Lake

Land use around GSL consists of a mix of residential, commercial, agricultural, recreational, and industrial uses common to population centers (Map 2.8). The east side of the lake has the higher concentration and diversity of land uses. Population growth in Weber, Davis, and Salt Lake counties is resulting in the conversion of agricultural land to residential and commercial uses. Numerous single-family subdivisions have been constructed in the last decade. Residential developments to the east of GSL have been built on elevations as low as 4,217 feet, which is the FEMA 100-year floodplain elevation. The 100-year floodplain around GSL generally lies at 4,217 feet, based on surveys completed by USACE on the lake’s eastern edges where residential development is most likely to occur. To prevent damage to property or to protect public safety, mortgage companies are required to determine if a property they are financing is located within the 100-year floodplain by reviewing FEMA’s Flood Insurance Rate Maps. As stated in section 2.9.1.1, development below 4,217 feet is discouraged due to flooding risks.



Map 2.8. Land uses adjacent to Great Salt Lake.

To accommodate the increasing northern Wasatch Front population growth and to decrease traffic congestion for commuters in Weber and Davis counties, the 14-mile Legacy Parkway opened in 2008. Built at elevations ranging from 4,215 to 4,282 feet, the Legacy Parkway has the potential to be impacted by and impact GSL. Northwest Quadrant's mixed-use development plan was recently approved by Salt Lake County. This plan permits development close to the lake's southern edges. Development will be permitted at 4,215 feet, provided sufficient fill is added to decrease the impacts from potential flooding (Salt Lake City 2009).

Associated with this changing land use is a shift in water use from agriculture to municipal and industrial uses, with a resulting reduction in subirrigation groundwater and return flows to lands adjacent to the lake. As development moves toward the lake, the uplands no longer provide a buffer to the lake wetlands, and diminishing irrigation return flows affect the wetland ecosystem (Davis County 2001). In addition, runoff from urban lands introduces water contaminants different from those of agricultural lands.

A number of landowners adjacent to the lake are managing their holdings primarily for habitat protection. Approximately 150,000 acres of adjacent lands are within state and federal WMAs. In addition, approximately 10,000 acres of wetland and upland parcels are owned and managed for habitat preservation by groups like The Nature Conservancy and the National Audubon Society. Private hunting clubs own and manage over 50,000 additional acres on the east side of the lake, primarily adjacent to Bear River Bay and south of Farmington Bay.

Grazing and crop production from dry and irrigated acreage are the most common land uses around the north and west sides of the lake. The notable exceptions are the mineral evaporation ponds of Bear River and Clyman bays and the bombing and gunnery range, which lies on the western shore of the lake. SLCIA is located approximately 2 miles southeast of Farmington Bay wetlands and approximately 8 miles from GSL open waters (Salt Lake City 2009).

2.9.1.1 LAKE LEVEL EFFECTS

Land uses around GSL are impacted at a range of lake levels. Residential developments built near the FEMA 100-year floodplain (4,217 feet) could begin to encounter drainage problems when the lake reaches 4,215 feet or more. It should be noted that drainage issues for residential developments could become problematic when the lake level reaches 4,210 feet due to increases in groundwater tables and the potential for a 5-foot lake level increase by wind and wave action (3 feet for wind tide and 2 feet for wave action). At higher lake levels, other municipal infrastructure is adversely impacted; for example, at 4,209 feet, I-80 encounters drainage problems and is flooded at 4,211 feet. SLCIA experiences drainage problems when lake level, including wide tide and wave action, increases to 4,212–4,216 feet, and flooding occurs above 4,217 feet. Lake level effects on other land uses are discussed for each resource in this chapter. Municipal infrastructure is less likely to be impacted by low lake levels. Residents living closest to GSL would be subject to the greatest amount of fugitive dust (and its particulates) as the lake level recedes and more lake bed becomes exposed to wind events.

2.9.2 County Zoning Adjacent to Great Salt Lake

As noted throughout this document, FFSL management jurisdiction lies below the meander line of GSL. Adjacent to the meander line, primarily along the east side of GSL, are large tracks of privately owned land within county boundaries. Although FEMA discourages development below 4,217 feet, the county has the authority to authorize land uses up to the meander line. Therefore, it is important to understand which type of land uses are authorized by each county’s general plan or GSL-specific guidance. Given that the biological and physical systems of GSL are not constrained by the meander line, coordination between counties and FFSL regarding future development is crucial for the health and well-being of local residents and for the lake itself.

2.9.2.1 BOX ELDER COUNTY

GSL covers approximately 800 square miles of Box Elder County, the largest area and the longest shoreline of the five counties adjoining the lake. Several abandoned industrial ventures abut the lake, but brine shrimping is the only current lakeshore commercial activity other than mineral production. Only a portion of the lake shoreline is zoned. The area on the west side of the lake from Kelton to the southern county line is zoned M-160 (multiple uses with 160-acre minimum lot size). The balance of the shoreline is not zoned.

In August 1999, Box Elder County completed the *Box Elder Comprehensive Wetlands Management Plan* "to conserve and enhance the integrity of [the] GSL wetland ecosystem in Box Elder County, incorporating provisions for appropriate urban development, infrastructure needs, resident livelihoods and quality of life, while ensuring perpetuation of these important natural resources" (Box Elder County 1999). One of the goals of this plan was to develop a SAMP to more thoroughly understand wetlands in the area and to simplify the CWA Section 404 permitting process for impacts to county wetlands and mitigation for those impacts. The Box Elder SAMP has not been completed due to lack of funding.

2.9.2.2 DAVIS COUNTY

Zoning along the GSL shoreline in Davis County is controlled by three governmental entities: Davis County, Kaysville City, and Centerville City. Most of the county-controlled land adjacent to the lake is zoned A-5 (agriculture and farm industry with a 5-acre minimum lot size). The A-5 zone is intended to promote and preserve agricultural uses and to maintain greenbelt open spaces. Primary uses include single-family dwellings, farm industry, and agriculture. Several conditional uses include stables and dog kennels. Kaysville City abuts the lake for only a few hundred feet and is also zoned A-5 with similar uses.

Davis County Council of Governments and others sponsored the development of the *Davis County Shorelands: Comprehensive Land Use and Master Plan* (Master Plan) published in July 2001, as a nonregulatory guidance document that provides each city within Davis County "the tools needed to manage land use at a local level while preserving regionally important resources of the Great Salt Lake Shorelands" (Davis County 2001). The purpose of the Master Plan is to take a county-wide, collaborative approach to recommending proposed land uses along the shores of GSL. The authors of the Master Plan encouraged local municipalities to adopt "appropriate portions of the Master Plan as an element of their community's general plan" (Davis County 2001). Although many of the Master Plan implementation strategies remain to be completed, the Master Plan establishes a blueprint for land management and use adjacent to GSL in Davis County.

Centerville City abuts the eastern shoreline of the lake for approximately 2.5 miles immediately to the east of the Farmington Bay WMA. City zoning in this area is A-1 (agricultural) or I-D (industrial development). The A-1 zone allows both standard agricultural activities and single-family dwellings on 0.5-acre lots. The I-D zone allows for a variety of industrial and commercial uses.

2.9.2.3 SALT LAKE COUNTY

The shoreline of GSL in Salt Lake County is generally unpopulated and is zoned A-20 (an agricultural zone with a 20-acre minimum lot size) or CV (a commercial visitor zone). The A-20 zone provides for standard agricultural uses, but also allows solar evaporation ponds. It typically acts as a large-acre holding zone until a specific use is proposed, which can result in rezoning for the use proposed. The CV zone allows for commercial uses to accommodate the needs of visitors and travelers.

The *Salt Lake County Shorelands Plan*, completed in 2003, identifies undeveloped county lands near GSL that are most critical for conservation and areas best suited for development (Salt Lake County 2003). The plan includes wetlands mapping and a functional assessment of the county's wetlands. However, the nonregulatory plan suggests that further understanding of the area's natural resources would be more fully understood with the development of a SAMP. The Salt Lake County SAMP has yet to be developed.

Salt Lake City's Northwest Quadrant borders GSL within the city's northernmost boundary. The *Northwest Quadrant: Creating a Sustainable Community* was completed in 2008 with the intention of incorporating "new sustainable development and permanently protecting critical areas of the Great Salt Lake ecosystem" (Salt Lake City 2009). Within Salt Lake City, the GSL shoreline is zoned as an open space district (OS) and is intended to limit development potential. The land directly west of the OS zone is zoned as an agricultural district (AG) and is intended to act as a holding zone until final zoning is determined. This zone allows for single-family development on 10,000 square-foot lots. In September 2011, the Church of Jesus Christ of Latter-day Saints sold 3,100 acres of land to KUCC; this land comprised a large portion of the Northwest Quadrant. At the time of the sale, KUCC reported no current development plans for the newly acquired land (Jensen 2011).

2.9.2.4 TOOELE COUNTY

The shoreline of GSL is not specifically zoned in Tooele County, with land uses reviewed and approved on a case-by-case basis as conditional uses. Current uses include agricultural operations, brine mineral extraction, industrial and commercial uses, and brine shrimping operations. GSL mineral extraction is most heavily concentrated in Tooele County when compared to the other four counties surrounding the lake.

Tooele County and partners began developing a SAMP in 2002. Wetlands mapping and functional assessment of the area was completed during the SAMP process. By the end of 2005, the project stalled out largely due to lack of funding.

2.9.2.5 WEBER COUNTY

Fifteen miles of GSL shoreline is in Weber County and is zoned S-1 (farming and recreation). Lands directly east of GSL around Little Mountain are zoned M-3 (manufacturing). The M-3 zone allows for the manufacture and testing of jet and missile engines, aircraft and spacecraft parts, similar heavy industry, and for the extraction and processing of brine minerals. Bordering the S-1 and M-3 zones on the east are agricultural zones A-1, A-2, and A-3.

2.9.3 Land Uses on Sovereign Lands

The framework for sovereign land management is found in the Utah Constitution (Article XX), state statute (primarily Chapter 65A-10), and administrative rule (UTAH ADMIN. CODE R652).

Constitution accepts sovereign lands to be held in trust for the people and managed for the purposes for which the lands were acquired. UTAH CODE § 65A-2-1 states that "The division [FFSL] shall administer state lands under comprehensive land management programs using multiple-use, sustained-yield principles." Briefly stated, the overarching management objectives of FFSL are to protect and sustain the trust resources and to provide for reasonable beneficial uses of those resources, consistent with their long-term protection and conservation. This means that FFSL will manage GSL's sovereign land resources under multiple-use sustained yield principles, implementing legislative policies and accommodating public and private uses to the extent that those policies and uses do not compromise Public Trust obligations (UTAH CODE § 65A-10-1) and economic and environmental sustainability is maintained. Any beneficial use of Public Trust resources is ancillary to long-term conservation of resources. Administrative rules address planning (UTAH ADMIN. CODE R652-90) and land-use authorizations including minerals (R652-20), special use lease agreements (R652-30), easements (R652-40), rights-of-entry (R652-41), grazing (R652-50), cultural resources (R652-60), exchanges (R652-80), and off-highway vehicles (OHV) (R652-110).

2.9.3.1 SOVEREIGN LAND CLASSIFICATIONS

Division rule allows for classification of sovereign lands based on current and planned uses (R652-70-200 Classification of Sovereign Lands). The use classifications set forth in UTAH ADMIN. CODE R652-70-200 were applied to GSL in the 1995 GSL CMP and have not been updated since. The current recommended use classifications for GSL are described below (Map 2.9).

2.9.3.1.1 Class 1: Managed to Protect Existing Resource Development Use

Lands under this classification include the area around Antelope Island delegated to DSPR for recreation management, the area around Saltair and GSL Marina, existing mineral extraction lease areas, and areas under special use lease for brine shrimp cyst harvest activities. These lands would be open to oil and gas leasing, but no surface occupancy would be allowed in the recreation areas.

2.9.3.1.2 Class 2: Managed to Protect Potential Resource Development Options

This area includes the previously explored West Rozel oil field and shoreline areas from the north end of Stansbury Island south along the west side of the island and then north along the west side of the lake to the south line of Township 11 North, Salt Lake Base and Meridian. This area has traditionally been open to mineral leasing, developed recreation, and other kinds of developments.

2.9.3.1.3 Class 3: Managed as Open for Consideration of Any Use

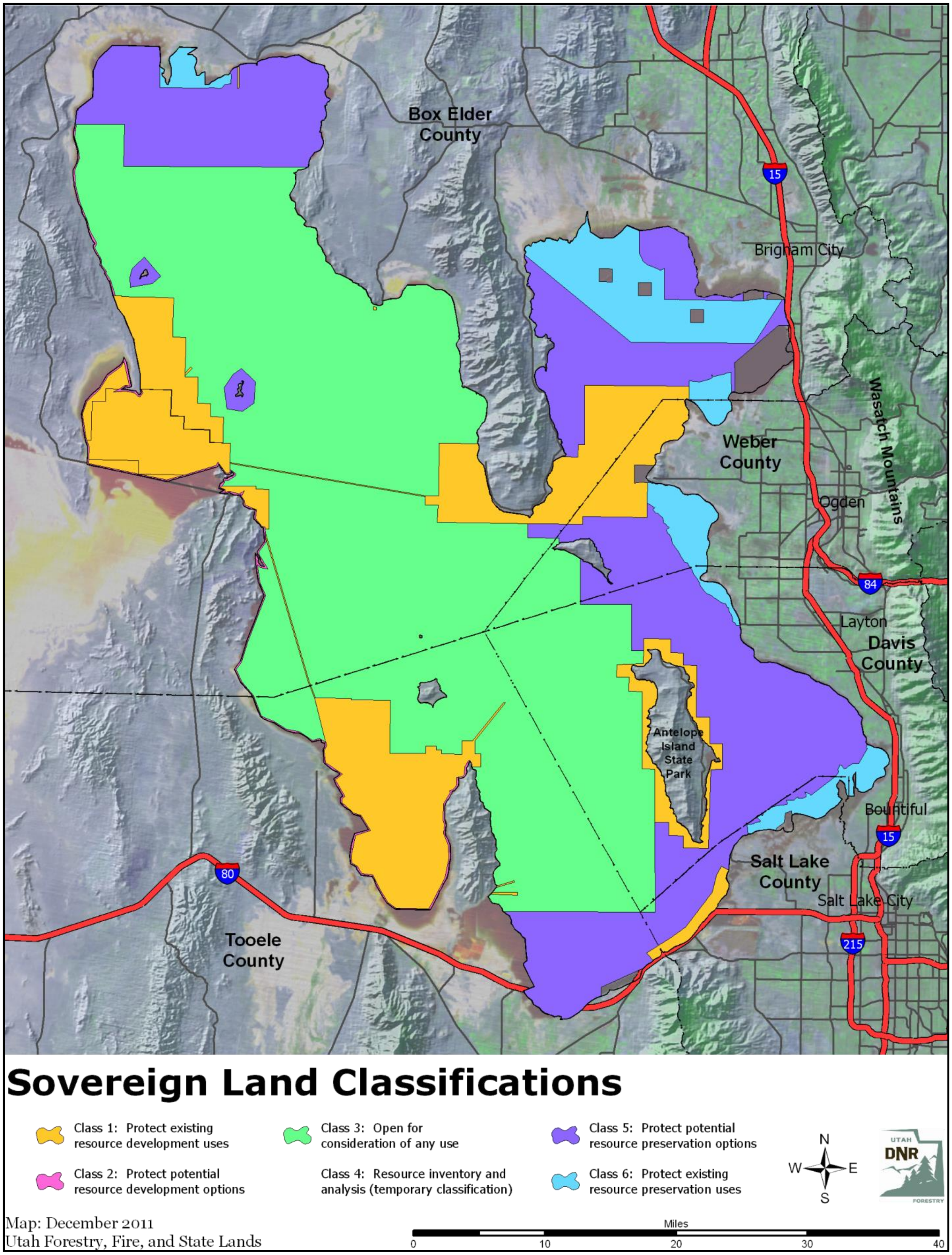
The remainder of the lake is recommended to be placed in Class 3.

2.9.3.1.4 Class 4: Managed for Resource Inventory and Analysis

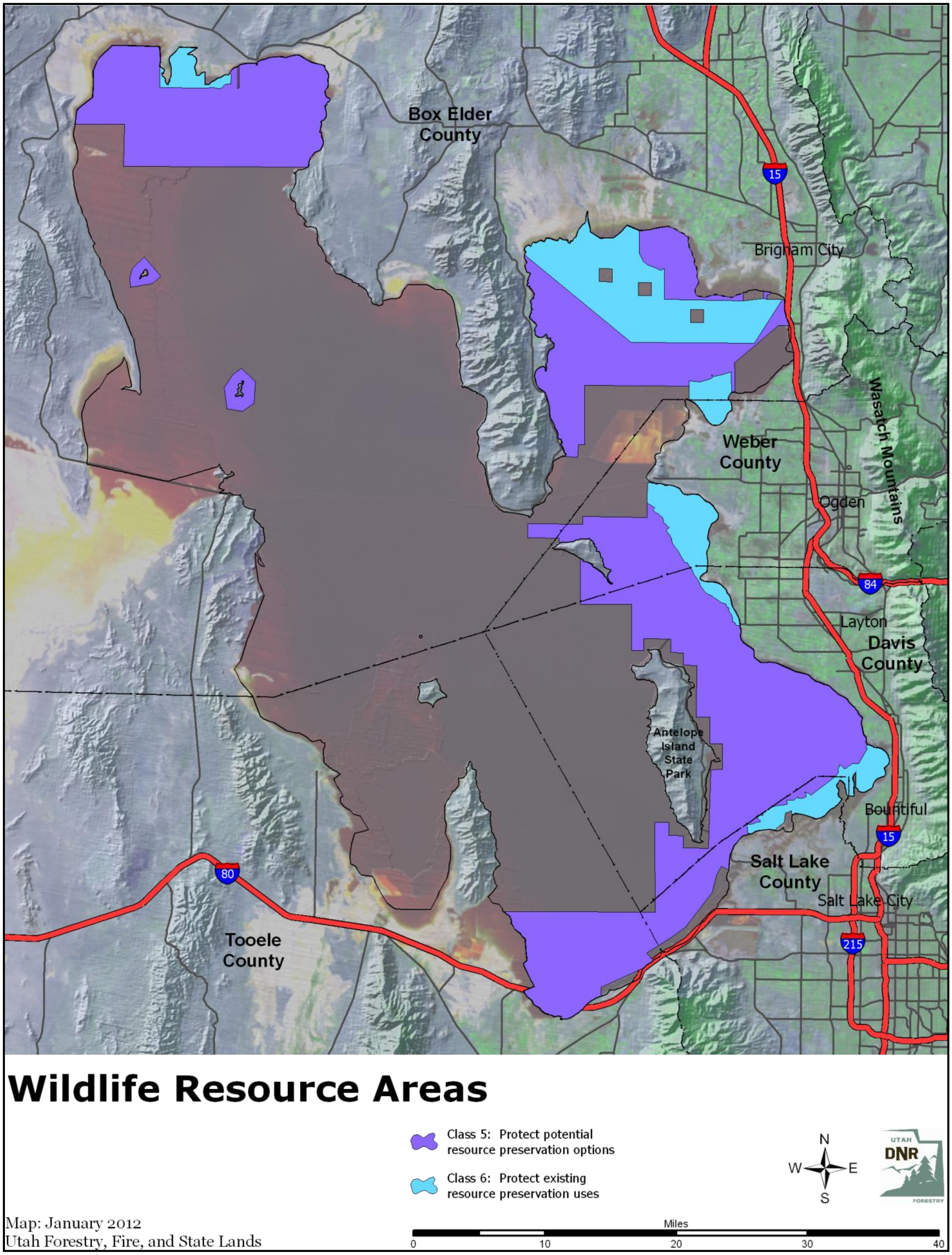
This is a temporary classification used while resource information is gathered pending a different classification. There are no Class 4 lands in the lake.

2.9.3.1.5 Class 5: Managed to Protect Potential Resource Preservation Options

This classification includes lands that the legislature has authorized DWR to use for wildlife purposes under UTAH CODE § 23-21-5 (Map 2.10) and a 1-mile buffer zone around islands in the North Arm. No surface occupancy for oil and gas exploration will be allowed in established WMAs or in the island buffer zones. Elsewhere, oil and gas surface occupancy constraints shall be determined in consultation with DWR. Mitigation strategies for developments not related to wildlife management in these areas shall also be determined in consultation with DWR.



Map 2.9. Sovereign land classifications.



Map 2.10. Wildlife protection areas.

2.9.3.1.6 Class 6: Managed to Protect Existing Resource Preservation Uses.

This classification covers existing WMAs. Lands would be available for oil and gas leasing with no surface occupancy.

As stated under the Class 5 use classification, the legislature has authorized DWR to use sovereign land in all or parts of 39 townships on GSL for the creation, operation, maintenance, and management of WMAs, fishing waters, and other recreational activities (UTAH CODE § 23-21-5). This geographic area covers Bear River Bay, Ogden Bay, Farmington Bay, portions of the south shore area, and the north end of Spring Bay. This statutory authorization is interpreted as establishing wildlife management and wildlife-related recreation as the primary intended land use, except for areas identified for other uses through a planning process. Land uses with significant adverse impacts on wildlife and recreation values may be prohibited, even though mitigation strategies are available. Some of this sovereign land is included in Antelope Island State Park and is managed by DSPR. Some of the land has been sold or exchanged.

In order to guide the orderly allocation of GSL resources, FFSL developed mineral leasing categories for GSL lands under FFSL jurisdiction. Current sovereign land mineral lease categories are found in the MLP. The mineral leasing categories (for salt and oil and gas) are illustrated in Maps 2.11 and 2.12.

2.9.4 Existing Uses and Leases

FFSL is responsible for issuing leases, permits, easements, and rights-of-entry on sovereign land. Existing GSL authorizations include grazing permits, special use leases, rights-of-entry, mineral leases, and easements (Map 2.13). There are oil, gas, and hydrocarbon leases on GSL. None are producing at this time. Details of existing uses and leases can be found on FFSL's website or by contacting the FFSL offices directly.

2.9.5 Sovereign Land Boundaries

2.9.5.1 UNCERTAINTIES AND DISPUTES

The meander line, which is the legal boundary between sovereign lands and adjacent lands, was established by a series of surveys over a period of years. A number of the original survey markers and monuments have been obliterated, and the exact location of the sovereign/private boundary is uncertain in many areas. Historically, areas where ownership has been uncertain have led to clarifications and legal disputes with FFSL. The only current land disputes pertain to land in the Bear River Migratory Bird Refuge, under the jurisdiction of USFWS, and Willard Bay Reservoir, under the jurisdiction of the Bureau of Reclamation.

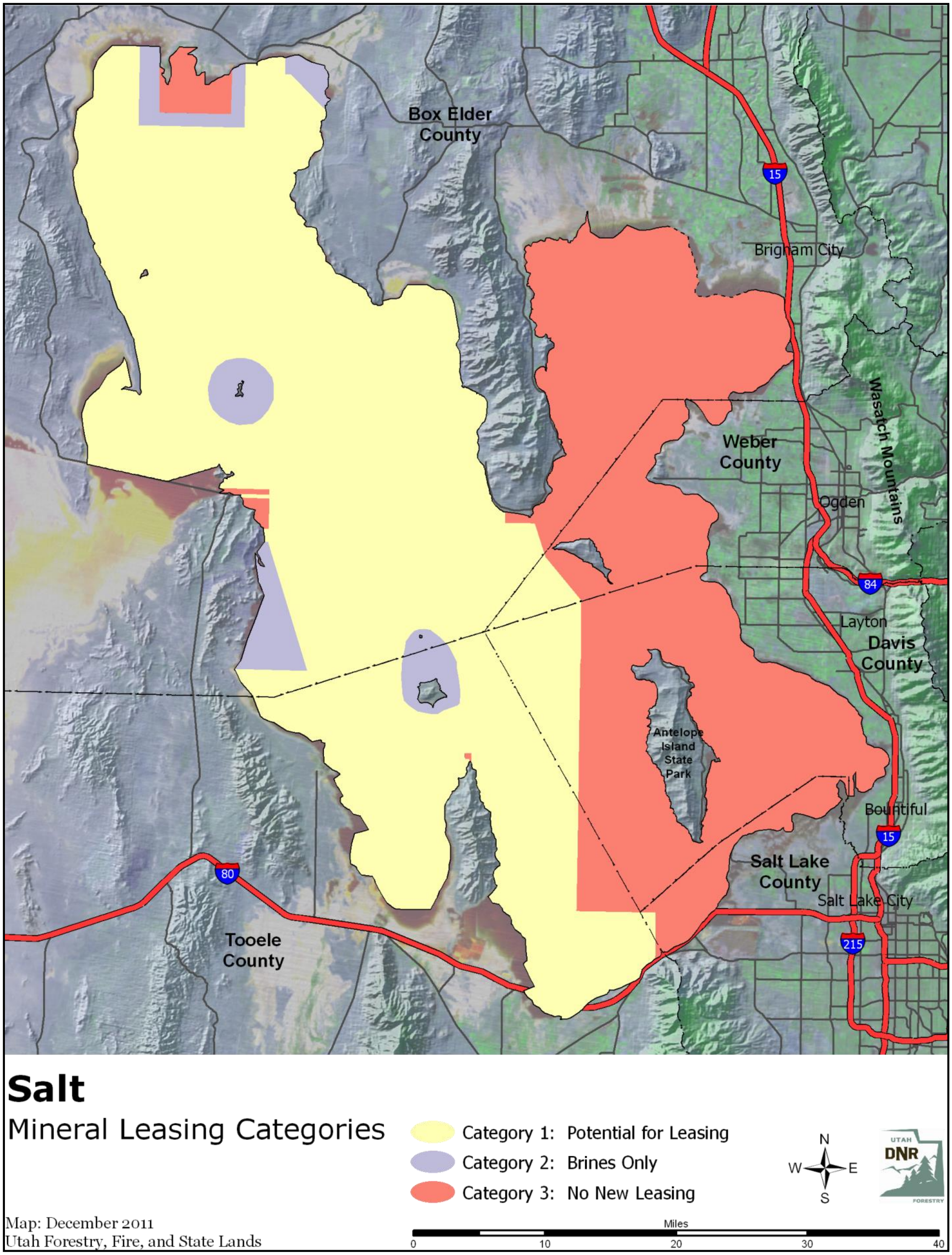
Should future land disputes occur, UTAH CODE § 65A-10-3 requires FFSL to consult with the attorney general and affected state agencies to develop a plan for the resolution of disputes over the location of sovereign land boundaries.

2.9.5.2 LANDS OWNED OR MANAGED BY OTHER STATE AGENCIES

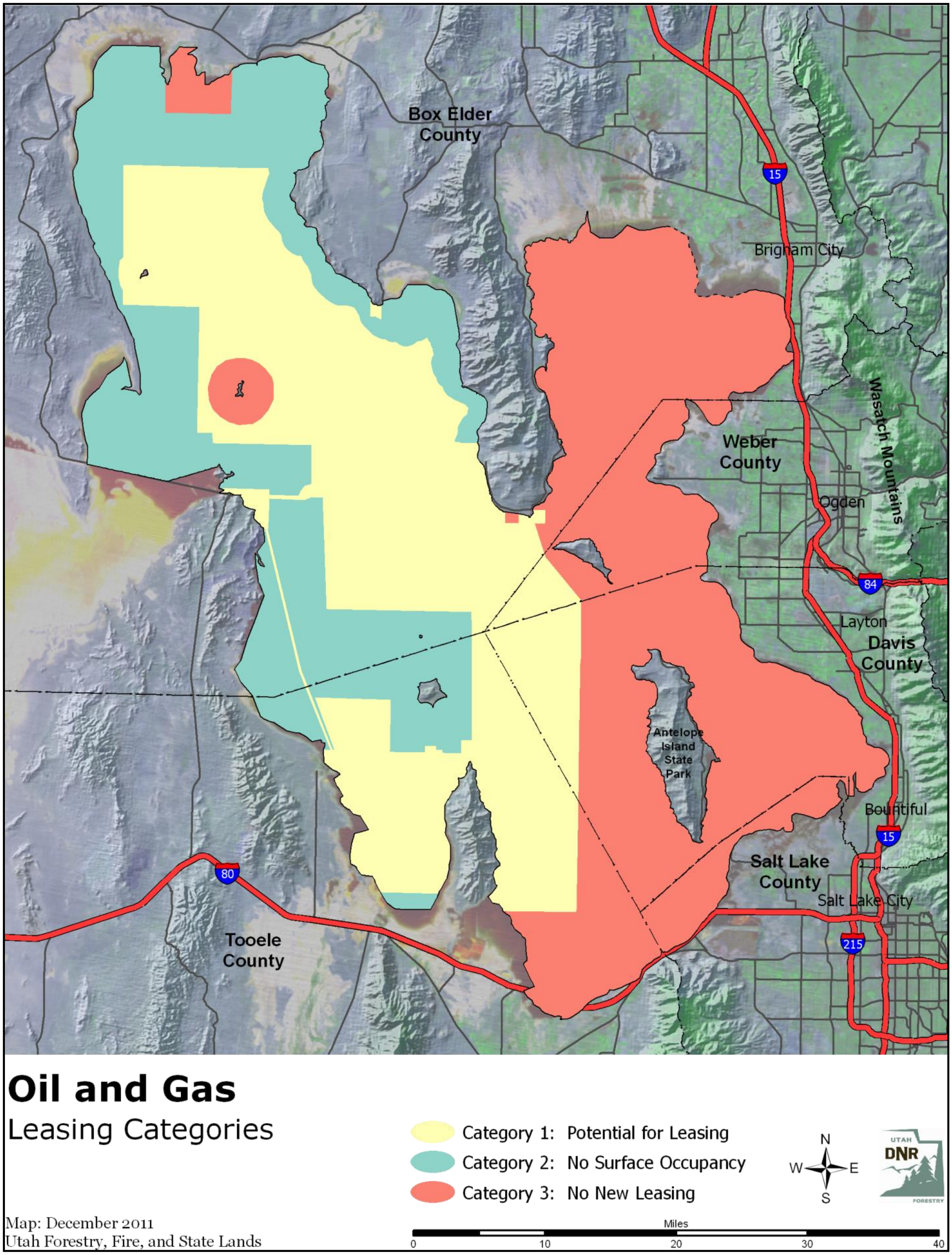
Within GSL, there are lands that are managed by other UDNR agencies and generally dedicated to specific uses. These lands are listed in Table 2.27. Badger, Goose, and Egg islands are owned by FFSL. Stansbury and Carrington islands are managed by the BLM and private land owners. Fremont Island is under private ownership.

Table 2.27. *Lands in Great Salt Lake Owned or Managed by Other State Agencies*

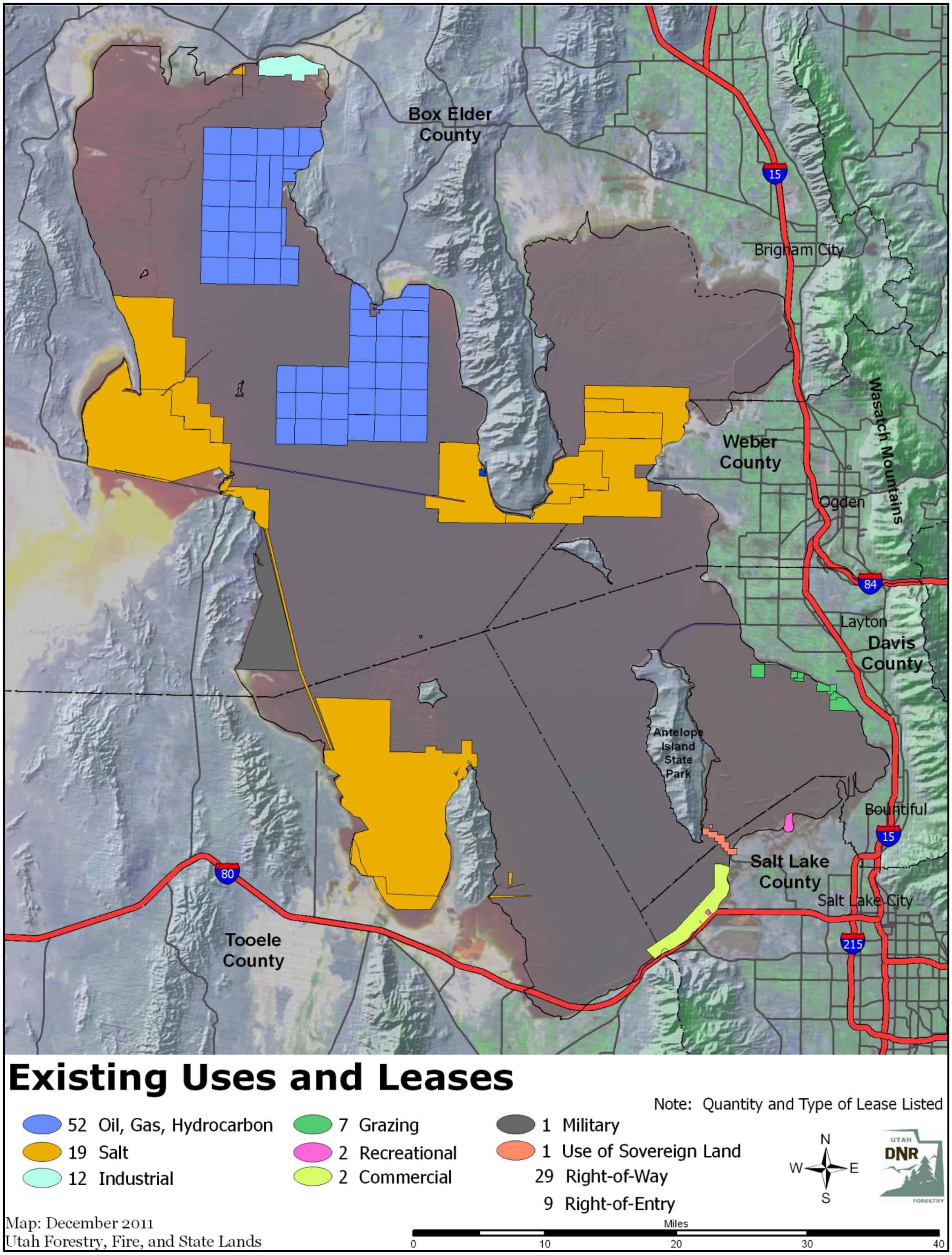
Agency	Area	Acres	Year	Land Status
DWR	Locomotive Springs	17,937	1931	Fee Title, estimated
DWR	Public Shooting Grounds	13,063	1923	Fee title, lease
DWR	Harold Crane	8,593	1963	Fee Title, dedicated
DWR	Ogden Bay	18,395	1937	Fee Title, dedicated
DWR	Howard Slough	3,300	1958	Fee Title, dedicated
DWR	Layton-Kaysville	25,000	1975	Dedicated
DWR	Farmington Bay	10,772	1935	Fee Title, dedicated
DWR	Hat (Bird) Island	22	1977	Fee title, state withdrawn
DWR	Gunnison/Cub Island	163	1977	Fee title, state withdrawn
DWR	Dolphin Island	624	1977	State withdrawn
DSPR	Antelope Island	28,022	1969/1981	Fee title
DSPR	South Shore Marina	5,874	1977	Delegation of authority
DSPR	Willard Bay	9,920	1965	Fee title, dedicated



Map 2.11. Mineral leasing categories (salt).



Map 2.12. Mineral leasing categories (oil and gas).



Map 2.13. Existing uses and leases.

2.9.6 Dikes and Causeways

Dikes and causeways in and around GSL serve many purposes. Dikes are used to impound fresh water (e.g., Bear River Migratory Bird Refuge, WMAs, Willard Bay Reservoir), impound brine pumped from the lake or trap brine in the lake for brine extraction (e.g., US Magnesium, GSL Minerals, Morton Salt), and protect facilities from high lake levels (wastewater treatment plants, sewage lagoons, power lines). Causeways are also used for transportation facilities along the shore or across the lake (I-80, Northern and Southern railroad causeways, Davis County Causeway).

The Northern Railroad Causeway was originally created in 1906 by the Southern Pacific Transportation Company to shorten the time required to go north around the lake. In 1959, the wooden trestle across the lake was replaced with a rock-fill and earthen causeway. The average elevation of the causeway was 4,209–4,210 feet in 1983. During the high water years, the causeway began to slough-off, settle, and subside into the lake. By spring 1984, very large inflows of fresh water into the South Arm and the restriction of flows to the north due to the plugged culverts in the causeway caused the water level in the South Arm to be 3 feet higher than the water in the North Arm. The higher elevation in the South Arm added greatly to flooding problems on the south and east shores of the lake. A 300-foot-long breach in the Northern Railroad Causeway was created by the State of Utah in 1984 to minimize flooding impacts. To repair the erosion damages resulting from the high water, surplus and scrap boxcars were used to create a “boxcar sea wall” on the north side of the causeway, which allowed the tracks and fill to be raised from 4,206 to 4,217 feet.

The Southern Railroad Causeway, located at the southern end of GSL, is a major rail line to the West Coast. It presently serves many chemical industries in this region and provides daily passenger service via Amtrak as part of an east-to-west rail corridor. In 1983, the rising lake began to affect the railroad track structure. Union Pacific raised the track in this area to protect it from the rising water. The elevation (top of the rail) through most of this area is 4,221.0 feet, with the subgrade (top of the embankment) at 4,218.5 feet.

Dikes and causeways influence lake level, salinity, habitat, and the surface area of the lake. The influence of causeways on salinity is evident. Where dikes or causeways constrain the area over which the lake could expand in high water periods, the water depth along shores may be too deep for shorebird habitat. Similarly, the formation of wetlands along shoreline areas may be affected. Some dikes and causeways constrict lake hydrodynamics and tributary flows as the water moves toward the lake, thereby exacerbating local flooding. For more information on how the dikes and causeways impact GSL, see section 2.3.

Further research is needed on the impacts of dikes and causeways on the GSL ecosystem. In addition, proposals to breach causeways should include an analysis of how the GSL ecosystem would be impacted. With the exception of studies regarding proposed, large freshwater impoundments (e.g., inter-island diking, Lake Davis, Lake Wasatch), assessments of effects have focused only on the intended purposes of dikes and causeways. Effects beyond the immediate vicinity of the impoundment have yet to be fully analyzed.

2.9.6.1 LAKE LEVEL EFFECTS

As indicated in the paragraphs above, GSL dikes and causeways are affected at higher lake levels. As the dikes and causeways are overtopped at increasing elevations, the salinity composition in the different bays begins to shift. The Southern Causeway to Antelope Island, which is no longer operable but impacts salinity levels between Farmington Bay and Gilbert Bay, begins to spill over at 4,205 feet. A breach in the Southern Causeway that goes down to approximately 4,200 feet allows water to flow between the bays.

The Davis County Causeway begins to have drainage problems at 4,205 feet and is overtopped at 4,208 feet. The Northern Railroad Causeway is overtopped at 4,217 feet, and when this occurs, all of the arms and bays of the lake are connected. At high lake levels, wind and wave action can cause infrastructure damage or hinder travel at an elevation 3–5 feet lower than the elevation at which the causeways are overtopped. At low lake elevations, the North Arm and South Arm become totally separated because the bottom of the 300-foot-long breach has a bottom elevation of approximately 4,193 feet (Klotz 2011).

2.9.7 Geologic Hazards

State law requires FFSL to disclose known geologic hazards affecting leased property. Information on known hazards is routinely provided to lessees but, in general, there is no follow-up activity.

2.9.7.1 SURFACE FAULTING

Surface faulting may accompany large earthquakes (greater than approximately magnitude 6.5) on active faults, including those in the bed of GSL. The resulting displacement at the ground surface produces ground cracking and typically one or more "fault scarps." The east GSL fault zone trends northwest along the west side of the Promontory Mountains and Antelope Island. Other faults are present elsewhere beneath GSL, particularly in the North Arm (Hecker 1993).

Although faults in GSL have generally not been mapped, surface faulting resulting from an earthquake on one of these faults may affect structures along the shoreline. Surface faulting beneath the lake may rupture dikes or in-lake structures that straddle the faults and may generate seiches, which could indirectly damage both in-lake and shoreline structures by flooding.

2.9.7.2 LIQUEFACTION

Liquefaction and liquefaction-induced ground failures are major causes of earthquake damage (Keller and Blodgett 2006). Upon liquefaction, a soil loses its strength and ability to support the weight of overlying structures or sediments. Liquefaction chiefly occurs in areas where groundwater is less than or equal to 50 feet deep, when a water-saturated, cohesionless soil is subjected to strong ground shaking (Seed 1979; Martin and Lew 1999). Cohesionless soils have loose grains that do not readily stick together and are typically sandy with little clay, although some silty and gravelly soils are also susceptible to liquefaction.

In general, an earthquake of magnitude 5 or greater is necessary to induce liquefaction. Larger earthquakes are more likely to cause liquefaction and may result in liquefaction at greater distances from the earthquake epicenter. Four types of ground failure can occur during liquefaction: 1) loss of bearing strength, 2) ground oscillation, 3) lateral-spread landslides, and 4) flow landslides (Lowe 1990a). The type and severity of the failure depend greatly on the surface slope.

Anderson et al. (1982, 1986 and 1990) and Lowe (1990a and 1990b) suggest that large areas within Salt Lake, Davis, and Weber counties east of the lake have a moderate to high potential for liquefaction during earthquakes. Regarding flooding related to local and distant earthquakes, liquefaction, and wind tides, Atwood and Mabey (1990) state that "Engineered structures (such as dikes and causeway embankments) founded on the lake bed, particularly those designed to provide protection from the lake water, pose special engineering-geology problems." These problems include settling, flooding, soil compaction, and erosion.

2.9.7.3 TECTONIC SUBSIDENCE

In the event of an earthquake within the Salt Lake Valley, the potential exists for the valley floor to drop relative to the adjacent Wasatch Range. Such movement could occur along the multi-segmented Wasatch fault zone. Keaton (1986) suggests that displacement could be approximately 5 feet at the fault line. The zero-subsidence line would be approximately 10–12 miles west of the fault. A drop and tilt of the valley floor of this magnitude would cause 1) waters of GSL to move east and 2) a rise in the water table in low areas near the fault. These effects could vary depending on the surface elevation of the lake at the time and the amount of displacement along the fault.

Earthquakes could also cause movement along the numerous faults within and adjacent to the lake. Such movement could cause damage to highways, railroads, dikes, and other existing or proposed structures in and around the lake.

2.9.7.4 GROUND FAILURE IN SENSITIVE CLAYS

Under some conditions, clays can become unstable by leaching salts. These are referred to as sensitive clays. During earthquakes, they can lose their strength, resulting in ground failures similar to those occurring during liquefaction.

2.9.7.5 SHALLOW GROUNDWATER

Groundwater is, by definition, water beneath the surface of the ground, which fills fractures and pore spaces in rocks and the voids between grains in unconsolidated sediments. Groundwater is considered shallow when it occurs at depths less than approximately 10 feet. Lowe (1990a and 1990b) suggests that groundwater adjacent to the lake, at depths less than 10 feet, may cause flooding of basements and other related problems. In the GSL area, the water table, or the top of saturated soil, fluctuates in response to the level of the lake. During times of high lake levels, the water table is higher than during times of low lake levels, and larger areas around the lake will be affected.

2.9.7.6 PROBLEM SOIL AND ROCK

Soil and rock with characteristics that make them susceptible to volumetric change, collapse, subsidence, or other engineering-geologic problems are classified as problem soil and rock (Mulvey 1992). Geologic parent material, climate, and depositional processes largely determine the type and extent of problem soil and rock. Problem soil and rock can be costly factors in construction and land development if they are not recognized and taken into consideration in the planning process (Shelton and Prouty 1979). Principal types of problem soil and rock may include 1) expansive soil and rock, 2) collapsible (hydrocompactible) soil, 3) shallow bedrock, 4) wind-blown sand, 5) caliche, and 6) soils susceptible to piping and erosion.

2.9.7.7 WIND TIDES AND SEICHES

Sustained winds blowing across the surface of GSL push the water to the shore, dike, and/or causeway where it "piles up," forming what is known as a wind tide or wind setup. The height or magnitude of the setup depends on the speed, direction, fetch, and water depth at that point and duration of the wind. Wind setup exceeding 2 feet is not uncommon and can cause localized flooding and subsequent damage. The combined effects of wind setup and high waves (wave runup) can produce adverse impacts to elevations 5–7 feet above the static lake level and locally even higher. As these winds cease or diminish, the water begins to oscillate back and forth in the lake, similar to water sloshing from end to end in a bathtub. This movement is referred to as a seiche. The period of the oscillation, or the time it takes to move from high to low and back to high, is approximately six hours in the South Arm (Lin 1976; Lin and Wang 1978b) and shorter in the North Arm.

Earthquakes also have the potential to cause large-scale surges and seiches in the lake. During such surges and seiches, the elevated water may cause repeated, short-term flooding around the lake. The heights of earthquake-induced surges and seiches are unknown, but may well exceed the heights of wind tides and seiches. A 1909 earthquake is reported to have generated a surge that sent water over the Northern Railroad Causeway and the pier at Saltair. The extent of flood damage in an earthquake affecting the lake would depend on the lake level at the time of the event.

2.9.7.8 WINDBLOWN ICE

During the cold, winter months, fresh water from the major tributaries to the lake flows out and over the heavier saline water of the South Arm and in Bear River Bay. If this water is not mixed, it freezes and can form large sheets of ice. As the winds blow, these sheets of ice are pushed around the lake and can destroy stationary objects (e.g., lake monitoring structures and power transmission poles) within the lake and at its margins.

2.9.7.9 LAKE LEVEL EFFECTS

The geologic hazards affected by lake level would include wind tides and seiches. As the lake level rises, the height of the wave runup and seiches increases. Should the elevation of the lake surge 5–7 feet when the lake is approximately 4,210 feet, flooding and infrastructure damage would occur in low-lying residential areas, I-80, and other roadways, causeways, marinas, and the airport.

2.9.7.10 GEOLOGIC-HAZARD PLANNING

The 1995 GSL CMP process recommends that all five counties on the lake establish ordinances requiring that all structures built in and around the lake be designed for additional short-term lake levels due to wind tides (and subsequent seiches), earthquake-induced seiches, and waves. Wind tides can raise the lake an additional 2–4 feet. Structures should be built to withstand windblown ice in the southern part of the lake.

The 1995 plan recommends that site-specific investigations be conducted, prior to development of proposed structures in and near the lake, to identify sensitive clays, soils susceptible to liquefaction, areas susceptible to earthquake-induced flooding, and shallow groundwater. UGS recommends retaining a geotechnical engineering firm to perform a geotechnical/geologic-hazard investigation for all development, including that within and/or adjacent to GSL. The potential for geologic hazards should be addressed in these investigations and should establish the type and likelihood of each geologic hazard and recommend mitigation measures to reduce the hazards (FFSL 1999).

Geologic-hazard investigation reports, prepared by a consultant licensed to practice geology in Utah, should address all geologic hazards present in the GSL area in accordance with UGS guidelines (UGS 2010). Although the *Guidelines for Evaluating Surface-fault-rupture Hazards in Utah* (Christenson et al. 2003) do not specifically address underwater faults, they do provide valuable information on assessing surface-fault-rupture hazards. These guidelines should be reviewed by the local government permitting authority, and steps should be taken by local governments to ensure that recommended mitigation measures are implemented. UGS has developed a set of report guidelines and a review checklist for Utah schools on the UGS website (UGS 2010). Although this document focuses on schools, it is also applicable to other types of development projects.

2.9.7.11 GEOLOGIC-HAZARD INFORMATION

The UGS Geologic Hazards Program has developed a website for consultants and design professionals containing recommended guidelines; published UGS geologic hazard maps, reports, site-specific studies, geologic maps, and hydrogeology publications; historical aerial photography; important external publications in the literature; and links to external websites (UGS 2011a). Although this website should be used during geologic-hazard investigations as a source of current, published information on Utah's geologic hazards, it is not a complete source for all geologic-hazard information. As a result, a thorough literature search and review should be performed.

UGS Circular 106 contains geologic-hazard maps for a portion of the east shore of GSL (UGS 2011a). These maps include surface-fault-rupture, liquefaction, landslide and debris-flow hazards, and indicate special study zones where specialized geologic hazard investigations are necessary. Geologic hazard maps of much of the remainder of GSL have not been produced, and detailed, site-specific geotechnical/geologic hazard investigations will be necessary.

2.10 Visual Resource Management

GSL is a unique and remarkable visual landscape. The lake's aesthetic value is a resource that should be managed much like the lake's other tangible resources such as biology and minerals. As part of the FFSL's multiple-use mandate, visual resources should be balanced with development and other multiple-use management objectives. However, assessing and specifically managing the scenic value of GSL has yet to be implemented.

Within the last decade, the management of scenic values on public land around the country has become more structured. The BLM has developed a Visual Resource Management system that provides a systematic way to identify and evaluate scenic values to determine the appropriate level of management. Further, it provides a methodology for analyzing potential visual impacts and applies specific design techniques that mitigate the impacts of surface-disturbing activities (BLM 2011).

The U.S. Forest Service has developed the Scenery Management System as a means to inventory and analyze aesthetic values of National Forest Lands. The Scenery Management System allows land managers to create and maintain visual diversity and prevent unacceptable alterations of the natural landscape (U.S. Forest Service 1995).

Similar to FFSL, the BLM and the U.S. Forest Service have multiple-use mandates with regard to public land management. Future visual resource inventory and analysis of GSL could be implemented using a methodology similar to those currently used by federal land management agencies. As appropriate, the aesthetic impacts of proposed actions on the GSL should be considered.

2.10.1 Lake Level Effects

GSL's visual resources would be most impacted at low lake levels. As the lake level recedes and larger amounts of lake bed become exposed, there is a greater potential for blowing dust to obscure the views of GSL. During a wind event, the increases in dust around GSL would impact basic visual elements like form, color, and texture.

2.11 Recreation Opportunities and Sites on Great Salt Lake

Perceptions of GSL vary among local residents. Some find that the lake offers great beauty and quality recreation and that it significantly enhances the quality of their lives. Others view the lake negatively and find little value in GSL (Trentelman 2009). Out-of-state tourists often view GSL as one of the most well-known natural resources in Utah and aspire to visit the lake while visiting northern Utah. The tourism industry and local residents alike desire greater access to GSL provided in a manner that does not impair lake resources.

The demand for recreational uses of GSL's resources is expected to grow in the future. The lake's extraordinary numbers of waterbirds, magnificent sunsets and vistas, no-sink swimming, trails, wildlife, cultural and range resources, development of Antelope Island, and open space next to a growing metropolitan area all point to growing interest in visiting and recreating at GSL.

2.11.1 Recreational Opportunities on Great Salt Lake

Most of the recreation that occurs on GSL is dispersed in nature, and visitor counts are not well quantified. Common recreational activities include boating (sailing and motorboats), canoeing, kayaking, hiking, biking, wildlife viewing, camping, picnicking, OHV use, bird watching, hunting, sightseeing, swimming, and sunbathing.

2.11.1.1 BOATING

There are two public boat ramps open year-round on the South Arm: GSL Marina and Antelope Island State Park Marina. Both are managed by DSPR and offer safe mooring sites and are developed for sailboat, motorboat, and other boating (canoe or kayak) use. The GSL Marina sponsors a large number of sailing races and festivals in conjunction with the GSL Yacht Club. Motor boating is feasible but not popular due to the corrosive nature of the lake's high salinity, which demands extra care and rinsing of engines and equipment. High salinity levels also curtail fishing and water skiing and also make navigation more difficult for novice boaters.

Farmington Bay WMA, Ogden Bay WMA, Bear River Migratory Bird Refuge, Bear River Bay, and Willard Spur also have boat ramps suitable for small vessels and air boats but are generally not open to the public. Antelope Island State Park and the WMAs also provide a popular launch site for kayakers and canoeists in GSL. The North Arm does not have a public boat ramp.

2.11.1.2 NONMOTORIZED RECREATION

Antelope Island State Park has an extensive backcountry trail system for hiking, biking, and equestrian use. Other nonmotorized GSL recreation options include a 9-mile hiking and biking trail on Stansbury Island and cycling on the DWR WMAs' roads and dike systems as well as on the Bear River Migratory Bird Refuge 12-mile graveled road. The Davis County Causeway also provides bike lanes in both directions.

Beach use is dispersed along the southeast shores of GSL, depending on water levels and access. Some of the more popular locations to visit and swim are Bridger Bay Beach on the north end of Antelope Island and the beaches from Saltair to the GSL Marina.

2.11.1.3 CAMPING AND PICKNICKING

Antelope Island State Park provides individual and group camping sites. There are also individual and group camping sites at Willard Bay State Park, and dispersed camping at several WMAs, in the area of Monument Point, and on BLM lands on Stansbury Island. Picnicking sites are available at most recreation locations across GSL.

2.11.1.4 OFF-HIGHWAY VEHICLES

Many of the public roads along the north and west sides of GSL are open to OHV use, including areas near Monument Point. Sovereign lands surrounding GSL are not open to recreational use by OHVs, although FFSL has noted that dispersed, illegal OHV use does occur in GSL where and when access and water levels permits (Zarekarizi 2011).

2.11.1.5 BIRD WATCHING AND WILDLIFE VIEWING

GSL is one of the most renowned bird watching areas in the United States. Nearly all recreation areas along GSL have been identified for outstanding bird watching opportunities. In addition, GSL supports small mammals and big game; in particular, Antelope Island State Park supports the third largest publicly owned bison (*Bison bison*) herd in the nation, as well as pronghorn, bighorn sheep (*Ovis canadensis*), and mule deer (*Odocoileus hemionus*). Based on the USFWS national survey of fishing, hunting, and wildlife-associated recreation, over 877,000 people participated in wildlife viewing in Utah for a total of 3.9 million viewing days in 2006 (USFWS 2008). Approximately 639,000 of those participants were bird watchers, and approximately half of bird watchers specifically observed waterfowl and other waterbirds. GSL bird watching events and programs, such as the GSL Bird Festival, Watchable Wildlife Program, Utah Bald Eagle Day, and Tundra Swan Day, have received steady attendance ranging from several hundred to several thousand participants over the past decade (Walters 2011)

2.11.1.6 HUNTING

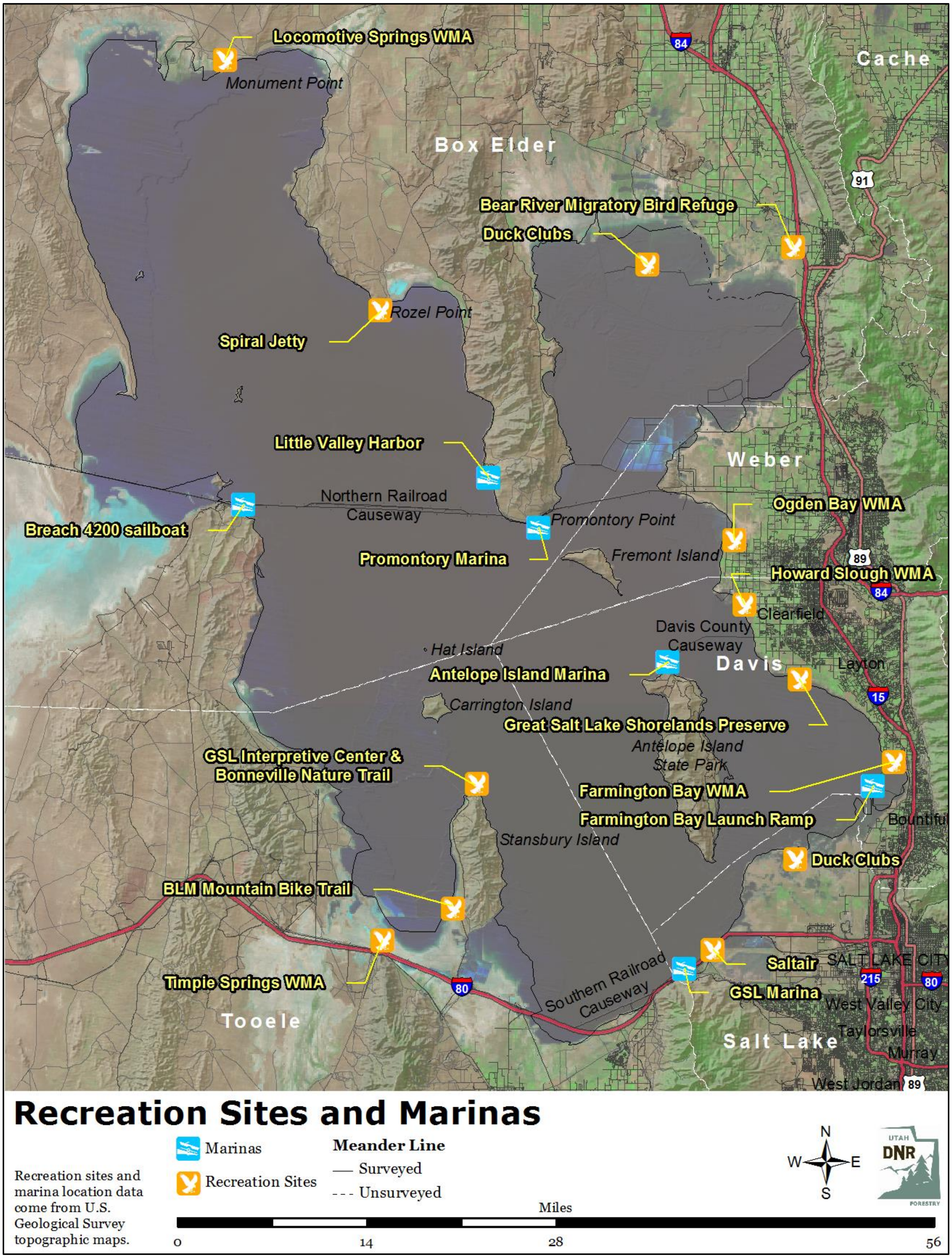
GSL provides an important source of waterfowl hunting in Utah. The DWR reported an estimated 194,557 waterfowl hunting trips in Utah in 2009. Of this total, approximately 55% of all hunter trips in Utah came from the GSL area.

2.11.1.7 SIGHTSEEING (AUTO TOURS)

Antelope Island State Park and the Davis County Causeway combined offer a 36-mile round-trip auto tour, and the Bear River Migratory Bird Refuge has a 12-mile round-trip auto tour. The Monument Point area and surrounding lands also have miles of remote dirt roads for auto touring, although the lack of a public thoroughfare between Lakeside and Hogup Ridge on the lake’s western shore precludes circumnavigation of the lake by automobile.

2.11.2 Recreation Sites on Great Salt Lake

Popular recreation sites and opportunities are shown in Map 2.14. A brief description of the sites is provided below.



Map 2.14. Recreation sites and marinas on Great Salt Lake.

2.11.2.1 ANTELOPE ISLAND

As Utah's largest state park, Antelope Island's annual visitation (approximately 280,000 in 2010) has remained steady over the past decade (DSPR 2011). Recreational opportunities on the island include scenic drives with bicycle lanes, a backcountry trail system, campgrounds and picnic areas, wildlife viewing, Garr Ranch (a historic ranching home), nature trails, wayside exhibits, interpretive information and programs, a swimming beach, outdoor amphitheater, and a marina. A private concession business, food and souvenirs, a small tour boat, and guided horseback rides are located on the island. The park provides educational talks to thousands of school children per year, and the proximity to universities and significance of resources allows for a number of outside research projects. The Antelope Island State Park Marina maintains a paved boat ramp with GSL access for sailboats, kayaks, and powerboats.

2.11.2.2 DAVIS COUNTY CAUSEWAY

The Davis County Causeway is one of the most scenic drives around GSL and is an outstanding bird watching area. The bike lanes provide one of the most popular cycling tours in northern Utah. When combined with the new east side road on Antelope Island, it offers a 36-mile round-trip. Davis County has developed a trailhead parking lot for cyclists and other areas, with interpretive information on GSL.

2.11.2.3 PRIVATE DUCK CLUBS

Over 25 private duck clubs exist around GSL with more than 42,000 acres of managed wetlands for waterfowl habitat (see section 2.4 [Wetlands]). All of the clubs are used for hunting by members only, and use is regulated with bylaws. Members also use these areas for wildlife observation and nature study. Other opportunities include fishing, bird watching, walking, bicycling, ice skating, and photography.

2.11.2.4 BEAR RIVER MIGRATORY BIRD REFUGE

At 70,000 acres, Bear River Migratory Bird Refuge is considered one of the premier bird watching sites in the United States. The refuge is recognized internationally and included within GSL as a site of hemispheric importance by the Western Hemispheric Shorebird Reserve Network. The refuge is also one of the finest waterfowl hunting areas in Utah and offers a 12-mile scenic drive that is popular for driving, bird watching, and bicycling; a 0.5-mile walking trail; a visitor center with interpretive information; an air boat ramp that is open during hunting season; and expanded access during hunting season. Fishing is allowed in the Bear River channel. The Bear River Migratory Bird Refuge also offers educational tours and programs by reservation. The refuge was visited by 42,209 people in 2006, with 9,907 being waterfowl hunters. In addition, 2006 visitation included 32,000 bird watchers, 612 fishermen, and 500 others (Carver and Caudill 2007). Hunting visitation continued to increase slightly throughout the latter half of the decade, rising to 10,618 waterfowl hunting trips in 2009 (Dolling 2011).

2.11.2.5 GREAT SALT LAKE STATE MARINA

The GSL Marina is the most popular launching and mooring site on the lake. The marina is highly developed and supports approximately 320 boats that range from 21 to 40 feet in length. The marina also provides access to the lake for boaters who do not moor their vessels at the site, as well as swimming beaches, rowing teams, and picnicking. Two tour boats operate occasionally on the lake—one based at Antelope Island and the other at the GSL Marina. Visitation to the GSL Marina in 2010 was reported at approximately 240,000 (DSPR 2011).

2.11.2.6 SALTAIR/SOUTH SHORE AND LEE CREEK

The recreational complex of the South Shore Beach Area and the Saltair Resort offers access to the lake, bird watching opportunities, and scenic vistas of the islands and evening sunsets. Saltair Resort also provides interpretive information, food, souvenirs, a historic site, and special events ranging from concerts to beach festivals. This site provides the quickest and easiest access to the lake from downtown Salt Lake City. For a time, the entire South Shore Beach Area and the marina were managed by DSPR as GSL State Park. Management of the South Shore Beach Area was returned to FFSL in 1997. At that time, over 600,000 people visited GSL State Park. Updated visitation numbers are not currently available. The Lee Creek area is approximately 2 miles northeast of Saltair. This 305-acre area managed by the National Audubon Society is open to the public for wildlife viewing and nature walks.

2.11.2.7 FARMINGTON BAY WATERFOWL MANAGEMENT AREA

This 17,000-acre management area is one of the most popular waterfowl hunting areas in Utah and also is an outstanding bird watching area. In 2010, the Farmington Bay WMA received 95,691 visitors (Hansen 2011). As of 2009, approximately 30% (25,475) of visitors were waterfowl hunters, and the rest were bird watchers, student groups, or other recreationists (Dolling 2011). DWR identified March 1–August 1 as a critical wildlife production period. During the critical production period, a 1.5-mile road is opened, with an overlook and interpretive signing, and an additional 2.5 miles are opened for nonmotorized use. During the noncritical production period, another 26 miles of dikes are opened to nonmotorized use. An air boat ramp is opened from two weeks prior to hunting season through the hunting season.

2.11.2.8 OGDEN BAY WATERFOWL MANAGEMENT AREA

Ogden Bay WMA is nearly 20,000 acres and is the largest WMA in the state. In 2009, the area hosted 19,497 hunting trips during the fall waterfowl season (Dolling 2011). A portion of the area is open year-round for hosted organized group tours; appointments must be made with the area superintendent. From April 1 to September 1, the area is closed to the public to protect wildlife habitat values. During the rest of the year, some portions are open for wildlife viewing, and hunting is allowed during the prescribed seasons. There are approximately 45 miles of dikes that control water, one air boat launch that allows access to the Ogden Bay portion of GSL, and several small boat ramps that allow access to interior ponds of the management area.

2.11.2.9 HOWARD SLOUGH WATERFOWL MANAGEMENT AREA

Howard Slough WMA is located along the GSL shoreline between the south boundary of Ogden Bay WMA and the Davis County Causeway to Antelope Island. This relatively small 3,210-acre area hosted 4% (8,049) of all waterfowl hunting trips in Utah in 2009 (Dolling 2011). Like other WMAs, the area is closed to the public from April 1 to September 1 to protect wildlife habitat values. When open, the area supports hunting, bird watching, and other recreational activities. There are approximately 7.5 miles of dikes and roadways that provide pathways for access, as well as several small boat ramps that provide access to interior ponds. Limited camping is allowed after the gates open in the fall.

2.11.2.10 STANSBURY ISLAND

There are two areas on Stansbury Island that are open to the public. The south end of Stansbury Island is used for dispersed recreation, including the Bonneville Nature trail, camping, some OHV use, and chukar (*Alectoris chukar*) hunting. The BLM has developed and maintains a 9-mile trail open for nonmotorized use along the southwest corner of the island. The other publically accessible area is an interpretive site on the northwestern side of Stansbury Island developed by Tooele County and partners. It is currently managed by FFSL.

2.11.2.11 LOCOMOTIVE SPRINGS WATERFOWL MANAGEMENT AREA

Locomotive Springs WMA is an isolated wetland at the north end of GSL that provides year-round fishing, hunting, bird watching, and primitive camping on approximately 18,000 acres. Locomotive Springs received approximately 351 waterfowl hunting trips in 2009 (Dolling 2011).

2.11.2.12 TIMPIE SPRINGS WATERFOWL MANAGEMENT AREA

Timpie Springs WMA is a 1,440-acre wetland near the southwest corner of the lake. Timpie Springs supports hunting, bird watching, and general sightseeing; in 2009, the area received approximately 400 waterfowl hunters (Dolling 2011). The WMA contains approximately 3 miles of dikes and dirt roads open to walking or nonmotorized traffic.

2.11.2.13 MONUMENT POINT

Monument Point offers one of the few OHV riding opportunities close to GSL. The area, located on BLM land, also offers pedestrian access to the North Arm of the lake, a vista of the lake, and nearby interesting historic sites. BLM has worked toward developing trail opportunities in this area and has added interpretive information. However, increasing OHV use around sensitive GSL lands is a concern for management agencies. The wetlands of Salt Wells Flat (an area identified by the BLM as an Area of Critical Environmental Concern) and wetlands between Locomotive Springs and Crocodile Mountain have been impacted by the growing level of OHV use.

2.11.2.14 ROZEL POINT

Rozel Point is one of the few access points to the North Arm of the lake, through the Golden Spike National Historic Site.

The Spiral Jetty is an “earthwork sculpture” on sovereign land off Rozel Point in the North Arm of GSL. The jetty was constructed in 1970 by Robert Smithson. In the years following its creation, it received a wealth of publicity in the national press, making it a classic of modern sculpture and a point of interest by many visitors.

2.11.2.15 LAYTON WETLANDS PRESERVE

Managed by The Nature Conservancy, the GSL Shorelands Preserve protects approximately 4,500 acres of shoreline and upland habitat. There is year-round, nonmotorized access to the preserve at the Gailey Access in Layton, and Nature Conservancy staff can provide educational tours by appointment.

2.11.2.16 PROMONTORY POINT

Promontory Point offers a striking vista and is the only location that can provide access to both the South and North arms of GSL. The site is currently accessible by a public road, but the surrounding lands are almost exclusively in private ownership, thus restricting recreation opportunities.

2.11.2.17 WILLARD BAY STATE PARK

Willard Bay Reservoir is a U.S. Bureau of Reclamation project that provides water for irrigation, mineral and industrial use, flood control, recreation, and fish and wildlife purposes. It is a self-contained freshwater waterbody adjacent to GSL. The state park provides a small marina, as well as camping and picnic sites. Visitation to Willard Bay State Park in 2010 was 349,645 (DSPR 2011).

2.11.2.18 LEGACY NATURE PRESERVE AND THE LEGACY PARKWAY TRAIL

The Legacy Nature Preserve was developed as mitigation for the construction of the Legacy Parkway project to restore wetland and upland habitat. The site provides approximately 2,225 acres of wildlife habitat. There is no current public access, although a 14-mile one-way trail adjacent to the Legacy Parkway provides nonmotorized recreation, bird watching, and interpretative opportunities.

2.11.2.19 OTHER ISLANDS

Gunnison and Fremont islands also occur in GSL. Gunnison Island is a sanctuary for mainly white pelicans, but it also provides year-round habitat for a large population of California gulls. It is not available for public access. Fremont Island is privately owned and not available for public access.

2.11.3 Lake Level Effects

2.11.3.1 RECREATIONAL ACTIVITIES

Recreational activities in GSL are best supported by lake levels ranging from 4,198 to 4,204 feet in elevation; levels above or below that range will influence recreational access and opportunity.

In general, marina access to the lake is significantly reduced at 4,194 feet and effectively eliminated at 4,192 feet, thus restricting motor and sailboat access and opportunities; although canoeists and kayakers can still use the lake at these lower levels. At the opposite spectrum, higher lake levels ranging upward from 4,204 feet can result in temporary or long-term flooding of shoreline marinas and other boating-related facilities.

Nonmotorized recreation activities, as well as camping and picnicking, are unlikely to be affected at lower water levels; increased shoreline exposure could be a perceived benefit to some visitors seeking sunbathing or other beach activities. Starting at approximately 4,208 feet, wave action and flooding could damage or destroy low elevation recreational facilities, trails, or other sites. When the Davis County Causeway is overtopped at approximately 4,208 feet, access to recreation opportunities (camping, picnicking, and mountain biking) on the island would be lost.

Motorized activities, including sightseeing and OHV use, would also not be adversely affected by lower water levels, although dry shorebeds could reduce some of the aesthetic quality of tours. At lower water levels (4,194 feet or below), increased shoreline exposure could increase the risk of dispersed, unauthorized OHV use along sovereign lands in GSL. Higher water level impacts would be similar to impacts to nonmotorized recreation.

Bird watching and hunting activities can be impacted at both high and low lake levels. As discussed in section 2.4 (Wetlands), waterfowl commonly use hemi-marshes and habitats with shallowly flooded ponds with water more than 1 foot deep. At elevations below approximately 4,194 feet, lower elevation water levels decrease, potentially reducing bird populations and hunting areas in GSL. Access and navigation to hunting areas by air boats and other small vessels are also restricted at elevations below 4,194 feet. At elevations starting at approximately 4,208 feet, flooding at lower elevations wetlands may also reduce bird populations and associated hunting areas, as well as damage roads, the dike system, duck club houses, or other facilities.

2.11.3.2 RECREATIONAL SITES

Access and use of specific recreation sites can also be affected by lake levels. Impacts to the GSL Marina, Antelope Island, and the Spiral Jetty are addressed in this section. There are no anticipated lake level effects to Promontory or Monument Point, Stansbury Island, or Saltair, with the exception of potential flooding at high (4,212 feet or greater) lake levels. At a lake level elevation of 4,209 feet, road access to the Great Salt Lake Interpretive Center at the north end of Stansbury Island would be flooded. Lake level effects to the causeways are discussed in section 2.9 (Land Use) and section 2.16 (Transportation). In general, recreational site impacts to the Bear River Migratory Bird Refuge, private duck clubs, and WMAs would be as discussed above under bird watching and hunting activities. Additional lake level effects to the Bear River Migratory Bird Refuge and WMAs, as well as other identified wetland and shorebird reserves, are discussed in section 2.4 (Wetlands).

2.11.3.2.1 Great Salt Lake State Marina

The GSL Marina can operate between 4,189 and 4,212 feet; however, below 4,194 feet, user access is increasingly restricted as illustrated in the Table 2.28.

Table 2.28. *Great Salt Lake Elevation Effects on Great Salt Lake State Marina*

Lake Elevation (feet)		Effects at GSL Marina
4,208	Operable range of marina	Flooding occurs at marina.
4,200		Marina is fully functional.
4,198		Commercial brine shrimp operations begin to have problems with access.
4,196		Fixed keeled sailboats and larger draft boats can no longer use the marina.
4,194		Marina is nonaccessible to almost all boats.
4,193–4,192		Marina is dry. Nonaccessible to boats without dredging marina and 0.5-mile channel to deep water.

2.11.3.2.2 Antelope Island State Park and Marina

At 4,208 feet, wave action could breach the causeway and lower elevations of Antelope Island, restricting access to the park and/or use of lower elevation recreation sites. The marina at Antelope Island can operate between 4,208 and 4,194 feet. At 4,196 feet, fixed keeled sailboats and larger draft boats can no longer use the marina.

2.11.3.2.3 Spiral Jetty

The spiral jetty is at 4,197.8 feet and would be inundated at lake levels approximately 2 feet higher. Although access to the site would be possible at higher lake levels, the sculpture would not be visible.

2.11.3.3 LAKE LEVEL EFFECTS

There are no anticipated lake level effects to interpretive and education opportunities at GSL, other than potential for loss of interpretive facilities or other structures as a result of flooding at high lake levels.

2.12 Cultural Resources on the Margins of Great Salt Lake

Protection of cultural resources is an important consideration for planned development located on sovereign lands surrounding GSL. State law requires the protection of prehistoric and historic cultural resources and Native American human remains. This section provides a general background of known cultural resource types located around GSL and state regulations that should be considered in the management of cultural resources located on sovereign lands.

2.12.1 Prehistoric Resources

Archaeological investigations have identified numerous prehistoric occupations around the margins of GSL, spanning from the beginning of the Archaic period (8000 B.P) through the Late Prehistoric period (<650 B.P) (Aikens 1966, 1967; Bright and Loveland 1999; Fry and Dalley 1979; Schmitt et al. 1994; Shields and Dalley 1978; Simms 1999; Steward 1937). These investigations focused on the northern portion of the lake, particularly the Bear River marshes and associated tributaries. However, recent projects have provided information on occupations in the Jordan River delta area (Allison 2000; Allison et al. 1997; Cannon and Creer 2010; Colman and Colman 1998; Coltrain and Leavitt 2002; Schmitt et al. 1994). Excavated sites include the Salt Lake Airport Site (42SL230; Allison et al. 1997) and Site 42Dv2 (Cannon and Creer 2010), which represent fairly significant occupations that included structures and may indicate the earliest sedentary or semisedentary lifestyle along the margins of the lake.

In addition to occupation sites, prehistoric human burials from the margins of GSL have been identified; the greatest number of reported remains was identified along the northeastern shore of the lake (near the Bear River marshes) following a sudden rise in lake level starting in 1983 and culminating in 1987. The decline following the flooding exposed more than 60 areas where human remains were visible on the exposed ground surface (Coltrain and Leavitt 2002; Simms et al. 1991). Although exact dating of the remains was difficult, the available evidence suggests that most of them were associated with Formative (Fremont Complex) and Late Prehistoric period populations (spanning from 2100 to 650 B.P.). Most of the burials were clearly associated with larger, possibly residential, occupations (Simms et al. 1991:22–24). The burials included members of both sexes, and a range of ages from children to older adults was present (Simms et al. 1991:26, 74). Stable isotope analysis of the remains suggests that although maize was exploited and consumed by the populations, there was significant variation in the levels of maize consumption depending on sex, social status, and time period (Coltrain and Leavitt 2002). Additional human remains have been reported from 42SL197 located at the southern end of GSL, on the edge of a natural levee in the Jordan River delta. Six individuals were identified, and the burials appear to date to two separate use episodes between A.D. 570 and 1011 (Schmitt et al. 1994:76).

Overall, it appears that exploitation of the wetland margins of GSL and the Jordan River delta area was common throughout the Prehistoric period. Reported sites range in age from the Archaic period through the Late Prehistoric period. The greatest intensity of occupation, if reported archaeological sites provide proxy data, appears to have been from 2100 B.P. to 650 B.P., with a variety of occupation types represented.

2.12.2 Historic Resources

Historically, the area around GSL attracted a diverse group of surveyors, settlers, and entrepreneurs. Among the earliest of trappers to pass through the GSL area was Jedediah Smith who, in 1826 and 1827, explored the region's resources on behalf of the Smith, Jackson, and Sublette Fur Company (DeLafosse 1998). In the early 1840s, the federal government sent several surveyors to develop more accurate and comprehensive maps of the territory. Among these surveyors was John C. Frémont who, in 1843 and 1845, issued reports on the Salt Lake Valley and Wasatch Mountain Range. Frémont's reports later served as a reference for Brigham Young during the Mormon migration westward (Leonard 1999:8).

Also beginning in the early 1840s was ongoing migration westward to California. In 1841, an immigrant party led by John Bidwell and John Bartleson traveled along the northern boundary of GSL while searching for an alternate route to California. The establishment of this route to California through the Great Basin increased the number of travelers through northern Utah and through what would later become Davis County. Within a few years, five wagon parties used this route. Among these groups was the ill-fated Donner-Reed party, which passed through the area in 1846. The Donner-Reed party deviated from the well-known route through Weber Canyon, opting instead to travel through Emigration Canyon. The route through Emigration Canyon would ultimately be followed by the Mormon pioneers (Leonard 1999:2). Following the arrival of the Mormon pioneers in the Salt Lake Valley in 1847, Brigham Young dispatched exploration parties to survey and report on the viability of communities in the surrounding areas, leading to the establishment of numerous settlements in the greater Salt Lake Valley area.

The completion of a series of railroads around GSL in the 1880s increased the availability of imported goods to Salt Lake Valley residents and provided them opportunities to sell local goods to outside markets (Leonard 1999:163). In addition to consumer goods, the railroads also carried people to newly established resorts located on the eastern shores of GSL. As a result, from 1870 through the 1880s, as GSL reached its highest historical levels, investors saw great opportunity in developing the resort business along its shores (McCormick and McCormick 1996), which offered swimming, boating, food, picnicking, and other activities (Leonard 1999:295–296).

In 1875 (Leonard 1999), Simon Bamberger built a spur running from the Denver & Rio Grande Railroad on the east side of the Salt Lake Valley for a few miles to the west to where he started a "…lovely park called Lake Park, on the banks of the Great Salt Lake" (Hess 1976:379). Patrons were brought in on the train from the Salt Lake City and Ogden areas. Lake Park attracted over 50,000 visitors in its second year of operation and became the most popular of the nineteenth century Salt Lake resorts. For only a 50-cent admission fee, patrons were offered bathhouses, picnic areas, a shooting gallery, concerts, a racetrack, footraces, rental cottages, rowboats, and island cruises (Leonard 1996). In 1879, Ephraim Garn and George O. Chase developed a small bathing resort called Lake Shore, located north and west of Centerville (McCormick 1996). The Utah Central Railroad provided access to this resort with a spur branching off its mainline (Strack 1997). Business was brisk for the small resort, which operated for roughly 10 years.

Once the rail lines reached the south shores of GSL, business increased rapidly, enabling resort owners to expand their services to include hotels, steamboats, and excursions to Antelope Island (McCormick 1985). Thus, resort businesses began to thrive in this decade, and more lavish and comfortable resorts, such as Saltair, were constructed into the 1880s (Alexander 1996). Unfortunately, rapidly dropping lake levels left many of the lakeside resorts stranded by the 1890s, and numerous resorts failed.

In 1918, Morton Salt, a national manufacturer, selected Davis County for the site of one of its facilities. Within a decade, the company also purchased the locally owned Inland Salt Company.

2.12.3 Regulatory Guidelines

The management of cultural resources on state sovereign lands falls under the jurisdiction of the State Historic Preservation Office (SHPO). UTAH CODE § 9-8-404 requires state agencies and developers using state funds to take into account how their expenditures or undertakings will affect historic properties. In this case, *historic properties* refer to cultural resource sites that are listed or have been recommended eligible for the National Register of Historic Places. UTAH CODE § 9-8-404 also allows the Public Lands Policy Coordinating Office authorization to review comments made by SHPO and mediate disputes between a state agency and SHPO.

Human remains found on state lands are protected by state laws (UTAH CODE § 9-9-402; UTAH ADMIN. CODE R230-1). If human remains are found, they must be left in place; doing otherwise is a third degree felony in Utah. Should it be determined that the remains are of indigenous people, the Utah State Native American Graves Protection and Repatriation Act provides a process through which they can be repatriated and reburied.

2.12.4 Lake Level Effects

The discovery of cultural resources is greatly affected by lake levels. The highest potential for artifact discovery occurs when lake levels recede, after a rise of greater than average levels. This was the scenario following the sudden increase in lake levels from 1983 to 1987, when the largest report of remains occurred during the declining lake levels from this event (Coltrain and Leavitt 2002). SHPO should be alerted to lake level declines succeeding lake levels that reach the high zone, in order to minimize the amount of unauthorized access to cultural sites and prevent illegal extractions of artifacts.

2.13 Paleontological Resources on the Margins of Great Salt Lake

Protection of paleontological resources is a minor but important consideration for planned development located on sovereign lands surrounding GSL. State law requires the protection of paleontological resources. This section provides a general background of known resource types located around GSL and state regulations that should be considered in the management of paleontological resources on sovereign lands.

2.13.1 Paleozoic Fossils

The mountain ranges surrounding GSL are composed largely of Paleozoic rocks (mostly limestones) that contain abundant marine invertebrate fossils. Invertebrate fossils are not generally considered significant paleontological resources, but some rock units have yielded evidence of early fossil fish from localities near the lake.

2.13.2 Pleistocene Fossil Vertebrates

Ice Age fossil vertebrates have been found in Pleistocene Lake Bonneville shoreline sand and gravel deposits for over 150 years. A diverse fauna of Ice Age mammals, including mammoths, musk ox, bison, and bighorn sheep, have been described by many researchers. Although most of the deposits known to contain these fossils are at a higher elevation and outside the GSL sovereign land holdings, there is still some potential for new discoveries of Ice Age vertebrates.

2.13.3 Stromatolites

Stromatolites are among the oldest fossil evidence of life on Earth, and they dominated the shallow seas for billions of years. Still forming today, stromatolites are limited to a few locations around the world that are inhospitable to other organisms that might otherwise outcompete or consume them. These locations are typically shallow, warm, hypersaline waters such as closed-basin lakes where there is no outflow, warm springs, or restricted marine embayments. GSL is ideal for stromatolites, and is home to some of the most extensive living stromatolites on Earth (Davis 2012). Although these are technically not fossils, they grow very slowly and some may be thousands of years old. However, even if these are not considered paleontological resources, they are still a significant resource that should be protected and preserved in a similar manner to significant paleontological resources.

2.13.4 Regulatory Guidelines

The management of paleontological resources on state sovereign lands falls under the jurisdiction of the UGS. UTAH CODE § 79-3-508 requires state agencies and developers using state funds to take into account how their expenditures or undertakings will affect paleontological resources. Although the potential is low for the discovery of significant paleontological resources in the GSL sovereign land holdings, knowledge of existing resources will streamline the mitigation process in the event of new fossil discoveries.

2.14 Economic and Sociological Trends

Adjacent to Salt Lake, Davis, Weber, Box Elder and Tooele counties, GSL is of high-amenity value to local residents and visitors alike. The area has economically benefitted from the availability of mineral, brine shrimp, and salvaged and remanufactured railroad causeway wood (trestlewood). Tourism and recreation are also important contributors to the economic stability of the area; economic benefits are derived not only from direct spending on food, gas, lodging, etc., but also from sales tax generated from visitor spending. In addition to economic resources, GSL also offers a diverse landscape that is often a place of significance for families who have lived in the area for decades, an escape for residents of urban centers and local communities in the region seeking recreation opportunities, and a place that offers unique opportunities for scientific research and environmental preservation. The following discussion focuses on both economic and sociological trends that are connected to GSL, including tourism, recreation, commercial and industrial uses, law enforcement, and quality of life issues. The study area for the discussion includes the five counties surrounding the lake.

It is noted that the GSLAC-sponsored report *Economic Significance of the Great Salt Lake to the State of Utah* contains findings that are relevant to this section of the 2013 GSL CMP. In principle, FFSL supports incorporating the findings of the GSL economic report into management of the lake. Unfortunately, the findings of the GSL economic report could not be incorporated in the 2013 GSL CMP due to the timing of the economic report's release (January 2012). FFSL will consider the GSL economic report and its updates into future management plans and future management decisions.

2.14.1 Tourism

Tourism is a major component of the region's economy. Thousands of people visit GSL for a variety of reasons, including recreational and sight-seeing opportunities. As in the past, visitorship to the area continues to provide employment to local residents and generate revenue for businesses throughout the region that, in turn, provide services to visitors.

GSL is a unique tourist destination. A portion of nontraditional resources on GSL is recreational (and to some degree tourist) and includes such activities as wildlife viewing, boating, hiking, hunting, and fishing. Moreover, GSL is one of the top areas in the western United States for bird watching. Given these unsurpassed opportunities, the nontraditional resources found at GSL are important to consider and study.

Some of the bigger attractions on GSL are Antelope Island State Park, Bear River Migratory Bird Refuge, GSL Marina, and Willard Bay; each has different users. Sailing is popular at the GSL Marina; bird watching at Bear River Migratory Bird Refuge; hiking, biking, and day picnics at Antelope Island; and boating and fishing at Willard Bay. Additionally, duck hunting is extremely popular on GSL, accounting for 60%–65% of the waterfowl hunting days in the state and approximately 80% of the total ducks harvested in Utah, according to state waterfowl managers. Expenditures for these activities are substantial. In 2006, over $800 million was spent on wildlife viewing and hunting in Utah (USFWS and U.S. Census Bureau 2008; Table 2.29).

Table 2.29. *2006 Expenditures for Wildlife Viewing and Hunting in Utah*

	Hunting	Wildlife Viewing
Resident		
Trip related	$60,606,000	$45,145,000
Equipment and other	$192,040,000	$73,200,000
Nonresident		
Trip related	$10,969,000	$276,878,000
Equipment and other	$10,167,000	$169,220,000
Total	**$273,782,000**	**$564,443,000**

Source: USFWS and U.S. Census Bureau (2008).

The significance of recreation and tourism extends beyond the activities themselves, because they also translate into spending. Obtaining true amounts of spending is difficult. For direct fees or charges (e.g., the fee to use the Davis County Causeway or the fee to moor a boat at the GSL Marina), valuation is simple: number of visitor units multiplied by the fee or charge. From this point, however, valuation becomes more complex and less objective. There are existing models that provide estimates for the amount of money spent per hunter day or spent by a typical angler. Data of this kind can be found in sources such as the USFWS's National Survey of Fishing, Hunting and Wildlife-Associated Recreation for Utah (USFWS 2008), which provides proxy data for expenditures spent on such activities. However, these figures are sometimes regional estimates and therefore may not reflect the "true" amount of spending for a particular city or county. It is often argued that if one particular area is closed, resident visitors will shift their attention to another recreation area within the state. Thus, the state's aggregate spending associated with nonconsumptive use remains the same; a dollar spent at a state park is a dollar spent regardless of which state park collects the dollar.

Also, out-of-state tourism is very difficult to predict because it depends on a number of variables. Several of these variables include level of development, tourism promotion, and local amenities. Utah state park visitation data indicate that 33% of visitation to Antelope Island State Park and the old GSL State Park is from out of state. The Utah Travel Council indicates that traffic through SLCIA has grown steadily at an average of 9% per year. State and local tourism agencies and the private tourism industry continue to promote area attractions. The 2002 Olympic Games may have had a significant and lasting influence on tourism to GSL. It is safe to project a growing number of out-of-state tourists to GSL attractions, particularly to sites of national significance or easy access from the interstates. The GSL Marina is also a highly visited area with an annual visitorship of 240,000 (DSRP 2011); approximately 60% of visitors come in from out of state, and the remaining 40% from in state. Visitors use the facility for day trips and/or boating activities. The 2010 visitor survey data for Antelope Island State Park indicate that of the 280,000 annual visitors, almost 75% of visitors to Antelope Island State Park came from out of state (DSRP 2011).

Ecotourism has evolved as an important resource value in Utah and specifically around the shores of GSL. Davis County promotes GSL wetlands, birds, and Antelope Island State Park as an ecotourism resource. The GSL Bird Festival in Davis County was first held in 1999 and was considered a successful first-year event. The festival, now a multi-day event in its thirteenth year, has been growing in popularity ever since. Brigham City—the gateway to the Bear River Migratory Bird Refuge—hosts a large bird watching event each year. Ecotourism is an important management consideration as new opportunities are developed and public awareness of GSL ecotourism resources increases.

Although outside of the GSL CMP project area, the Wasatch Mountain ski resorts host millions of visitors annually. In the 2010–2011 winter season, Utah's 14 ski resorts recorded 4.2 million skier day visits (*skier day* is defined as one person visiting a ski area for all or any part of a day or night for the purpose of skiing or snowboarding) (Ski Utah 2011). Skier spending during the 2010–2011 ski season contributed $1.1 billion to the state economy (Ski Utah 2011). As noted in section 2.6.2, the lake effect plays a role (approximately 10%) in annual snow fall in the Wasatch Mountains (Steenburgh et al. 2000, 2011). Further study is needed to discern whether the lake effect snowfall has an economic impact on visitor spending.

2.14.2 Economic Values of Great Salt Lake Tourism and Recreation

2.14.2.1 TOURISM SECTORS EMPLOYMENT

With available employment opportunities as a result of tourism, counties in the study area have experienced population increases. As a result, tourism-related sectors represent a large percentage of the regional economy. Employment, annual mean wages, and output attributed to tourism-related sectors are discussed below. To determine impacts on tourism, IMPLAN (Version 3.0) was used. IMPLAN is an economic modeling tool that can create a detailed social accounting picture and a predictive multiplier model for a regional economy. Data for IMPLAN are compiled from sources such as the Bureau of Economic Analysis, Census Bureau, and the Bureau of Labor Statistics. It is important to note that economic modeling considers a regional economy, which for this project includes Box Elder, Davis, Salt Lake, Tooele, and Weber counties. Although IMPLAN provides an accurate depiction of relationships within local industries, it should be noted that these numbers include economic activities that are not solely attributed GSL; however, GSL provides substantial economic contributions within these sectors.

According to IMPLAN, industry employment for tourism-related sectors in 2008 was 22,884.73, or 2.08% of the five-county area's employment (Table 2.30). Of the five-county study area, tourism-related sectors were similar, with Salt Lake County generating the most employment at 16,481.05, or 1.50% of the regional sector total, followed by Davis County at 2,799.88 and Weber County at 2,707.05. Tooele County generated the least employment at 411.43, or 0.04% of the regional sector total, followed by Box Elder County at 485.32. Sectors included in the broader category of tourism for this analysis include food and beverage stores and drinking locales; gasoline stations; clothing, sporting goods, and general merchandise stores; lodging; travel arrangement and reservation services; and transportation (transit/ground passenger and scenic/sightseeing).

2.14.2.2 TOURISM WAGES

Although tourism-related sectors (i.e., sales and related occupations, food preparation, and serving-related occupations) provide more industry employment than the mining sector in the study area, wages for employees in these sectors are typically low. According to the Bureau of Labor, the 2010 mean annual wage for a Utah employee in the food services sector was $20,690. For personal care and services, the mean annual wage was slightly higher at $24,100 (Bureau of Labor Statistics 2011).

2.14.2.3 TOURISM SECTORS OUTPUT

Towns and cities in the study area that are located near GSL profit economically from expenditures made by visitors to the area. Visitors to the region enjoy thousands of acres of scenery and recreation opportunities. GSL is a tourist destination and is an ideal area for nature-based activities that are popular in the region, such as hiking, camping, wildlife viewing, scenic viewing, hunting, and fishing. Towns in the area benefit from visitors who book hotel rooms, eat, purchase gas, and shop.

According to IMPLAN, industry output for tourism sectors in the study area in 2008 was $1.56 billion, or 1.0% of the region's production output. Of the five-county study area, tourism sectors in Salt Lake County generated the most output at $1.16 billion, or 0.75% of the region's total production output, followed by Weber County at $171.99 million and Davis County at $168.16 million. Toole County generated the least output at $23.74 million, or 0.02% of the region's total production output, followed by Box Elder at $31.21 million.

2.14.2.4 ECONOMIC VALUATION OF RECREATION ACTIVITIES

Two important contributions to the GSL economy are bird watching and waterfowling. Economic contributions associated with bird watching were calculated as an annual value per person participating in bird watching. These per-person values are multiplied by the number of recreationist per year to get the annual contribution. Waterfowling values were calculated using a per-day expenditure average multiplied by the number of active hunting days. Estimates were obtained through contingent valuation surveys conducted by the USFWS and an independent study of waterfowling on GSL.

2.14.2.5 BIRD WATCHING

In 2008, 639,000 people participated in bird watching in Utah; approximately half (319,500) of these people viewed waterfowl and other waterbirds (USFWS 2008). Based on USFWS surveys, waterfowl viewing can be valued at $312 per person annually for resident viewers and $593 for nonresident viewers (USFWS 2008). Given the 2008 numbers for waterfowl viewing, this provides a value between $99,684,000 and $189,463,500 for the 2008 viewing year.

2.14.2.6 WATERFOWLING

In 2009, 197,557 waterfowling trips took place in Utah. Of these trips, approximately 55% or 108,656 took place in the GSL area (DWR 2009). In 2010–2011 waterfowl season, the average hunting trip was calculated as $180 per trip (day) for the public and $563 per trip (day) for club members (Duffield et al. 2011). DWR estimated that duck and goose hunters hunted approximately 210,000 days during the 2010–2011 waterfowl season. It is estimated that waterfowl hunting–related spending totaled $61.9 million ($26.5 million in direct hunting trip expenditures and $35.4 million in other hunting equipment expenditures) in the Salt Lake City area (Duffield et al. 2011). In 2010, the estimated spending related to waterfowl hunting accounted for over $97 million in total economic output, $36.8 million in total job income, and 1,600 full-time jobs in the Salt Lake City area (Duffield 2011).

2.14.2.7 LAKE LEVEL EFFECTS

Changes in lake levels could have an adverse effect on tourism of GSL because resources that area visitors seek (e.g., recreational opportunities such as boating) could be impacted. At a high lake level of 4,212 feet or more, flooding of marinas and the shoreline would occur. This would mainly affect boating activities because access would be reduced. Conversely, boating activities would also be adversely affected by low levels (4,195 feet or less) because motorized boats and most sailboats could remain stranded in the marina. As previously mentioned, visitor survey data of the GSL Marina for 2010 indicate that at least 20% of the 240,000 annual visitors used the facilities for sailboats and other watercraft activity. A reduction of a minimum of 48,000 visitors annually would result in a loss of revenue and potentially a decrease in the number of jobs needed to sustain such visitor activity.

For the average recreationist, lake levels of 4,205 feet or more would have a negative effect because there would be a loss of beach access and, subsequently, a reduction in camping and hiking opportunities. Lake levels would also impact the hunting industry. Hunting activities would be adversely affected at lake levels of 4,208 feet or more because sections of duck clubs would become inundated and inaccessible for hunters. High lake levels could also result in losses of foraging areas and waterfowl habitat. Such impacts would result in a loss of industry output for tourism sectors because there could be a reduction in visitation to the lake. This could also adversely affect tourism-related employment if activities related to tourism were minimized.

Table 2.30. *Tourism-related Sectors: Industry Employment and Adjusted Using Tourism Impact Ratios*

Industry	Box Elder County	Davis County	Salt Lake County	Tooele County	Weber County	Total
Transit and ground passenger transportation	0.46	1.31	42.38	2.08	6.74	52.97
Scenic and sightseeing transportation	3.69	29.99	111.34	1.14	8.59	154.74
Motor vehicle and parts stores	77.47	540.37	2,292.19	43.17	446.17	3,399.36
Food and beverage stores	13.56	63.70	331.94	10.23	63.96	483.39
Health and personal care stores	14.13	127.00	775.12	6.64	76.36	999.24
Gasoline stations	70.78	131.89	497.39	52.16	165.40	917.63
Clothing and clothing accessories stores	1.39	30.00	206.04	0.72	22.20	260.35
Sporting goods, hobby, book, and music stores	1.79	39.50	208.30	1.05	32.24	282.88
General merchandise stores	19.05	138.38	466.49	19.28	110.96	754.16
Miscellaneous store retailers	6.37	37.69	316.92	1.32	45.02	407.31
Travel arrangement and reservation services	0.28	3.03	203.47	0.06	4.02	210.86
Other amusement, gambling, and recreation	6.49	53.83	169.23	6.37	75.55	311.47
Hotels and motels, including casino hotels	49.12	203.69	3,933.24	78.75	455.33	4,720.13
Other accommodations	0.00	51.90	349.20	8.03	64.84	473.97
Food services and drinking places	216.64	1,305.79	6,382.19	174.85	1,100.02	9,179.49
Auto repair and maintenance (except car)	4.12	41.21	195.62	5.38	29.39	275.72
Total	**485.32**	**2,799.88**	**16,481.05**	**411.43**	**2,707.05**	**22,884.73**

Source: IMPLAN (2008).

Another impact to tourism would result at high lake levels of 4,208 feet or more, which would cause the Davis County Causeway to flood. As previously stated, there were 280,000 annual visitors to Antelope Island State Park in 2010 (DSRP 2011). Without access to the park via the causeway, there would be an overall decline in tourism, which would result in a negative impact to tourism-related output and employment sectors.

2.14.3 Research and Education

2.14.3.1 WORLD CLASS RESEARCH OPPORTUNITIES

Rapid urbanization and population growth is destroying the unusually rich record of earth history preserved in lake sediments. GSL and its environs have one of the best preserved and easily accessible earth systems histories of lake processes in the world, as well as a complete climate record extending back several thousand years. Urbanization and development within the floodplain has destroyed this record at an alarming and accelerating rate. GSL offers one of the best histories of climate change, and Utah higher-learning institutions have a great opportunity to contribute to climate change research (FFSL 1999).

2.14.3.2 GREAT SALT LAKE EDUCATIONAL RESOURCES

GSL educational resources are recognized by state universities, other educational professionals, the Natural History Museum, Utah Society for Environmental Education, Friends of GSL, the GSL Coalition, The Nature Conservancy, the National Audubon Society, and others. GSL and its environs provide an excellent field educational opportunity for Utah’s school children. The complexity and the dynamics of the lake’s hydrology, chemistry, geology, and biology provide outstanding opportunities to teach several subjects from kindergarten through high school. Service learning is a new way to teach science subjects at universities, and GSL provides many hands-on opportunities. An outdoor classroom provides an effective setting for learning. GSL is an important educational resource, and planners and managers benefit from a better understanding of the lake’s resources (FFSL 1999).

Facilities that provide interpretative and educational opportunities at GSL include the visitor center on Lady Finger Point, the Fielding Garr Ranch, Antelope Island, Stansbury Island, the South Shore, the Salt Lake Convention and Visitors Bureau, and the GSL Nature Center in Farmington Bay WMA. The GSL Shorelands Preserve, the Legacy Nature Preserve, and the Bear River Migratory Bird Refuge visitor center also provide interpretive information.

2.14.3.3 LAKE LEVEL EFFECTS

Because numerous resources ranging from biological to commercial and industrial uses would be affected by changes in lake levels, research and educational opportunities pertaining to these resources could simultaneously be affected. For example, at low levels (4,193 feet), foraging areas would be reduced because of loss of habitat for bird species that migrate to these areas to use lake marshes. Conversely, at high levels (4,208 feet), nesting bird populations typically move to higher ground, which, due to residential and commercial development, may not be available. This could result in reducing or displacing bird population in GSL, thereby affecting research opportunities for those who study bird species. Other resources of particular interest to researchers may also be affected by varying lake levels. At high levels of 4,208 or more, natural wetlands such as the Bear River Bay fringe wetlands, the east side GSL mudflats, the Antelope Island State Park, the Farmington Bay fringe wetlands, and the Gunnison Bay fringe wetlands would be flooded and inundated, thus hindering access and potentially minimizing wildlife habitat, which would affect subsequent research opportunities.

Damages caused to facilities as a result of high lake levels as well as business interruption as a result of low lake levels could minimize research and educational efforts of the mineral extraction industries. In addition, changes in salinity as a result of both high and low lake levels would have adverse effects on the brine shrimp populations, which could also affect research opportunities regarding the resource and industry.

2.14.4 Mineral Salt Extraction

Mineral production from brines is an important industry in Utah and totals approximately 4.4 million tons per year with a value of $445 million in 2009; much of that production was from GSL (value excludes magnesium metal value) (Bon and Krahulec 2010). In 2010, mineral production from GSL totaled nearly 3 million tons (UGS 2011).

Currently, there are five companies and one private individual that have active mineral extraction operations on the lake. Three of the companies produce salt from the lake: Morton Salt in Tooele County, GSL Minerals in Weber County, and Cargill Salt in Tooele County. US Magnesium, located 60 miles west of Salt Lake City, produces magnesium metal and other salable by-products. North Shore Limited Partnership, in the North Arm of GSL in Box Elder County, produces dietary supplements from GSL minerals. GSL Minerals also produces potassium sulfate and magnesium chloride. William J. Colman leases state trust property adjacent to GSL and has an easement and a minimum royalty rate for sodium chloride production with sovereign lands. However, there has been no production to date (Sullivan 2010).

Employment at each of these companies varies. According to the Utah Department of Workforce Services, US Magnesium is the largest employer at 250–499 employees for actual extraction and production and 10–19 for management and administration. This is closely followed by GSL Minerals, which has 250–499 employees. Morton Salt employs approximately 100–249 employees, and Cargill Salt employs 50–99 employees. Using these current estimates, employment within the mineral extraction industry can range from 661 to 1,369 employees. Wages for this industry are typically higher than the state average. Average annual wages for the state of Utah were $37,272 in 2010. The average annual wage for chemical manufacturing is $53,292, a 42.9% increase from the state’s average (Utah Department of Workforce Services 2010).

2.14.4.1 VALUE OF PRODUCTION

Because there are five companies on the lake harvesting various minerals, data on extraction are presented in aggregate form. Therefore, instead of reporting a unit value of the product, this section emphasizes the overall value of production of the minerals harvested. Although the dollar amounts of value of production of minerals extracted is held in confidence by FFSL, general trends can be noted. All revenue received on state sovereign lands (including rentals, royalties and fees), however, goes to a restricted account, which is appropriated through the Utah State Legislature.

Solar salt (i.e., salt produced by natural evaporation) produced from GSL represents a significant and increasing share of total domestic solar salt production. The remainder of solar salt produced in the United States is primarily from California, with some production from New Mexico. Solar salt competes in regional markets with rock salt for chemical, industrial, water-conditioning, and agricultural uses. Nationwide, the consumption of rock salt is four times that of solar salt. However, USGS data show that these markets are regional and, with respect to road salt, local. Solar salt dominates in Western markets and appears to be increasing in certain Midwestern markets for certain end uses. FFSL believes that the growth of regional solar salt markets, in which Utah producers compete, could continue to grow in the coming decades. Salt production in Utah in 2009 amounted to approximately 3.3 million tons per year, with most of that production coming from operators processing brine from the GSL (Bon and Krahulec 2010).

In 2009, magnesium metal was only produced in the United States by US Magnesium, using an electrolytic process that recovers magnesium from brines in the GSL. Production of magnesium metal in the United States declined from 1996 to 1998. Production values from 1998 to 2009 have been withheld by the UGS to avoid disclosing company proprietary data (Kelly and Matos 2010). However, 2010 plant production capacity for US Magnesium was 57,000 tons per year. Planned plant expansion to 77,000 tons per year has been delayed due to reduced demand for magnesium in end-use markets and secondary aluminum products (USGS 2010b).

World magnesium oversupply, variable prices, and changing end-use markets are primarily responsible for the decline in magnesium production over the past two decades. 1996 marked the first time in 20 years that the United States imported more magnesium than it exported, and that trend continued through 2009 (Figure 2.15). Magnesium metal is used for aluminum alloying, die casting, and automotive applications.

However, slumping demand for magnesium in automotive applications led to additional closures of magnesium diecasting capacity; vehicle production in North America for the first three quarters of 2009 was more than 40% lower than production in the comparable period of 2008 (USGS 2010b).

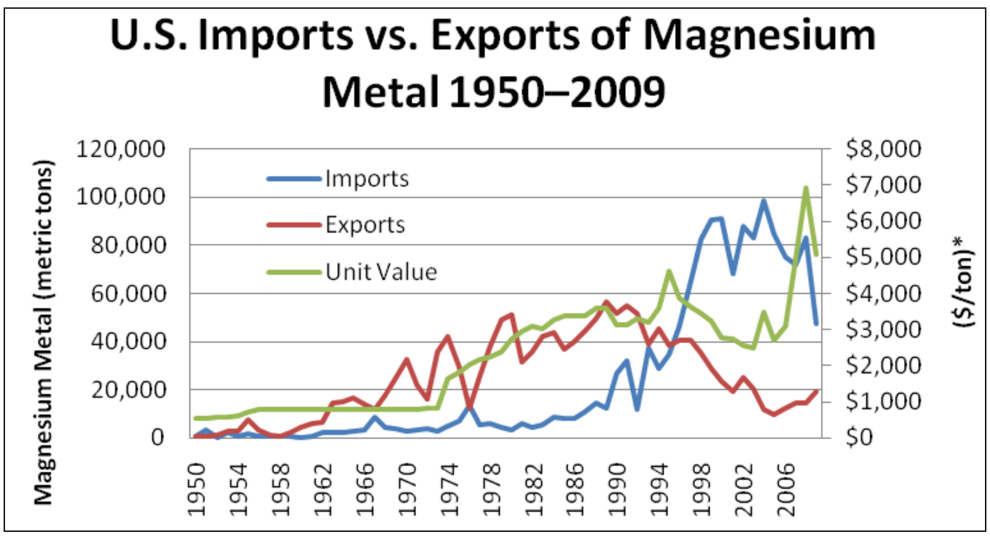


Figure 2.15. United States imports and exports of magnesium metal 1950–2009 (Kelly and Matos 2010); *not adjusted for inflation.

United States production of magnesium compounds was approximately 243,000 metric tons in 2010, up slightly from 2008 rates due to increased steel production and capacity in the United States. Magnesium chloride is used as a chemical intermediate in agricultural, chemical, construction, environmental, and industrial applications, with magnesium chloride brines used principally for road dust and ice control.

The term *potash* denotes a variety of mined and manufactured salts, all containing the element potassium in water-soluble form. Potash is generally produced in two forms: 1) potassium sulfate, also called sulfate of potash and 2) potassium chloride, also called muriate of potash. GSL is the only place where sulfate of potash is produced domestically. Sulfate of potash is a unique fertilizer because it is essentially free of chlorides, making it an essential source of potassium for chloride-sensitive crops, including fruits, nuts, and turf grasses. Sulfate of potash also acts to increase crop yields and requires less water for crops to which it is applied. Sulfate of potash produced from GSL is also certified organic. Muriate of potash is produced in Michigan, other parts of Utah, and New Mexico. Because it is a source of soluble potassium, potash is used primarily as an agricultural fertilizer. The worldwide economic downturn caused a decrease in potash production and trade. United States potash production decreased 23% from 2008 to 2009. However, the long-term potash demand is anticipated to increase steadily over time; potash markets began to recover slightly in 2010 (USGS 2010a and 2011b).

Currently, GSL Minerals is the only company that produces sulfate of potash domestically, with an estimated plant production capacity of approximately 550,000 tons of sulfate of potash in 2011 (Compass Minerals International 2011). All GSL Mineral's production of sulfate of potash is mined at GSL. Of the 550,000 tons of sulfate of potash, approximately 65% (350,000 tons) is produced from GSL in solar evaporation ponds. The remaining 35% is produced by importing potassium chloride from a supplier in Canada and converting it into sulfate of potash (Compass Minerals International 2011). However, the contract between GSL Minerals and the Canadian supplier expired in 2011. Due to economic reasons, GSL Minerals will not renew its contract and will instead expand its solar evaporation pond operations (White 2010). Planned capacity expansions at the GSL facilities would increase sulfate of potash capacity to 570,000 tons per year by 2015 (Compass Minerals International 2011).

2.14.4.2 ROYALTIES

Royalty rates for mineral leasing and extraction are paid annually to FFSL as per the royalty agreement between lessee and FFSL. In 2011, the royalty rate for magnesium was 1%–1.5% and potash was 5% (UTAH ADMIN CODE R652-20). Effective January 1, 2001, the royalty rate for sodium chloride was $0.50. The royalty rate per ton of sodium chloride is adjusted annually by the Producer Price Index for Industrial Commodities and is calculated by dividing the Producer Price Index for Industrial Commodities for the current year by the Producer Price Index for Industrial Commodities for 1997 (UTAH ADMIN CODE R652-20). The annual royalty receipts to FFSL are available by request. All royalties received by FFSL are placed into the State of Utah's Restricted Fund and must be appropriated by legislature for any use. Royalty receipts to FFSL totaled $1,759,619 in 2000 and increased steadily over time to $5,320,837 in 2009.

2.14.4.3 ECONOMIC IMPACT OF MINERAL SALT EXTRACTION

The impact of mineral salt extraction from GSL is substantial. The mineral industry not only provides employment specifically attributable to development and extraction of salts, but also provides other indirect forms of employment and income in the local economy. These effects are quantified in Table 2.31 using IMPLAN regional economic modeling.

Table 2.31. *Economic Impacts of GSL Mineral Extraction Industries*

Sector	Number of Employees	Labor Income	Value Added	Output
Nonferrous metal (except copper and aluminum)	496.4	$46,868,636	$81,956,440	$342,192,192
Wholesale trade businesses	262.2	$17,445,302	$29,988,484	$44,441,224
Food services and drinking places	127.9	$2,378,896	$3,493,834	$7,413,684
All other basic inorganic chemical manufacturing	127	$14,180,433	$21,464,086	$107,839,120
Real estate establishments	96.8	$1,681,188	$7,888,381	$10,473,596
Transport by truck	72.5	$3,836,250	$5,126,270	$10,172,681

Table 2.31. *Economic Impacts of GSL Mineral Extraction Industries*

Sector	Number of Employees	Labor Income	Value Added	Output
Management of companies and enterprises	64.5	$4,964,788	$6,652,747	$13,140,969
Employment services	57.8	$1,476,834	$1,590,604	$2,214,508
All other chemical products and preparation manufacturing	51.7	$4,720,950	$6,215,339	$28,683,238
Securities, commodity contracts, investments, and related activities	51.6	$1,521,563	$1,549,964	$6,231,542
Total	**1,408.4**	**$99,074,840**	**$165,926,149**	**$572,802,754**

Source: IMPLAN (2011).

2.14.4.3.1 Employment and Wages

These sector impacts are estimated to indicate the total employment and total output for the industries that benefit from GSL's resources. Wholesale trade businesses benefit the most from the salt industries of GSL with over 262 indirect employees and $44,441,224 in additional economic output. Food services and drinking places where the employees of these industries dine and spend create an extra 128 jobs and $7,413,684 in output. Management of companies and enterprises also gains over 64 employees and an additional $13,140,969 in economic output associated with the salt industry. Transport by truck and employment services also benefit substantially from the salt extractive industries of GSL. Total direct and indirect employment is over 1,408 with an economic output of $572,802,754 (IMPLAN 2011).

2.14.4.4 LAKE LEVEL EFFECTS

Economic impacts due to changes in lake levels would vary for each mineral production company. In general, optimal lake levels for mineral production range between 4,195 and 4,204 feet above sea level. At levels of approximately 4,210 feet or more, flooding could occur, which would force the relocation of structures used for production. Such high lake levels could also damage dikes. The cost of repairing, rebuilding, and reinforcing dike structures can incur a cost of millions of dollars in damage or capital expenditures. Additional ponding areas would also need to be created to make up for the dilution of brines at high lake levels.

As lake levels rise, the dilution of the lake brines makes it harder to produce sufficient quantities of precipitated salt and concentrated brine. For companies that extract minerals, high lake levels would prove costly because extraction would be difficult with the dilution of previously concentrated feed brines. Marginal costs would rise, providing less profit for the extractor. As these costs rise, the demand could decrease and have a negative effect on production. Changes in production for any of the mineral extraction industries at GSL would also affect employment levels and royalties paid to the state, which are based on a percentage of the total value of production.

At very low lake levels, intake canals to pumps may need to be dredged and/or extended, and the pumps may also be repositioned into deeper water to continue extracting minerals. This would result in an increase in production costs and require additional permits to maintain production activities. At lower levels, between approximately 4,188 and 4,192 feet, pumping might cease altogether, which would cause business interruption and, consequently, a loss of revenue. With regard to mineral production, the advantage of lower lake levels is that the GSL brine is more concentrated and needs less evaporation time to produce the desired brines and salt.

2.14.5 Brine Shrimp Harvesting

2.14.5.1 INDUSTRY OVERVIEW

The presence of brine shrimp in GSL is noted as early as 1900. Brine shrimp cysts are harvested from the lake's surface in the fall. The cysts are used by commercial aquaculture operations around the world. Cysts are hatched, and the young brine shrimp are used as feed for fish and shrimp for human consumption.

Brine shrimp cysts harvested from GSL provide approximately one third of the world's supply of cysts used for feeds for aquaculture. That market share diminished from prior decades because of increased harvests from remote sources in China and Russia (Leonard 2010). GSL brine shrimp cysts are known for their consistency, small nauplii (the young brine shrimp), low contamination, and quality. Most of the cysts sold (80%) are used in Thailand, China, Indonesia, and Ecuador in panaeid shrimp (Penaeidae) hatcheries. Panaeid shrimp are those cultivated for human consumption. The rest are consumed in shrimp operations in other parts of the world as well as by marine finfish, primarily in Europe, Korea, Japan, China, and Taiwan (Newman 1998). Harvesting trends from the 1993–1994 harvest season to the 2008–2009 harvest season are shown in Table 2.32, as reported by the harvest companies to DWR. Note that many variables influence the total number of pounds harvested. These variables include 1) legal harvest season rules; 2) number of harvesters; 3) shrimp populations; 4) market demand; 5) processing, selling, and inventory needs; and 6) area of the lake being harvested (FFSL 1999).

As shown in Table 2.32, the total pounds of biomass harvested varied greatly from the 1993–1994 to 2008–2009 harvest seasons, with harvest season 2008–2009 resulting in the highest pounds of biomass at 19.8 million (DWR 2011a). Harvest season 1999–2000 was the worst harvest year with a total of 2.63 million pounds harvested. However, between harvest seasons 1993–1994 and 2008–2009, the total number of pounds harvested increased by 121.6%. It is estimated that approximately 10%–15% of the recently reported harvest weight is sold, whereas the rest is moisture and raw waste (Leonard 2010).

Table 2.32. *Harvest Year and Total Pounds of Brine Shrimp Harvested*

Harvest Year	Number of Companies	Number of Certificates of Registration	Total Harvest (pounds)*
1993–1994	12	18	8,864,092
1994–1995	14	25	6,485,954
1995–1996	21	63	14,749,596
1996–1997	32	79	14,679,498
1997–1998	32	79	6,113,695
1998–1999	32	79	4,606,352
1999–2000	n/a	79	2,631,853
2000–2001	n/a	79	19,963,087
2001–2002	n/a	79	18,287,569
2002–2003	n/a	79	13,242,343
2003–2004	n/a	79	5,001,959
2004–2005	n/a	79	6,821,295
2005–2006	n/a	79	10,100,948
2006–2007	19	79	17,413,045
2007–2008	19	79	14,795,155
2008–2009	19	79	19,802,788

Source: DWR (2011a).

*Denotes the total pounds (unprocessed) of biomass harvested that year as reported to DWR. Biomass includes cysts, cyst shells, shrimp, brine fly pupal chambers, and algae.

Seventeen companies harvest brine shrimp cysts from the lake. Since 2006, 16 of them have joined to form the GSL Brine Shrimp Cooperative to protect the value of the GSL brine shrimp resource against foreign sources. Ocean Star International Inc. is not part of the cooperative. The cooperative has approximately 50–99 full-time employees, and Ocean Star International Inc. has approximately 10–19 full-time employees; therefore, the total number of full-time workers in the brine shrimp industry ranges from 60 to 118 (Utah Department of Workforce Services 2010). During harvest season, these numbers increase to almost 300 employees.

2.14.5.2 VALUE OF PRODUCTION

In all, 109,798,606 pounds of biomass were harvested from GSL between 1993 and 2009. In the 2008–2009 harvest season, 19.64 million pounds of biomass were harvested by 19 companies that hold 79 certificates of registration. Recently, the state increased the registration fee from $10,000 to $15,000 per certificates of registration per year. More than one certificate of registration can be held by a company.

Processed brine shrimp cysts are a value-added product. The industry takes the raw material removed from the lake, separates out the unprocessed cysts, and through a series of biologically driven processes, converts the raw product into eggs that hatcheries can hatch out on demand into live feed for early-stage shrimp and fish.

The market value of the finished/dry GSL cysts varies based on cyst quality (the percentage hatch rate and number of nauplii per gram), world supply of cysts, varying levels of capacity of and use by hatcheries, and other factors. Historically, values have varied dramatically from year to year based principally on the quality and yield from the raw harvest and also on global supply and demand. These and other variables created high price volatility. Recently, with improvements in processing technology and stability in the industry, prices have become slightly less volatile.

Currently, prices for finished product (processed cysts) continue to be based principally on the quality of the raw product, the yield that can be achieved through processing, the quality of the finished product, harvest quantities available from foreign sources, world hatchery capacity, end user demand for aquaculture products, and other factors. Current prices for finished product (cysts) range from $3.63 to $22.67 per pound (including packaging).

2.14.5.3 ROYALTIES

In 1997, the state enacted the Brine Shrimp Royalty Act, which imposes a royalty to be paid by the brine shrimp harvesters to compensate the state for the use of the brine shrimp eggs.

"It is the policy of the state that when its natural resources are used, a royalty should be paid to compensate the state for the use of the natural resource. The state receives royalties on minerals extracted from GSL. A market has developed for brine shrimp eggs; therefore, the state should be compensated for the use of this natural resource" (UTAH CODE § 59-23-4).

The 1997–1998 harvest season was the first year the new brine shrimp royalty was imposed. At that time, the brine shrimp royalty equaled 3.5% of the value of unprocessed brine shrimp eggs (UTAH CODE § 59-23-4). Brine shrimp harvesters paid $60,790.81 in royalties for the 1997–1998 harvest season. The Utah State Tax Commission records harvest years as beginning in February and ending in January of the following year (to coincide with the October 1–January 31 harvest season). Table 2.33 shows the amount of royalties collected from brine shrimp harvesting between harvest years 2002–2003 and 2009–2010. On average, $673,622 in royalties was generated per year between 2002 and 2010.

On February 1, 2004, the Brine Shrimp Royalty Act was amended to require the Utah State Tax Commission to assess the tax value of brine shrimp by multiplying the total pounds of unprocessed brine shrimp eggs harvested by 3.75 cents (Utah State Legislature 2004).

In 2010, the Brine Shrimp Royalty Act was amended by the State House of Representatives and the State Senate and signed by the Utah governor on March 23, 2010, to remove obsolete language. However, the tax rate per pound remains the same.

The Tax Commission annually collects the brine shrimp royalty. All revenue generated by the royalty is deposited in the Species Protection Account. These funds can then be appropriated by the legislature for actions to protect any plant or animal species identified as sensitive by the state or as threatened or endangered under the Endangered Species Act of 1973, 16 U.S.C. § 1531 et seq. (UTAH CODE § 63-34-14).

Table 2.33. *Tax Revenue from Brine Shrimp Industry 2002–2010*

	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010
Harvested (pounds)	13,242,343	5,001,959	6,821,295	10,100,948	17,413,045	14,795,155	19,802,788	19,830,451
Total tax assessed	$1,483,142	$576,676	$256,311	$378,786	$652,987	$554,819	$742,611	$743,644
Rate	3.5% of RV	3.5% of RV	$0.0375/ pound	$0.0375/ pound	$0.0375/ pound	$0.0375/ pound	$0.0375/ pound	$0.0375/ pound

Source: Utah State Tax Commission (2010).

Note: RV = Royalty Value.

2.14.5.4 ECONOMIC IMPACT OF BRINE SHRIMP HARVESTING

Brine shrimp harvesting is a major source of GSL's economic contribution. The direct and indirect effects of the brine shrimp harvesting industry provide substantial economic impacts to the economy surrounding GSL. Using IMPLAN analysis for brine shrimp harvesting, the direct and indirect economic impacts of this industry are shown in Table 2.34.

Table 2.34. *Economic Impact of GSL Brine Shrimp Industries*

Sector	Number of Employees	Labor Income	Value Added	Output
Other animal food manufacturing	118.5	$7,801,082	$13,722,290	$116,969,624
Wholesale trade businesses	59.2	$3,936,368	$6,766,620	$10,027,745
Transport by truck	24.1	$1,272,260	$1,700,084	$3,373,684
Food services and drinking places	17.0	$315,250	$463,001	$982,457
Real estate establishments	16.3	$283,454	$1,330,006	$1,765,882
Management of companies and enterprises	9.9	$760,932	$1,019,638	$2,014,061
Grain farming	7.9	$16,235	$293,320	$560,217
Offices of physicians, dentists, and other health practitioners	7.1	$421,853	$489,766	$761,251
Employment services	7.0	$178,400	$192,143	$267,510
Transport by rail	6.8	$721,262	$1,679,698	$2,846,766
Total	**273.7**	**$15,707,095**	**$27,656,566**	**$139,569,196**

Source: IMPLAN (2011).

2.14.5.4.1 Employment and Wages

Wholesale trade business is the largest sector affected by the brine shrimping industry, with indirect employment of 118.5 people and economic output of $116,969,624. Transport by truck and food services and drinking places also benefit from the brine shrimp industry by employing over 41 people and generating over $4 million in economic output. According to IMPLAN, real estate establishments, management companies, professional health care offices, employment services, and transport by rail are also beneficiaries of this industry. According to the analysis, total employment (indirect and direct) related to the brine shrimp industry is just over 273.7 people, with an aggregate economic output of $139,659,196.

2.14.5.5 ACCESS AND IMPACTS

Commercial brine shrimping is regulated by DWR and the Wildlife Board to guard against overharvesting and to ensure compliance with operational rules. By rule, the shrimping season generally begins on October 1 of each year and continues until January 31 of the following year. However, DWR may close the season early if it determines that the harvestable surplus of brine shrimp cysts has been collected. The 1998–1999 harvest season was closed early, and the 1999–2000 season was delayed. “About one-half of the most recent fourteen (14) harvest seasons have been suspended or closed early by DWR” (Leonard 2011). A sufficient number of cysts are left unharvested to leave an overwintering supply to ensure a viable brine shrimp population in GSL the following spring and to provide forage for birds. Ongoing research by DWR focuses on developing a better understanding of the life cycles of, and environmental stressors on, brine shrimp.

The conduct of commercial brine shrimping requires access to navigable harbors on the lake, an area for staging, and maintenance and storage of materials. Current access is from the public marina at Antelope Island as well as a number of privately constructed and operated harbors around the lake. Commercial access to GSL should be at dispersed strategic locations where water depth is suitable, access is reasonably available, and conflicts with other Public Trust resources are minimized. The South Arm sites determined to satisfy these criteria are Black Rock, Stansbury Island/US Magnesium dike, Lakeside, Promontory Point, and Antelope Island. The Antelope Island Marina is available for commercial uses until DSPR determines commercial use to be in significant conflict with recreational use of the marina and that adequate alternative access for brine shrimping exists.

2.14.5.6 LAKE LEVEL EFFECTS

Changes in lake levels would subsequently change salinity in GSL. Such changes in salinity could adversely impact brine shrimp population. However, it is important to recognize that there are complicated biotic and abiotic interactions that take place at similar or dissimilar lake elevations and that are influenced by factors not directly linked to lake elevation. Additionally, long-term trends, such as multi-year climatic conditions, can exert an over-arching effect on GSL, resulting in ecological conditions that vary significantly in a temporal manner, yet the elevation is essentially the same as another year. For example,

- the ecological conditions on GSL may differ substantially,
- salinity may differ,
- bidirectional flow between the North and South Arm may vary,
- nutrient loads can vary,
- algal composition and abundance can be very different, and
- the zooplankton population size and structure may vary widely even though the GSL elevation is the same as another comparable year (Bosteels 2011).

Typically, brine shrimp populations diminish with decreases in salinity. Optimal salinity levels in Gunnison Bay for brine shrimp harvesting occur at lake levels above 4,209 feet. In Gilbert Bay, optimal salinity levels occur when lake level is between 4,193 and 4,201 feet. Although lake levels could drastically affect brine shrimp populations, percentages of brine shrimp that could be harvested at varying levels are unknown. By the time salinity affects brine shrimp reproduction at low levels, predation is already an issue. At higher salinities, there is not enough oxygen to maintain the survival of the brine shrimp, which would have a significant impact on brine shrimp industries that generate revenue through the amount of brine shrimp harvested.

Salinity and lake level also affect nutrients and algal growth. In the harvest year 1997–1998, the levels of salinity in the lake allowed brine shrimp to thrive, but nutrients caused diatom blooms that starved brine shrimp, which do not consume diatoms. As a result, there was no harvest in 1999 in the South Arm. Inversely, higher levels of salinity create difficult conditions for algae to thrive, which subsequently affect brine shrimp survival. Similar to mineral extraction and production, any decreases in total brine shrimp harvested from GSL would result in a reduction of revenue generated and a decrease to royalties paid to the state.

2.14.6 Salvaged and Manufactured Wood

Salvaged and remanufactured trestlewood from GSL is another resource provided by previous construction that took place in the lake; its use has spawned its own industry. From 1902 to 1904, the Southern Pacific Company built the Lucin Cutoff railroad trestle to transport people and materials across GSL, specifically across Promontory Point. By the beginning of the 1960s, all traffic on the railroad trestle was replaced with the present-day causeway, leaving millions of feet of unused timber. In the early 1990s, Cannon Structures, Inc. acquired salvage rights to the railroad trestle and has since developed a new industry of salvaging, remanufacturing, and selling this wood (Trestlewood 2010).

2.14.6.1 LAKE LEVEL EFFECTS

At high levels (4,213 feet or more) and low levels (4,197 feet or less), it would be difficult to salvage the trestlewood due to lack of access. With high lake levels, marinas would be flooded, thus adversely affecting the ability for boats to access the railroad and haul trestlewood to the shore. At low levels, there would not be enough water for gas-powered motorboats to move safely through the lake without being stranded. Given these scenarios, Cannon Structures, Inc. would be negatively impacted economically because the ability to salvage the trestlewood would be minimized or nullified altogether.

2.14.7 Quality of Life

Following is a discussion of the social values and attitudes of various stakeholders who would be affected by changes in management of GSL. The stakeholder groups include area communities, recreation groups, resource/environmental groups, economic groups, and local governments. It should be noted that these discussions generalize from and simplify the members' actual values and attitudes. In addition, this format is not meant to imply that these groups are mutually exclusive, and examples of individuals fitting into all categories are likely to be present. For instance, recreationists may engage in motorized and nonmotorized types of recreation and may have high levels of concern about the environment. In addition, people's attitudes and interests may change over time.

The following discussion presents some general ideas on how perspectives are developed and what they are related to, though there are likely to be any number of reasons people support management alternatives or oppose them (or some variation in between). This discussion is not intended to be exhaustive; it is meant to present an overview of potential stakeholder values related to the project.

2.14.7.1 STAKEHOLDER VALUES, BELIEFS, ATTITUDES, AND SENSE OF PLACE

Because GSL represents a unique place in the northern Utah landscape, people's values, beliefs, and attitudes are shaped by each individual's sense of place of GSL. The term *sense of place* refers to how people see, understand, experience, and connect to places on the landscape (Allen et al. 2009; Farnum et al. 2005). This sense of place is bound by cultural and historical factors, allowing people from separate backgrounds to experience the same place in different ways. Individuals' sense of place cannot be easily measured because it is the product of emotions and experience (Allen et al. 2009). Four essential qualities help shape a person's sense of place: personal memory, community history, physical landscape appearance, and emotional attachment (Galliano and Loeffler 1999).

Clearly, many people, especially local residents, may be linked to GSL in multiple and overlapping ways. The nature of people's linkages strongly influences their values and attitudes toward public lands and their social and cultural relationships to the land and to other people. These relationships are much more nuanced than any numbers in a social and economic profile can convey. They involve sentiments and emotions, attachments to specific special places, and beliefs and traditions developed through contact with public lands like GSL.

Utah benefits tremendously from the proximity to several state and national parks, GSL, national forests, and public lands in general. Similar to government agencies, states traditionally have instilled an institutional culture that does not necessarily dictate a sense of place but rather views parks, national forests, and public lands as providing resources that could economically benefit the agencies, states, and respective counties where these lands are located. However, some local governments throughout Utah view the large amounts of public lands within its border as economically adverse due to the loss of revenue from property taxes.

Recently, government entities have viewed parks, national forests, and public lands as economic opportunities for private entities (through resources such as minerals), but also as recreation and tourism opportunities for the general public. Government agencies have also managed the area to serve the interest of others. For example, of the five counties in the study area, all but Weber County have developed and implemented wetland plans (Trentelman 2009). This type of management can serve the interests of those that use or monitor the lake, such as scientists and environmental groups, and preserve the sense of place and/or quality of life for other interest groups.

Residents in communities in the study area have both positive and negative perceptions of the lake, stemming from the availability of recreational opportunities and traditions associated with the lake to odors and floods from the lake. Positive perceptions were associated with the opportunities provided by the lake, such as recreational and sightseeing activities as well as economic opportunities. Many families that have lived in the area for several generations have strong connections to the lake for earning a living and traditional and subsistence uses. Residents from elsewhere visit these areas for what may be perceived as a better quality of life attributable to the rural nature of communities along the lake in the study area, as well as potential recreation opportunities such as hiking, walking, running, bird watching, waterfowl hunting, and wildlife viewing. The lake is also valued as a landmark and enhances visitors' and residents' sense of direction. Negative perceptions of the lake are due to reports of pollution, malodor, the influx of insects present caused by the lake, and floods caused by changes in the water table that have damaged homes and businesses closest to the lake (Trentelman 2009).

Economically, GSL provides resources from which private entities have been able to capitalize, which have also benefited the local, regional, and state economies. The local economic contributions of GSL resources also contribute to the quality of life of those around GSL. Thus, the revenue and employment generated from the mineral extraction/production industry and the tourist industry influence the social conditions of communities connected to GSL.

As previously mentioned, GSL also serves as an important place of recreation for residents near the lake. The GSL Marina and Antelope Island are two state parks previously mentioned that are located in GSL and provide recreational opportunities. The importance of these activities can date back to traditions within the area where many have participated in such activities as children and, as adults, are doing the same with their own children (Trentelman 2009).

According to recent research by Trentleman (2009), many residents near GSL have chosen to live there because of the area's natural features. Many of those who live near the GSL visit GSL, such as bird watchers and day visitors, are there to experience and enjoy "nature." The lake also draws a number of visitors who seek to experience the night skies and sunsets on the water (Trentelman 2009). For environmental and preservation groups, or resource-oriented groups, the primary concern is the preservation of GSL due to its unique ecosystem with distinctive habitats and species and landscapes full of scenic views.

For some of the activities available at GSL, suitable replacement sites may not exist. It is also debatable whether the state's other waterfowl hunting sites could fully absorb all the duck hunters that typically use GSL (Trentelman 2009). Therefore, GSL should be respected for its rich, diverse recreational and tourist resources. The recreation and tourist opportunities are truly a treasure for Utah's citizens and out-of-state visitors.

Even more problematic is the method of valuation used to place a price on the loss of a physical system. Rhetorically the question is posed: How should one assign a value to losing a wetland? Because physical systems rarely contribute tangible goods or services to the economy (excluding agriculture), their valuation must be measured in something other than production costs and revenues. Measures can be made in terms of the spending or expenditures associated with the recreational uses. However, this considers only one dimension of the equation. The actual loss of an area or system must be accounted for in and of itself, which is a problem encountered by natural resource economists. Although the GSL Planning Team would prefer to have estimations on the value of GSL wetlands and other subecosystems, to do so requires resources beyond our means. Therefore, it is assumed the value and the health of GSL ecosystems are paramount, and hopefully future methodologies may be developed to assist in this type of analysis.

Additional nontraditional resources stem from the nonmarket goods and services associated with GSL. This class of nontraditional resources is exemplified by the natural functions performed by GSL, such as soil formation, flood and erosion control, biological control of waste and detritus, climate regulation, and education. These functions have both qualitative and quantitative aspects. Regarding the former, the lake and its environs contribute to the quality of life along the Wasatch Front because the lake performs such functions without people having to pay for them. Additionally, people enjoy living near the lake and the physical and aesthetic amenities it offers. The lake is also a source of distinction and opportunity unsurpassed in the region. The quantitative aspect of these functions is more problematic to determine. In the event that humans had to mimic such functions, the cost to do so would be very large. Moreover, some natural functions like climate regulation could not be supplanted by human means. Wasatch Front ski areas would be hard pressed to implement snow-making equipment that could duplicate the "lake effect" on snow storms. In the absence of a rigorous, long-term research analysis to put a value on the natural services offered by GSL, it can be concluded that they are priceless.

2.14.7.2 LAKE LEVEL EFFECTS

Changes in lake levels could affect the perceived quality of life for residents and visitors to GSL alike. As previously discussed, positive perceptions of the lake have largely been a direct result of the availability of the aforementioned resources. In most respects, changes in lake levels are directly correlated with the quality of life associated with GSL. For example, areas used for ecotourism, educational research, recreation, and hunting would be adversely affected by low lake levels because both wetland habitat and wildlife areas would be reduced. Such low lake levels would result in a reduction of foraging areas and a subsequent reduction in available opportunities typically offered by the high-amenity area. Low lake levels also produce lake dust from exposed lake bed. This affects air quality and visibility, and when blown in strong lake-related winds, it can damage property (e.g., finish on painted items such as cars and items on porches). As stated in the dissertation by Trentelman (2009), the production of lake dust is a significant quality of life problem for residents close to GSL. High lake levels would also adversely affect tourism, research, and recreation opportunities because the higher lake levels would result in a loss of habitat for numerous species in GSL. Specifically, any changes in waterfowl populations as a result of a loss of foraging areas or habitat would reduce hunting opportunities.

As previously stated in section 2.11.1, recreation opportunities such as hunting, camping, hiking, and boating would be largely affected by both low and high water levels. Flooding in certain areas could affect boating opportunities as well as access to areas such as Antelope Island where recreation opportunities are abundant. A decrease in recreational resources would diminish the perceived quality of life that is typically heightened due to the availability of such resources.

Public access to GSL amenities would begin to be restricted at a level of 4,208 feet. As previously stated, the Davis County Causeway would flood if lake levels were to rise to 4,208 feet or more. Such flooding and subsequent damage would adversely affect the perceived quality of life for residents because existing negative perceptions of the lake would be further exacerbated. As a result of specific access restrictions to Antelope Island State Park due to flooding to the Davis County Causeway, there would be an overall decrease from the typical high number of visitors, which would result in a reduction in revenue generated from visitorship. This could have a negative impact on the quality of life for not only those who enjoy the amenities offered by Antelope Island State Park but are unable to access such amenities, but also local and regional economies that benefit from visitorship revenue.

For those that view the lake as an economic source—area governments, communities, and specifically residents who depend on the mineral extraction, brine shrimp, and trestlewood industries at GSL for employment—changes in lake levels could dramatically alter the quality of life for many. High and low lake levels that could adversely affect operations of these industries could also result in changes to employment, revenue, and royalties. In turn, this would negatively impact local, regional, and state economies.

2.15 Agriculture

The only current agricultural use of sovereign lands is grazing. There are seven grazing permits on sovereign lands in Davis County. The permits cover 1,589 acres for a total of 239 animal unit months and are held by three landowners (two private individuals and The Nature Conservancy). Grazing use on sovereign lands has declined 15% from the 2000 plan, perhaps due to decreasing water levels and increasing urban development and population growth in the region.

Issuance of grazing permits by FFSL is usually an over-the-counter land-use authorization. In response to grazing permit applications for lands within the townships DWR is authorized to use for wildlife purposes, FFSL consults DWR for inclusion of stipulations to address DWR's concerns. This usually takes the form of seasonal restrictions and a stipulation to allow early cancellation of the permit.

2.15.1 Lake Level Effects

Current permitted grazing allotments occur below the meander line, which varies from approximately 4,212 to 4,220 feet in elevation in these locations. As the lake level increases, drainage of grazing allotments becomes problematic. Should the lake level reach 4,211 feet, the allotments would experience flooding as they did in the mid-1980s. During low lake levels, adequate irrigation to allotments could prove challenging because surface and groundwater around the lake is reduced.

2.16 Transportation

Existing transportation uses on sovereign lands include the Northern and Southern railroad causeways and portions of I-80 along the south shore of the lake. Both railroad causeways are located on easements granted by the predecessor to FFSL or the legislature for those purposes. Causeway easements vary in width between 200 and 2,900 feet and allow for construction, operation, and maintenance of structures within the easement to support and facilitate the transportation uses. The Davis County Causeway is a county road right-of-way.

The Legacy Parkway (State Road 67) is a 14-mile highway that provides an alternative to I-15 between Davis and Weber counties. The parkway is at its closest point to the lake at the northern end, when it is due east of Farmington Bay. Construction was completed on the first phase of the project from North Salt Lake to Farmington and opened to traffic on September 13, 2008. The Legacy Nature Preserve, a 2,225-acre wildlife preserve on the southeastern shore of GSL, was established as an environmental mitigation effort for the Legacy Parkway (UDOT 2011c).

In 2010, UDOT began an environmental study for the West Davis Corridor Study. In early 2011, the EIS was in the initial stages of development, including the development of alternatives for highway locations. Several of the alternatives being considered are located within a couple of miles of GSL near the northern end of Farmington Bay at an elevation of approximately 4,225 feet. A final decision on the project is expected to be announced in 2013 (UDOT 2011a).

I-80 crosses the lake bed from approximately mile post 112 to mile post 88. In the 1980s, sections of the interstate on the GSL lake bed were raised to endure higher lake level elevations. According to UDOT's *Long Range Transportation Plan 2011–2044* (2011b), there are several projects on I-80 in Toole County, south of GSL. Plans include construction of interchanges to facilitate traffic flow on the proposed local government Mid-Valley Highway in Toole County. There is also a planned widening of I-80 in Toole County to increase carrying capacity of the interstate. I-80 is located directly south of GSL and is on the lake bed; it would be very vulnerable to higher lake elevations.

2.16.1 Lake Level Effects

The lowest elevation of the Legacy Parkway is approximately 4,215 feet, which is within the meander line at this location. The parkway is buffered from the lake to the west by the preserve, which acts as a natural barrier to waves and wind tide effects when the lake reaches the high elevation threshold. However, if the lake level were to rise to 4,215 feet or more, the parkway risks inundation and possible damage of transportation structures and facilities.

Throughout the stages of the EIS for the West Davis Corridor Study, it will be necessary to evaluate the impacts and associated risks to building the corridor close to GSL. Alternatives that include portions of the highway extending further west will need to be adequately assessed for impacts to infrastructure during high lake levels.

The lowest elevation of I-80 near the proposed widening occurs at Milepost 94 at 4,214 feet. There is very little natural protection from the lake to the south in this location, and the interstate is at risk of inundation or damage during elevations at or above 4,214 feet. The proposed projects in this area will need to address potential impacts on GSL before construction commences. Lake level during construction of proposed projects could dictate the degree or magnitude of potential impacts.

2.17 Law Enforcement and Search and Rescue

Law enforcement for illegal behavior at GSL is enforced through FFSL coordination with county sheriff offices and the 2009 DSPR Boating Laws and Rules. Any law enforcement officer in the adjacent five counties is authorized under UTAH CODE § 53-13 (Peace Officer Classifications) to stop and board any vessel, whether on water or land, to enforce the law's rules and provisions.

OHV use on sovereign lands has become a management concern in recent years. With receding lake levels and a region-wide increase in OHV use, current law enforcement efforts by FFSL and state and county sheriff offices have yet to curtail the illegal activity.

The GSL Marina and Antelope Island provide 24-hour search-and-rescue service to the lake. Salt Lake City's search-and-rescue team, the Utah Air Boat Association, brine shrimpers, and DWR may also provide search-and-rescue support on an as-needed basis. Every major search-and-rescue effort follows an established five-county operational preplan and action plan for the lake, which are designed to coordinate search-and-rescue activities in a timely and professional manner with all five counties and FFSL. In 2011, the preplan and action plan were undergoing revisions and presented before county commissioners for review and comment.

The GSL Marina receives several hundred search-and-rescue calls per year due to a combination of high salinity, low water temperatures, rapid water level changes (from storm surges), presence of a living reef (bioherm), and the overall size of the lake—all of which can produce unpredictable and dangerous boating conditions for nonexperienced boaters. Response time to most search-and-rescue requests is usually 30 minutes or less, depending on the time of day, marina access, location of emergency, and staff availability. Response time to outlying areas, such as the Bear River Bay or the North Arm, can take up to several hours, however, because boats must be towed to other locations and launched. Higher water density in the North Arm or emergencies requiring search-and-rescue passage through bioherms (large deposits of calcium carbonate that form large rock or reef-like formations in the bottom of the lake) also increase response time. Map 2.14 shows the location of existing marinas potentially available for use by search and rescue in GSL.

2.17.1 Lake Level Effects

At low lake levels (4,194 feet and below), illegal use of OHVs on the lake bed becomes a law enforcement issue. Despite the fact the use of all-terrain vehicles is not allowed on sovereign lands, OHV use increases as the dry lake bed exposes a perceived increase in lands available for off-road use.

As lake levels rise or fall below normal lake thresholds of 4,918–4,204 feet, opportunities to mount search-and-rescue operations decrease. Although higher lake levels are not usually a concern, at 4,210 feet, the GSL Marina would start to flood; significant wave action could cause temporary flooding at lower water levels (approximately 4,204 feet). Additionally, at low water levels (below 4,918 feet), portions of the bioherm would be exposed or would be close to the lake's surface, creating additional navigational hazards along the eastern edge of the lake. At 4,192 feet, rescue boats would not be able to access the lake using the marina and at 4,189 feet, all search-and-rescue operations would cease (Shear 2011).

Other potential search-and-rescue marinas would suffer from similar issues at low lake levels. At elevations below 4,194 feet, most marinas indentified in Map 2.14 are either nonviable for rescue vehicles or would result in boat impact to shallow shelves/bioherms or potential grounding outside the marinas.

Sanders and Promontory marinas would be viable down to 4,192 feet, but Sanders does not have a launch ramp at this time, and Promontory is subject to large wave exposure and would require frequent dredging.

Past experience (GSL Marina 2011) suggests that the number of rescue calls significantly increases below 4,198 feet. Typical rates for mid-summer boat assists are four to five at moderate to high water levels; during recent low-water years, the GSL Marina reported that rates have increased to 20–25 assists during the same time period.

CHAPTER 3 MANAGEMENT STRATEGIES

3.1 Introduction

This chapter focuses on management strategies that FFSL will implement to meet the needs of GSL resources described in Chapter 2 of this plan. The management strategies will be integrated as necessary and appropriate to meet resource issue objectives and to achieve multiple GSL resource benefits, including management of the lake's resources at a variety of lake levels. The strategies focus on management actions that are within FFSL's jurisdiction. In instances where FFSL does not have direct management authority over a particular resource, FFSL will endeavor to coordinate with and support agencies that do have management and/or permitting jurisdiction over the resource in order to achieve the resource issues objectives. The management strategies allow numerous opportunities for coordination with respect to GSL resources, a fundamental responsibility of FFSL according to UTAH CODE § 65A-10-8. Collectively, the following management strategies are designed to facilitate FFSL's management of GSL and its resources under multiple-use, sustained-yield principles, as stated in UTAH CODE § 65A-2-1.

The management strategies are organized by resource and follow in the same order as they appear in Chapter 2 (Current Conditions). Each management strategy is organized in a table that concentrates a large amount of information into a concise and user-friendly format. An explanation of each of the sections within the management strategies tables is provided below.

3.2 Resource Issue

Throughout the 2013 GSL CMP planning process, numerous issues regarding each GSL resource were raised during the public comment periods, stakeholder meetings, and GSL CMP Planning Team meetings. Relevant issues from the 2000 GSL CMP were also carried forward during this process. Within each resource, the numerous issues were distilled down into a few substantive resource issues. Most of the resource issues raised overlap with other resource issues. As a result, obtaining the objective for one resource issue may require management actions for different resources. The most critical of these interlinkages has been captured in the management strategies of both resources. The unique objectives and management strategies that follow each issue were developed to resolve, clarify, alleviate, or improve the specific GSL resource issue.

3.3 Objective

Each objective states the desired outcome or future condition for the GSL resource issue. The objectives reflect the intention of FFSL, which is to protect and sustain the trust resources while providing for their use. Where sustainability of a particular resource is highlighted as an objective, *sustainable* is defined as harvesting or using a resource so that it is not permanently depleted or damaged. Further defining what sustainability means for GSL will be an ongoing process that could outline thresholds, targets, and/or standards.

3.4 Agency Involvement

Effective coordination and communication with government agencies regarding GSL resources is vital to ensuring the health and long-term stability of the GSL ecosystem. Coordination between FFSL and other agencies will vary in timing and intensity based on the resource issue at hand. For the purposes of developing the GSL CMP management strategies, the government agencies involved fall into three different categories depending on their participation in each unique resource issue:

1. Management Agency: A management agency is directly responsible for the management of a particular GSL resource. As mandated through Utah Code, administrative rule, or agency objectives, the agency is responsible for on-the-ground management and/or monitoring. In some instances, the title *Management Entities* is used because Union Pacific Railroad (Union Pacific), a private company, is directly responsible for the management of the Northern Railroad Causeway.

2. Permitting Agency: A permitting agency is responsible for authorizing GSL resource-related permits. The agency has the potential to impact the resource via permit authorizations including mitigation. The agency is responsible for monitoring permit compliance.

3. Intersecting Agency: An intersecting agency is an agency that does not have direct responsibility for managing a particular resource or permitting activities on the lake but is tangentially related. The decisions of these agencies may directly or indirectly impact a particular GSL resource. FFSL management decisions have the ability to impact resources managed, influenced, and/or researched by intersecting agencies. These agencies have the tools, data, and information that could be used by FSSL to make well-informed management decisions. Intersecting agencies may be responsible for research and/or monitoring at a broad scale.

By identifying which agency (or agencies) has management, permitting, or other responsibility for a particular GSL resource, FFSL can ensure that they are coordinating with the appropriate agency to efficiently address resource concerns. It is important to note that although adjacent private land owners, businesses, special interest groups, and local universities are not listed as responsible parties within each resource issue, FFSL is interested and available to discuss resource-specific matters with concerned entities.

Throughout the Management Strategies section, terms such as *participate*, *coordinate*, *support*, and *promote* occur often. These terms are used to highlight FFSL's responsibility to coordinate activities of various UDNR revisions under UTAH CODE § 65A-10-8. They are used to promote FFSL's involvement with the diverse range of GSL resources within sovereign land boundaries. Further, FFSL is interested in supporting other agencies and being involved in projects and resource issues that impact (or have the potential to impact) the GSL ecosystem. The levels to which FFSL will coordinate, support, participate, and promote depend on the project or resource issue. For example, a right-of-entry permit to host a photography event on GSL would require less communication between agencies than would an easement to place a new dike in Gilbert Bay. Ultimately, FFSL is optimistic that participation and communication between agencies and entities throughout the stages of project planning or while addressing resource concerns will lead to beneficial outcomes for GSL resources.

3.5 Lake Level–specific Management Strategies

FFSL recognizes that the level of GSL fluctuates naturally and that no agency has the authority or ability to maintain the lake at a constant level. Rather, FFSL has identified lake level–specific management strategies to mitigate impacts to GSL resources when the lake is very high or very low. The strategies are intended to provide guidance for FFSL as the lake levels fluctuate. Each resource issue has a lake level management strategy section. FFSL will be guided by the lake level–specific strategies when lake level elevation is within the following three zones:

- High: 4,205.0–4,213.0 feet or more
- Medium: 4,198.0–4,204.9 feet

- Low: 4,188.0–4,197.9 feet or less

In some instances, a transition zone management action is also defined. As highlighted in the GSL Lake Level Matrix, the transition zones are within the high (4,205–4,208 feet) and low (4,197–4,195 feet) zones. Within each transition zone, management strategies are provided that will allow FFSL to prepare for lake level elevations that are trending upward or downward and minimize the possibility of negative impacts to the resource.

3.6 Management Common to All Lake Levels

The management strategy tables (Tables 3.1–3.16) focus on management actions that FFSL may implement at any lake level. These management actions are not lake level specific. However, as part of a management strategy, FFSL may ask that an applicant consider impacts of a proposed project at high, medium, and low lake levels.

Table 3.1. *Ecosystem*

Resource Issue: Health and sustainability of GSL		
Objective: Understand the components and linkages that define a sustainable GSL ecosystem.		
Management Agency: DAQ, DSPR, DWR, DWRi, DWQ, FFSL		
Permitting Agency: DAQ, DOGM, DWQ, FFSL, USACE		
Intersecting Agencies: DWRe, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Gather research to understand how high lake levels impact short- and long-term health and sustainability.	Gather research to understand how medium lake levels impact short- and long-term health and sustainability.	Gather research to understand how low lake levels impact short- and long-term health and sustainability.
Management common to all lake levels: • Support agency management and permitting actions that strive to attain key ecological targets/benchmarks developed in future peer-reviewed research. Support research by and coordinate efforts with all agencies listed above to better understand the minimum lake level required to support the GSL ecosystem. • Identify constraints and opportunities to achieve ecological targets and/or benchmarks established in future peer reviewed research. • Identify and support research that further defines GSL ecological condition.		

Table 3.1. *Ecosystem*

Resource Issue: Multiple-use, sustained yield		
Objective: Protect and sustain GSL resources while providing for multiple uses.		
Management Agency: DSPR, DWR, DWQ, FFSL, SHPO, USFWS		
Permitting Agency: DAQ, DOGM, DWRi, FFSL, USACE		
Intersecting Agencies: DWRe, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Together with all agencies listed above, consider how a proposed project would impact GSL resources at high lake levels.	Together with all agencies listed above, consider how a proposed project would impact GSL resources at medium lake levels.	Together with all the agencies listed above, consider how a proposed project would impact GSL resources at low lake levels.
Management common to all lake levels: • Request site-specific impact analyses, as deemed appropriate by the FFSL Division Director, for a proposed project. Site-specific analyses required by other permitting agencies may provide FFSL with an adequate level of project-specific analysis. • Consider the range of ecosystem effects resulting from a proposed project (including cumulative effects) through consultation with all management and intersecting agencies listed above. • Consider and evaluate the cumulative impacts of past, present, and reasonably foreseeable future projects on the GSL ecosystem through consultation with all agencies listed above. • When appropriate, upon receipt of a proposed project, identify mitigation efforts in cooperation with all management and intersecting agencies listed above to reduce impacts to and/or benefit the GSL ecosystem. • Coordinate with DWQ to promote compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).		

Table 3.2. *Water*

Resource Issue: Fluctuating lake levels			
Objective: Manage at extremely high and low lake levels to reduce impacts to ecosystems, industry, and infrastructure**.**			
Management Agency: FFSL			
Permitting Agency: DWRi, FFSL			
Intersecting Agencies: DWR, DWRe, local cities and counties, DSPR			
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Transition (4,197–4,195)	Low (4,188–4,197 feet or less)
Support DWRe pumping activities when the lake reaches 4,208 feet to mitigate impacts to GSL resources.	Initiate coordination with DWRe and legislature to mitigate impacts to GSL resources through pumping if lake is trending upward.	–	–
Coordinate with industry to monitor and maintain breach near Strong's Knob to facilitate pumping.	Coordinate with industry to remove/breach dikes near Strong's Knob to facilitate pumping if lake is trending upward.	–	–
–	–	Notify new lease holders that operations may need to be suspended if the lake is trending down and reaches 4,193* feet in October. Requires coordination with DWRi and USACE on adaptive management strategies.	New leases subject to suspended operation when the lake is trending down and reaches 4,193* feet in October. *Note*: existing operators may not be subject to this management strategy. New leases and permits† may not be authorized if the lake is at 4,193 feet or less (UTAH CODE 65A-6-5[1])
Management common to all lake levels: • Include a term in new and renewal leases stating that operations may be suspended or modified if the lake level reaches 4,193 feet on October 15.			

* Upon reviewing the GSL Lake Level Matrix and determining the numerous amounts of GSL resources that would be negatively impacted once the lake reaches 4,193 feet, this threshold has been determined to be an acceptable level at which new mineral extraction operations would cease pumping activities. GSL resources begin to be adversely impacted at a range of low lake levels, but by the time GSL reaches 4,193 feet, nearly all of the resources have begun to be impaired. For example, all islands would be accessible by land (leaving nesting birds more vulnerable to predation and increasing the risk of trespassing); fringe and impounded wetlands would be drying up and vulnerable to *Phragmites* intrusion; and habitat for open water, shoreline, and island colonial nesters would decrease. Further, recreation access and opportunities would be minimized, search-and-rescue efforts would become more challenging, and several existing mineral extraction operations would be compromised. As stated in section 2.3.1.4, the annual low lake level occurs between September and October. Thus, should the elevation only reach 4,193 feet or less on October 15, new mineral extraction operations would be required to temporarily cease or modify operations until the lake reaches 4,194 feet or June 15, whichever is later.

† *A new lease or permit* is defined as one that is issued by FFSL subsequent to the Record of Decision adopting this plan. Minor modifications to permits or leases for maintenance or site improvements would require only an amendment to the existing permit or lease and would not be considered a new lease or permit. The determination of whether a modification is minor would be made at FFSL Director's discretion. Renewals of expiring leases will be considered new leases.

Table 3.2. *Water*

Resource Issue: Water Quality		
Objective: Consider water quality in all management actions.		
Management Agency: DWQ		
Permitting Agencies: DWQ, FFSL		
Intersecting Agencies: DWR, EPA, USACE, USFWS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Participate with DWQ to research water quality implications of high lake levels.	Participate with DWQ to research water quality implications of medium lake levels.	Participate with DWQ to research water quality implications of low lake levels.

Management common to all lake levels:

- When considering new permits or permit renewals, coordinate leasing with DWQ-required permits (UPES, general, stormwater, and the associated antidegradation review) where applicable, including research on negative water quality impacts associated with actions.
- Support DWQ to establish numeric criteria for mercury, nutrients, and other contaminants as they are identified and as they have the potential to impact GSL recreation and aquatic life beneficial uses.
- Communicate new project proposals to DWQ to help ensure impacts do not affect compliance with the existing narrative standard and the numeric selenium standard.
- Continue to support DWQ's efforts to assess the water quality condition of the lake and track contaminants of concern.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).

Table 3.2. *Water*

Resource Issue: Salinity management and circulation between GSL bays		
Objective: Maintain existing facilities and consider other opportunities to improve connectivity between bays in a manner that supports FFSL's multiple-use, sustained yield mandate.		
Management Entity: Davis County (Davis County Causeway), Union Pacific (Northern Railroad Causeway)		
Permitting Agencies: FFSL, USACE		
Intersecting Agencies: DWR, DWRe, DWQ, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	–

Management common to all lake levels:

- Support efforts to improve circulation between bays in a manner that supports food webs dependent on brine flies and brine shrimp, brine shrimp cysts, and current mineral extraction.
- Understand the hydrologic effects of the Northern Railroad Causeway culverts and how proposed modifications to the causeway would impact salinity in the North and South arms.
- Promote maintenance of structures to ensure bidirectional flow in Northern Railroad Causeway culverts.
- Enforce agreement with Union Pacific to maintain or increase circulation through culverts or other structures.
- Together with USACE, consider proposals to increase circulation in the lake in a manner that supports FFSL's multiple-use, sustained yield mandate.
- Continue and expand GSL salt cycle research by DWRe, UGS, and USGS, including efforts to quantify volume of salt and other minerals within various parts of the lake at different lake levels (e.g., quantify volume of precipitated salt and other minerals in the North Arm, quantify volume of salt and other minerals in solution in various arms of GSL, quantify volume of salts retained in evaporation ponds, etc.).
- Support research by DWR, UGS, DWRe, and USGS on the role of lake circulation on the occurrence of the DBL, brine shrimp populations, bioherms, and water quality at varying lake levels.
- Coordinate with Davis County to help ensure safe operation and good maintenance of the Davis County Causeway.
- Continue to support DWQ's efforts to assess the water quality condition of the lake and track contaminants of concern.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).

Table 3.3. *Wetlands*

Resource Issue: Wetland water quality

Objective: Maintain GSL water quality to help ensure wetland health and beneficial uses.

Management Agencies: DWQ

Permitting Agencies: FFSL, USACE

Intersecting Agencies: BLM, DSPR, DWR

High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Participate with DWR and DWQ to research wetland water quality implications of high lake levels.	Participate with DWR and DWQ to research wetland water quality implications of medium lake levels.	Participate with DWR and DWQ to research wetland water quality implications of low lake levels.

Management common to all lake levels:

- When considering new permits or lease renewals, coordinate with USACE and DWQ to help ensure impacts do not affect compliance with applicable water quality standards.
- Coordinate with BLM, DWR, DSPR, and other land managers to discuss potential impacts to wetlands resulting from a proposed project.
- Continue to support DWQ to assess and protect the aquatic life beneficial uses of GSL wetlands.
- Coordinate with DWQ issuance of water quality certifications pursuant to Section 401 of the Federal Water Pollution Control Act and Utah Water Quality Act (UTAH ADMIN. CODE R19-5-101–124).
- Continue to support DWQ in identifying water quality standards for wetlands.

Resource Issue: Invasive plant species

Objective: Target and treat invasive weed species (especially *Phragmites*) and eradicate colonizing invasive species in GSL wetlands.

Management Agency: FFSL, DWR, and local cities and counties

Permitting Agency: DAQ

Intersecting Agencies: DSPR, USFWS

High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Identify current concentrations and vectors of invasive weed spread.	Identify and treat priority concentrations of invasive weeds.	Identify and treat priority concentrations of invasive weeds.

Management common to all lake levels:

- Identify concentrations and dispersal vectors for *Phragmites* during receding lake levels.
- Coordinate with DWR, USFWS, local cities and counties, and other landowners or managers adjacent to GSL on weed control and removal programs.
- Develop annual weed management objectives and facilitate their implementation.
- Aggressively eradicate colonizing invasive plant species. Eradication efforts should focus on areas where there are high-quality and/or numerous resource values (e.g., wetlands and recreation opportunities).

Table 3.3. *Wetlands*

Resource Issue: Wetland hydrology and connectivity		
Objective: Recognize the importance and support the sustainability of a wetland mosaic**.**		
Management Agency: DWR, USFWS		
Permitting Agency: FFSL, USACE		
Intersecting Agencies: DWRi, DWQ, UDOT, UGS, local cities and counties		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Collaborate with USFWS, DWR, and other land managers to preserve a wetland mosaic around GSL through water level management within impoundments.	–	Collaborate with USFWS, DWR, and other land managers to preserve a wetland mosaic around GSL through water level management within impoundments

Management common to all lake levels:

- Coordinate with all agencies listed above regarding how proposed infrastructure would impact wetland connectivity.
- Consider implications to wetland hydrology and connectivity when evaluating permits on sovereign lands.
- Support wetland managers as they seek to achieve optimum duration and seasonality of inundation.
- Support efforts by DWR in working with DWRi to acquire water rights for specific areas of ecological importance such as wetlands and WMAs.
- Support and encourage wetland protection efforts adjacent to sovereign lands. Assist with development of a list of priority wetlands that could be protected where protection efforts would benefit the GSL ecosystem.

Resource Issue: Wetland assessment		
Objective: Understand the extent and condition of wetlands around GSL.		
Management Agency: DWR, DWQ, FFSL, USFWS		
Permitting Agency: n/a		
Intersecting Agencies: UGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Understand and document how high lake levels affect wetlands.	Understand and document how medium lake levels affect wetlands.	Understand and document how low lake levels affect wetlands.

Management common to all lake levels:

- Foster collaboration between research and management entities, including DWR, DWQ, USFWS, and UGS, on future assessment and mapping of impounded and unimpounded wetlands.
- Coordinate with research and management entities to identify wetland stressors.
- Continue to support DWQ to assess and protect the aquatic life beneficial uses of GSL wetlands.

Table 3.4. *Air Quality*

Resource Issue: Fugitive dust emissions from exposed lake beds		
Objective: Reduce fugitive dust emissions from exposed lake beds.		
Management Agencies: DAQ		
Permitting Agencies: n/a		
Intersecting Agencies: DSPR, DWR, FFSL, Utah Department of Health		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	Increase law enforcement to prevent illegal all-terrain vehicle use on mudflats.
Management common to all lake levels: • Coordinate with DSPR and DWR to manage illegal motor vehicle traffic on dirt roads around the lake and on the exposed lake beds.		
Resource Issue: Emissions from industries that use GSL resources		
Objective: Promote compliance with emissions standards for industries that use GSL resources.		
Management Agency: DAQ		
Permitting Agency: DAQ		
Intersecting Agencies: FFSL		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	–
Management common to all lake levels: • Coordinate with DAQ to evaluate emissions of all criteria pollutants associate with proposed projects and work with DAQ to identify appropriate mitigation strategies to offset major emissions. • Coordinate with DAQ to evaluate whether industries with FFSL leases meet DAQ emission standards.		

Table 3.5. *Climate*

Resource Issue: Climate change impacts on lake level and water chemistry		
Objective: Understand the impacts of climate change on GSL lake level and water chemistry.		
Management Agency: FFSL		
Permitting Agency: n/a		
Intersecting Agencies: DWR, DWRe, FFSL, DWQ, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Coordinate with intersecting agencies to document lake conditions at high lake level and current climate conditions.	Coordinate with intersecting agencies to document lake conditions at medium lake level and current climate conditions.	Coordinate with intersecting agencies to document lake conditions at low lake level and current climate conditions.
Management common to all lake levels: • Consider emerging climate change research and findings from the appropriate resources and agencies when making future management decisions. • Support research to evaluate the impacts of climate change on GSL lake level and water chemistry.		

Table 3.6. *Biology*

Resource Issue: Brine shrimp		
Objective: Recognize the importance and support a range of salinity levels that support the brine shrimp population, the associated food web, and the brine shrimp harvesting industry**.**		
Management Agencies: DWR (GSLEP)		
Permitting Agencies: DWR		
Intersecting Entities: DWQ, DWRi, FFSL, UGS, Union Pacific		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	–

Management common to all lake levels:

- Coordinate with DWRi and UGS to evaluate how authorization of water rights applications would affect salinity of GSL at a range of lake levels.
- Coordinate with DWR to evaluate impacts to brine shrimp populations at a range of lake levels when reviewing new permits/leases and permit/lease renewals.
- Identify research opportunities with DWQ, DWR, and UGS for studying the effects of lake salinity levels and water quality on brine shrimp.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).
- Continue to support DWQ's efforts to monitor contaminants of concern in both brine shrimp and the water column.
- Coordinate with DWQ to help ensure compliance with numeric criteria for pollutants of concern as they are established.
- Coordinate with the managing, permitting, and intersecting entities to maintain ideal salinity levels for brine shrimp resources.
- Continue to partner with UGS to monitor salinity levels and DWR to monitor brine shrimp populations.

Table 3.6. *Biology*

Resource Issue: Brine flies		
Objective: Recognize the importance and support the sustainability of a range of salinity levels that supports the brine fly populations and the associated food web.		
Management Agency: DWR		
Permitting Agency: n/a		
Intersecting Agencies: DSPR, DWQ, FFSL, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	Promote, in partnership with DWR, the identification of ecological baseline conditions for brine flies.	–
Management common to all lake levels: • Promote research (e.g., USGS, DWR, and DWQ) on the drivers of the brine fly trophic web, including nutrient loading effects on brine shrimp populations, brine fly populations, phytoplankton, and bioherms. • Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317). • Coordinate with DWQ to help ensure compliance with numeric criteria for pollutants of concern as they are established. • Continue to support DWQ's efforts to monitor contaminants of concern in both brine flies and the water column.		

Table 3.6. *Biology*

Resource Issue: Nesting bird populations of regional/global importance		
Objective: Recognize the importance and support the sustainability of viable populations of nesting bird species of regional/global importance and the habitats that support them**.**		
Management Agency: DWR, USFWS		
Permitting Agencies: DWR		
Intersecting Agencies: DOGM, DSPR, DWQ, FFSL, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support management actions that minimize habitat loss.	Recognize the need for a diversity of quality nesting habitats.	Support management actions that minimize habitat loss.
Coordinate with other landowners and managers to support upland wetland habitats in other nesting and foraging areas near and associated with GSL (e.g., Cutler Reservoir, Utah Lake, Fish Springs National Wildlife Refuge, and Bear River).	–	Coordinate with other landowners and managers to support upland wetland habitats in other nesting and foraging areas near and associated with GSL (e.g., Cutler Reservoir, Utah Lake, Fish Springs National Wildlife Refuge, and Bear River).

Management common to all lake levels:

- Coordinate and encourage the maintenance of a diversity of habitats and adequate food supply that support nesting birds.
- Coordinate with DOGM to help ensure compliance with permitting rules that pertain to bird habitat.
- Consider the impact of recreational activities (hunting and boating) on nesting bird populations and coordinate with DWR to minimize impacts to nesting bird habitat.
- Support inventory, monitoring, and research of nesting bird populations through DWR.
- Support DWQ and USGS research and monitoring of water quality impacts to nesting bird populations.
- Support DWQ in maintaining water quality sufficient to protect the waterfowl, shorebird, and wildlife beneficial uses for GSL.
- Minimize disturbance to nesting habitat areas by coordinating permitting and land management activities with DWR.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).
- Coordinate with DWQ to help ensure compliance with numeric criteria for pollutants of concern as they are established.

Table 3.6. *Biology*

Resource Issue: Migratory bird populations of regional/global significance		
Objective: Recognize the importance and support the sustainability of viable populations of migratory bird species of regional/global significance and the habitats that support them.		
Management Agency: DWR, USFWS		
Permitting Agency: DWR		
Intersecting Agencies: DOGM, DSPR, DWQ, FFSL, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support management actions that minimize habitat loss.	Recognize the need for a diversity of quality foraging and resting habitats.	Support management actions that minimize habitat loss.
Coordinate with other landowners and managers to support upland wetland habitats in other migratory stopover areas near and associated with GSL (e.g., Cutler Reservoir, Utah Lake, Fish Springs National Wildlife Refuge, and Bear River).	–	Coordinate with other landowners and managers to support upland wetland habitats in other migratory stopover areas near and associated with GSL (e.g., Cutler Reservoir, Utah Lake, Fish Springs National Wildlife Refuge, and Bear River).

Management common to all lake levels:

- Coordinate with DWR to encourage the maintenance of a diversity of habitats and adequate food supply that support migratory stopover, staging, and wintering birds.
- Coordinate with DOGM to help ensure compliance with permitting rules that pertain to bird habitat.
- Consider the impact of recreational activities (hunting and boating) on migratory bird populations and coordinate with DWR to minimize impacts to migratory bird habitat.
- Support DWQ in maintaining water quality sufficient to protect the waterfowl, shorebird, and wildlife beneficial uses for GSL.
- Support DWQ and USGS research and monitoring of water quality impacts to migratory bird populations.
- Support inventory, monitoring, and research of migrating bird populations through DWR.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).
- Coordinate with DWQ to help ensure compliance with numeric criteria for pollutants of concern as they are established.

Table 3.6. *Biology*

Resource Issue: Island bird rookeries		
Objective: Recognize the need to maintain the isolation of nesting and breeding habitats for bird species of regional/global importance.		
Management Agency: BLM, DSPR, DWR		
Permitting Agency: n/a		
Intersecting Entity: DOGM, FFSL, Union Pacific, USACE, USFWS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	Promote research into identifying suitable lake levels for rookeries.	Coordinate with DWR and USFWS to identify predator pathways and facilitate the protection of rookeries.
Management common to all lake levels: • Coordinate with DWR and USFWS to determine effects of permitting action on rookeries. • Coordinate with DWR to implement activities that protect rookery habitat. • Coordinate with DOGM to help ensure compliance with permitting rules that pertain to bird habitat. • Consider the impact of recreational activities (hunting and boating) on island rookeries and coordinate with DWR to minimize impacts to bird habitat.		

Table 3.7. *Minerals and Hydrocarbons*

Resource Issue: Salt balance		
Objective: Recognize and better understand the effects of mineral extraction on GSL salt balance.		
Management Agency: FFSL		
Permitting Agency: FFSL		
Intersecting Agencies: DOGM, DWRe, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Consider how salt balance would be impacted at high lake levels when issuing new leases in coordination with DOGM, DWRe, and UGS.	Consider how the salt balance would be impacted at medium lake levels when issuing new leases in coordination with DOGM, DWRe, and UGS.	Consider how the salt balance would be impacted at low lake levels when issuing new leases in coordination with DOGM, DWRe, and UGS.
Management common to all lake levels: • Promote research efforts by USGS and UGS to quantify GSL salt inflow and outflow. • Encourage research to understand sustainable levels of mineral extraction for GSL. • Encourage salt balance modeling analysis for new mineral leasing proposals, as appropriate.		

Table 3.7. *Minerals and Hydrocarbons*

Resource Issue: Future GSL mineral leasing activities

Objective: Allow for new mineral leasing activities that are consistent with the long-term sustainability of GSL, according to UTAH CODE § 65A-10-8(b).

Management Agency: FFSL

Permitting Agency: DOGM, FFSL, USACE

Intersecting Agencies: DSPR, DWQ, DWR, DWRe, DWRi

High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Transition (4,197–4,195)	Low (4,188–4,197 feet or less)
Consider new leases, upon completion of site-specific analysis.	Consider new leases, upon completion of site-specific analysis.	–	Consider new leases, upon completion of site-specific analysis.
–	–	Notify new lease holders that operations may need to be suspended or modified if the lake is trending down and reaches 4,193* feet in October.	New leases subject to suspended or modified operation when the lake is trending down and reaches 4,193* feet in October. *Note*: existing leases and permits may not be subject to this management strategy. New leases and permits† may not be authorized if the lake is at 4,193 feet or lower (UTAH CODE 65A-6-5[1]).

Management common to all lake levels:

- Follow guidance for mineral leasing process outlined in the MLP.
- Include a term in new and renewal leases stating that operations may be suspended or modified if the lake level reaches 4,193 feet on October 15.
- Consider new leasing activities in areas determined to have potential for leasing, as specified by the mineral leasing categories in the MLP.
- Consider how proposed mineral extraction projects would affect GSL resources through review of site-specific analysis. Site-specific analyses required by other permitting agencies may provide FFSL with an adequate level of project-specific analysis.
- Coordinate with permitting and management agencies to determine the appropriate level of involvement in processes that consider impacts of future mineral extraction projects.
- Coordinate with permitting and intersecting agencies to identify effective lease stipulations and/or mitigation strategies.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317)

* Upon reviewing the GSL Lake Level Matrix and determining the numerous amounts of GSL resources that would be negatively impacted once the lake reaches 4,193 feet, this threshold has been determined to be an acceptable level at which new mineral extraction operations would cease pumping activities. GSL resources begin to be adversely impacted at a range of low lake levels, but by the time GSL reaches 4,193 feet, nearly all of the resources have begun to be impaired. For example, all islands would be accessible by land (leaving nesting birds more vulnerable to predation and increasing the risk of trespassing); fringe and impounded wetlands would be drying up and vulnerable to *Phragmites* intrusion; and habitat for open water, shoreline, and island colonial nesters would decrease. Further, recreation access and opportunities would be minimized, search-and-rescue efforts would become more challenging, and several existing mineral extraction operations would be compromised. As stated in section 2.3.1.4, the average low lake level occurs between September and October. Thus, should the peak elevation only reach 4,193 feet or less on October 15, new mineral extraction operations would be required to temporarily cease or modify operations until the lake reaches 4,194 feet or until June 15 of the following year, whichever is later.

† *A new mineral lease or permit* is defined as one that is issued by FFSL subsequent to the Record of Decision adopting this plan. Minor modifications to permits or leases for maintenance or site improvements would require only an amendment to the existing permit or lease and would not be considered a new lease or permit. The determination of whether a modification is minor would be made at FFSL Director's discretion. Renewals of expiring leases will be considered new leases.

Table 3.7. *Minerals and Hydrocarbons*

Resource Issue: Oil, gas, and hydrocarbon leasing

Objective: Allow for new oil, gas, and hydrocarbon leasing activities that are consistent with the long-term sustainability of GSL, according to UTAH CODE § 65A-10-8.

Management Agency: FFSL

Permitting Agency: DOGM, FFSL, USACE

Intersecting Agencies: DWR, DOGM, DWQ

High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Consider potential damages to extraction infrastructure and require mitigation accordingly.	–	–

Management common to all lake levels:

- Consider new leases according to oil, gas, and hydrocarbon leasing categories and leasing processes outlined in the MLP.
- Consider how proposed oil, gas, and hydrocarbon projects would impact GSL resources through review of site-specific analysis.
- Coordinate with DOGM to incorporate best management practices in new leases.
- Coordinate with permitting and management agencies to determine the appropriate level of involvement in processes that consider future oil, gas, and hydrocarbon projects.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).

Resource Issue: Mineral lease modifications

Objective: Ensure mineral lease modification is consistent with the current statute, rules, the GSL CMP, and the MLP.

Management Agency: FFSL

Permitting Agency: DOGM, FFSL

Intersecting Agencies: DSPR, DWQ, DWR, DWRe, DWRi

High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	–

Management common to all lake levels:

- Any modification to existing leases may require site-specific analysis in coordination with DOGM, DWQ, DWRi, DWRe, DWR, and DSPR.
- Include a term in new mineral leases and renewals stating that operations may be suspended or modified if the lake level reaches 4,193 feet on October 15.
- Consider impacts to lake resources upon the amendment or renewal of existing leases in coordination with DOGM, DWQ, DWRi, DWRe, DWR, and DSPR.
- Align bonding and reclamation provisions upon the amendment or renewal of existing leases to be consistent with DOGM standards.
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).

Table 3.8. *Land Use*

Resource Issue: Changes in land use		
Objective: Consider how changes in land use above and below the meander line could have adverse impacts on GSL resources and development.		
Management Agencies: DWR, DWQ, FFSL, local cities and counties, USFWS		
Permitting Agencies: FFSL, local cities and counties, USACE		
Intersecting Agencies: DSPR, DWRe		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Consider how proposed development/infrastructure would be impacted at high lake levels.	–	Consider how proposed development/infrastructure would be impacted at low lake levels.

Management common to all lake levels:

- Coordinate with management agencies listed above to understand how proposed changes in land use would impact GSL resources and surrounding communities.
- Coordinate with local cities, counties, and land managers that have jurisdiction of lands above the meander line to help ensure future development would not have adverse effect on GSL resources or that GSL would have adverse effects on future development.
- Support FEMA determination* that residential and commercial development should not occur below 4,217 feet; this would be done to minimize impacts to GSL resources and infrastructure during periods of high lake levels.

*Through FEMA's National Flood Insurance Program, the agency maintains a set of floodplain maps called Flood Insurance Rate Maps. To prevent damage to property or to protect public safety, mortgage companies are required to determine if a property they are financing is located within the 100-year floodplain by reviewing the Flood Insurance Rate Maps. The 100-year floodplain around GSL generally lies at 4,217 feet, based on surveys completed by USACE on the lake's eastern edges where residential development is most likely to occur.

Table 3.8. *Land Use*

Resource Issue: Diking and causeways		
Objective: Recognize how human modifications to GSL impact the GSL ecosystem.		
Management Entity: Davis County, DWR, Union Pacific		
Permitting Agency: FFSL, USACE		
Intersecting Agencies: DWQ, DWR, DWRe, DWRi, USFWS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Consider how proposed modifications would impact GSL at high lake levels, and develop mitigation strategies to offset impacts, as appropriate.	Consider how proposed modifications would impact GSL at medium lake levels, and develop mitigation strategies to offset impacts, as appropriate.	Consider how proposed modifications would impact GSL at low lake levels, and develop mitigation strategies to offset impacts, as appropriate.
Together with DWR, Davis County, and Union Pacific, evaluate and mitigate impacts to dikes and causeways associated with flooding.	–	Together with DWR, Davis County, and Union Pacific, evaluate the use of dikes, berms, and dredging to mitigate impacts of low lake levels on industry and ecosystems.

Management common to all lake levels:

- Support continued research by all entities listed above to understand the impacts of human modifications on the GSL ecosystem due to dikes and causeways.
- Request site-specific analysis assessments from applicants that consider the impacts of a proposed causeway or dike on the GSL ecosystem.
- Consider how proposed causeway projects and mineral extraction projects would impact GSL resources through review of site-specific analysis.
- Coordinate with responsible agencies and entities to determine the appropriate level of involvement in processes that consider impacts of causeway construction or modification
- Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).

Table 3.8. *Land Use*

Resource Issue: Risk from geologic hazards		
Objective: Recognize the potential impacts of geologic navigational hazards to human health and safety.		
Management Agency: Division of Emergency Management, DSPR, DWR, UDOT, UGS, USGS		
Permitting Agency: n/a		
Intersecting Agencies: local cities and counties		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Coordinate with UGS and DSPR to minimize impacts to existing structures from wind tides and seiches.	–	Coordinate with UGS and DSPR to flag geologic hazards (e.g., bioherms).
Consider how existing and proposed structures would be impacted at high lake levels.	–	Support and coordinate with DSPR, UGS, and USGS on identifying bioherm locations that could impact boaters at low lake levels.

Management common to all lake levels:

- Support and coordinate with UGS on further understanding of potential adverse impacts of shifts in tectonic tilt and how the shifts could impact the current slope of lake bed and floodplain.
- Support Division of Emergency Management and local city and county efforts to prepare, recover from, respond to, and mitigate geologic hazards in and around GSL.
- Support and coordinate with DSPR, UGS, and local cities and counties to develop educational material and public notification tools that disclose geologic hazards.
- Minimize the adverse impacts of windblown ice on lake monitoring structures through support and coordination with USGS, UGS, and DWR.
- Minimize the adverse impacts of windblown ice on other infrastructure through support and coordination with DSPR and UDOT.

Table 3.9. *Visual Resource Management*

Resource Issue: Visual resources of GSL		
Objective: Minimize impacts to the scenic values of GSL.		
Management Agencies: FFSL		
Permitting Agencies: DAQ, FFSL		
Intersecting Agencies: DOGM, DSPR, local cities and counties		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	Support and coordinate with DAQ to research the implications of fugitive dust on visual resources.
Management common to all lake levels: • Consider visual impacts of a proposed project on the visual character of GSL when considering new actions. • Consider how additional lighting from a proposed project would impact GSL resources and visitor experience. • When considering a proposed project, identify strategies to mitigate impacts from surface-disturbing activities as appropriate. • Coordinate with local cities, counties, and other landowners to minimize impacts to visual resources outside of the meander line, but within the GSL viewshed.		

Table 3.10. *Recreation*

Resource Issue: OHV use		
Objective: Protect GSL resources from impacts resulting from OHV trespassing**.**		
Management Agency: FFSL		
Permitting Agencies: FFSL		
Intersecting Agencies: BLM, DSPR, DWR, local cities and counties**,** Utah Office of Tourism		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Promote education efforts that would discourage OHV users from trespassing.	Promote education efforts that would discourage OHV users from trespassing.	Increase law enforcement efforts on areas known to attract illegal OHV users.
–	Coordinate with state, federal, and local law enforcement agencies to construct features and/signage to discourage trespassing.	Coordinate with state, federal, and local law enforcement agencies to increase patrolling on areas known to attract illegal OHV users.
Management common to all lake levels: • Together with the BLM, DSPR, and DWR, identify areas where OHV trespassing is a problem and develop methods to prohibit illegal access. • Coordinate with industry groups and landowners on the authorized locations of OHV use on private land around GSL. • Coordinate with intersecting agencies to develop educational material and enforcement strategies that would discourage OHV users from trespassing.		
Resource Issue: Marina access		
Objective: Promote the importance of access to GSL marinas from land and open water.		
Management Agency: DSPR		
Permitting Agency: DSPR		
Intersecting Agency: FFSL, DWR, local cities and counties		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Coordinate with and support DSPR to minimize negative impacts to marinas and boats during high lake levels.	Support the maintenance of marina access and associated facilities.	Coordinate with and support DSPR to dredge channels, as needed, to provide passages for boats from existing marinas.
Management actions common to all lake levels: • Coordinate with DSPR to sustain access to marinas from land and open water. • Together with DSPR, DWR, and local cities, counties, and marina users, identify marina access issues and concerns at a range of lake levels and support improvements for access.		

Table 3.10. *Recreation*

Resource Issue: Navigational hazards		
Objective: Protect recreation users from navigational hazards on GSL.		
Management Agencies: DSPR, FFSL		
Permitting Agencies: DSPR		
Intersecting Agencies: DWR, UGS, USGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support and coordinate with DSPR and UGS to identify and document navigational hazards that occur at high lake levels.	Support and coordinate with DSPR and UGS to identify and document navigational hazards that occur at medium lake levels.	Support and coordinate with DSPR and UGS to identify and document navigational hazards that occur at low lake levels.
Management common to all lake levels: • Support and coordinate with DSPR, DWR, UGS, and USGS to develop educational materials and public notification tools that disclose navigational hazards.		
Resource Issue: Recreation opportunities		
Objective: Recognize the importance of bird watching and waterfowl hunting and primary contact (e.g., swimming) and secondary contact (e.g., boating, paddle boarding) recreation as multiple-use components of GSL resources.		
Management Agency: DSPR, DWR		
Permitting Agency: DSPR, DWR		
Intersecting Agencies: FFSL, DWQ, local cities and counties, USFWS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support DSPR, DWR, USFWS, and local cities and counties in ensuring high-quality recreation opportunities at high lake levels.	–	Support DSPR, DWR, USFWS, and local cities and counties in ensuring high-quality recreation opportunities at low lake levels.
Management common to all lake levels: • Support and coordinate with DSPR, DWR, DWQ, USFWS, and local cities and counties to provide for high-quality recreation opportunities, including bird watching and waterfowl hunting opportunities and safe primary and secondary contact recreation opportunities. • Consider how management actions impact high-quality recreation opportunities at varying lake levels. • Consider the impact of invasive species (e.g., *Phragmites*) on boating opportunities. • Maintain water quality sufficient to protect the recreation beneficial uses designated to GSL. • Identify areas where recreation opportunities may be impacted by other uses.		

Table 3.11. *Cultural Resources*

Resource Issue: Cultural resource protection		
Objective: Recognize the importance of cultural resource protection on sovereign lands.		
Management Agencies: SHPO		
Permitting Agencies: n/a		
Intersecting Agencies: FFSL, DWR		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	Coordinate with SHPO to minimize the amount of unauthorized access and prevent illegal extraction of artifacts.	Coordinate with SHPO to minimize the amount of unauthorized access and prevent illegal extraction of artifacts.
Management common to all lake levels: • Support SHPO on the management of known cultural resource sites on sovereign lands. • Consider how future projects using state funds would affect historic properties, according to UTAH CODE § 8-8-404. • Adhere to UTAH CODE § 9-9-402 and UTAH ADMIN. CODE R230-1 regarding the discovery of human remains on sovereign lands. • Consult with SHPO regarding how future proposed uses may impact cultural resource sites, as needed.		

Table 3.12. *Paleontological Resources*

Resource Issue: Paleontological resource protection		
Objective: Recognize the importance of paleontological resource protection on sovereign lands.		
Management Agencies: UGS		
Permitting Agencies: n/a		
Intersecting Agencies: FFSL, DWR		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	Coordinate with UGS to minimize the amount of unauthorized access and prevent illegal extraction of resources.	Coordinate with SHPO to minimize the amount of unauthorized access and prevent illegal extraction of resources.
Management common to all lake levels: • Support UGS on the management of known fossil locations on sovereign lands. • Consider how future projects using state funds would affect paleontological resources, according to UTAH CODE § 79-3-508. • Consult with UGS regarding how future proposed uses may impact paleontological resources, as needed.		

Table 3.13. *Economic and Sociological Trends*

Resource Issue: Commercial and industrial activities		
Objective: Allow for commercial and industrial uses while protecting and sustaining long-term health of GSL resources.		
Management Agencies: FFSL		
Permitting Agencies: DAQ, DOGM, DWQ, DWRi, FFSL, USACE		
Intersecting Agencies: DSPR, DWR, DWRe, local cities and counties		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Consider potential economic implications of high lake levels on existing commercial and industrial operations.	–	Consider potential economic implications of low lake levels on existing commercial and industrial operations.
Management common to all lake levels: • Authorize mineral extraction and oil, gas, and hydrocarbon development, brine shrimp harvesting, and aquaculture under multiple-use, sustained yield principles under UTAH CODE § 65A-2-1. • Coordinate with USACE, DAQ, DWQ, DWRi, and DOGM to evaluate resource impacts of a proposed use and identify necessary permits. • Consult with DWRe, DWR, local cities, and counties to minimize resource impacts associated with permit authorization. • Coordinate with resource extraction industries on potential mitigation strategies as new information becomes available regarding the industry's impacts to other GSL resources. • Coordinate with DWQ to help ensure compliance with Utah Water Quality Act regulations (UTAH ADMIN. CODE R317).		
Resource Issue: Valuation of GSL ecosystem resources		
Objective: Promote the development of quantitative metrics to determine the values of GSL noncommodity resources.		
Management Agency: FFSL		
Permitting Agency: FFSL		
Intersecting Agencies: DOGM, DSPR, DWQ, DWR, local cities and counties, UGS, Utah Office of Tourism		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support further research that identifies the implications of high lake levels on economic values.	–	Support further research that identifies the implications of low lake levels on economic values.
Management common to all lake levels: • Recognize the importance of determining accurate valuation of GSL's resources in coordination with UGS, DSPR, Utah Office of Tourism, DOGM, DWQ, DWR, and cities and counties. Specifically, resource valuations could include recreation (e.g., bird watching, waterfowl hunting, and boating), mineral extraction, and oil, gas, and hydrocarbon production.		

Table 3.14. *Agriculture*

Resource Issue: Grazing on sovereign lands		
Objective: Provide grazing opportunities that promote the long-term health of GSL land available for grazing.		
Management Agencies: FFSL		
Permitting Agencies: FFSL		
Intersecting Agencies: DWR, DWQ, Natural Resources Conservation Service, Utah Department of Agriculture and Food		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	Coordinate with land owners and managers to minimize livestock trespass onto adjacent private lands.

Management common to all lake levels:

- Coordinate with DWQ, Utah Department of Agriculture and Food, and Natural Resources Conservation Service to encourage and support best management practices.
- Manage grazing opportunities and potential conflicts of grazing with other GSL resources.
- Allow grazing that helps reduce growth and spread of noxious weeds (e.g., *Phragmites* sp.).
- Promote research and methods to yield sustainable foraging habitat.
- Coordinate with DWR to evaluate the impacts to wildlife, including nesting bird habitat, associated with proposed grazing.

Table 3.15. *Transportation*

Resource Issue: Existing and future transportation infrastructure impacts on GSL		
Objective: Protect GSL resources from adverse impacts resulting from transportation infrastructure.		
Management Entity: UDOT, Union Pacific, Davis County (Davis County Causeway)		
Permitting Agencies: FFSL, USACE		
Intersecting Agencies: DSPR, DWQ, DWR, DWRe		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	–	–

Management common to all lake levels:

- Consider how proposed transportation projects would impact GSL resources through review of agency-led analysis.
- Coordinate with responsible agencies to determine the appropriate level of involvement in processes that consider future transportation projects.
- Coordinate with DWQ to address potential water quality impacts associated with runoff from transportation projects, which could affect the GSL ecosystem.
- Coordinate with USACE and Union Pacific regarding a potential increase in boat access to the North Arm with the future modification of the Northern Railroad Causeway.

Table 3.15. *Transportation*

Resource Issue: Impacts to existing and future transportation infrastructure from GSL		
Objective: Minimize damage to transportation infrastructure from GSL.		
Management Agency: DSPR, local cities (e.g., SLCIA) and counties, UDOT		
Permitting Agency: FFSL, USACE		
Intersecting Agencies: Bear River Association of Governments, DWRe, Wasatch Front Regional Council		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Support DWRe pumping activities to mitigate impacts to GSL resources.	Initiate coordination with DWRe and legislature to mitigate impacts to GSL resources through pumping if lake is trending upward. Discuss the possibility of dredging the intake canal to facilitate pumping if lake level is trending upward rapidly.	–
Coordinate with DSPR, DWRe, Davis County, UDOT, and USACE to minimize impacts to other GSL resources when protecting transportation resources from high lake levels.	–	–

Management common to all lake levels:

- Coordinate with responsible agencies to determine the appropriate level of involvement in processes that consider impacts of future transportation projects.
- Participate in transportation planning efforts with UDOT, Wasatch Front Regional Council, and the Bear River Association of Governments that promote safe and effective transportation routes that minimize impacts to GSL resources.
- Encourage transportation and residential and commercial-related infrastructure development to occur above 4,217 feet (FEMA 100-year floodplain).

Table 3.16. *Law Enforcement and Search and Rescue*

Resource Issue: OHV use		
Objective: Protect GSL resources from adverse impacts resulting from OHV trespassing.		
Management Agencies: FFSL		
Permitting Agencies: n/a		
Intersecting Agencies: adjacent county sheriff departments, BLM, DSPR, DWR, HAFB		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
–	Coordinate with state, federal, and county law enforcement agencies to construct features and/signage to discourage trespassing.	Coordinate with state, federal, and county law enforcement agencies to increase patrolling on areas known to attract illegal OHV users.
Management common to all lake levels: • Identify areas where OHV trespassing is a problem; coordinate and develop methods to prevent illegal access. • Coordinate with BLM, DSPR, DWR, HAFB, and adjacent county sheriff departments to develop enforcement strategies that would discourage OHV users from trespassing.		
Resource Issue: Search-and-rescue access		
Objective: Recognize the importance of search-and-rescue access.		
Management Agency: DSPR		
Permitting Agency: n/a		
Intersecting Agencies: counties' sheriff's departments (search-and-rescue teams), UGS		
High (4,205–4,213 feet or more)	Medium (4,198–4,204 feet)	Low (4,188–4,197 feet or less)
Coordinate with DSPR to identify alternative search-and-rescue access points should marinas not be able to accommodate rescue boats.	–	Coordinate with DSPR to identify alternative search-and-rescue access points should marinas not be able to accommodate rescue boats.
–	–	Coordinate with DSPR and UGS regarding the identification of bioherms that could cause navigational hazards.
Management common to all lake levels: • Support DSPR and counties' sheriff's departments (search-and-rescue teams) in facilitating rescues. • Coordinate with search-and-rescue entities to identify areas or infrastructure within the lake that have lake level access constraints, including marinas, and identify how to operate safely around constraints.		

CHAPTER 4 COORDINATION FRAMEWORK

4.1 Introduction

Multiple state and federal agencies are involved in management, research, and permitting on and around GSL (Figure 4.1). Although FFSL is primarily involved in permitting activities on sovereign land below the meander line, UTAH CODE § 65A-10-8 states that FFSL is responsible for coordinating activities of the various divisions within the UDNR with respect to GSL. As such, FFSL has an interest in improving coordination with other agencies with respect to management, research, and permitting. Currently there is a need for more coordination on a day-to-day basis between and within these spheres. GSL research plays an important role in informing resource-specific management and evaluating impacts associated with those specific permitting activities. Likewise, permitting new activities can have important implications on the management of some of the lake's resources, and resource managers are well placed to evaluate mitigation options for new projects. For this reason, it is important for permitting agencies to better coordinate, not only with other permitting agencies but also with resource managers. Likewise, better coordination between researchers and permitting agencies and resource managers will improve the value and applicability of future research.

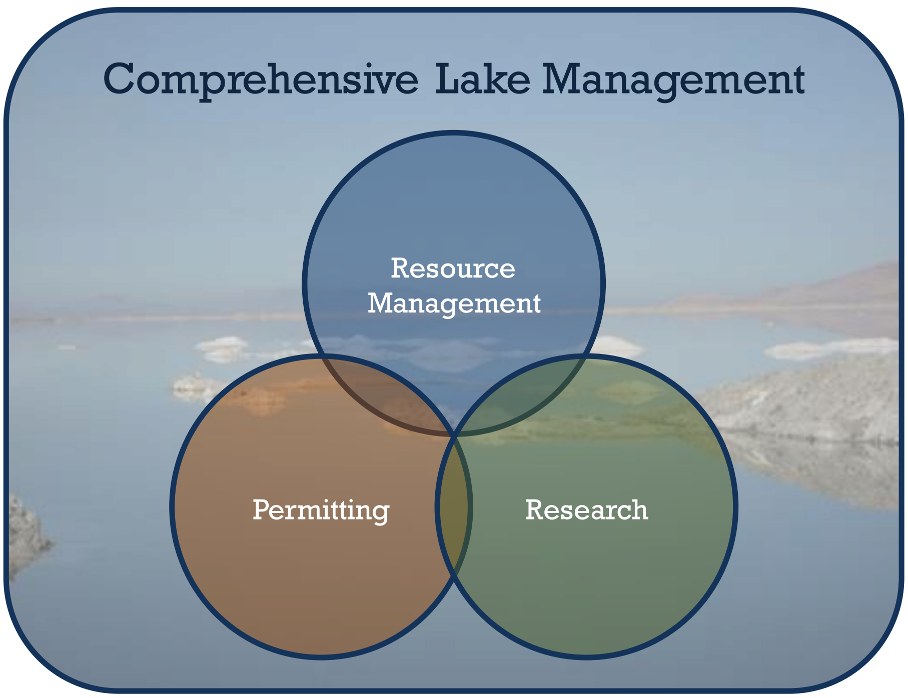


Figure 4.1. Overlapping spheres of comprehensive lake management.

As described in the Management Strategies chapter, much of FFSL's responsibility as a manager of GSL resources is communication and coordination with other agencies. This chapter of the GSL CMP describes the existing collaborative features between the three spheres and provides a framework for enhanced future coordination and communication efforts. Coordination between the management, research, and permitting spheres is essential to achieve comprehensive lake management and to sustain the multiple uses of the lake into the future.

Table 4.1 illustrates the coordinating agencies involved with GSL. Cross-agency overlap is highlighted under permitting and compliance, management, and research (see Table 4.3 for a more comprehensive table).

Table 4.1. *Role of State and Federal Agencies in Permitting, Management, and Research on Great Salt Lake*

Agency		Permitting and Compliance	Management	Research
UDNR	FFSL	X	X	X
	DOGM	X		
	DSPR	X	X	
	DWRi	X		
	DWR		X	X
	DWRe		X	X
	UGS			X
UDEQ	DWQ	X	X	X
	DAQ	X		
Utah Department of Community and Culture	SHPO	X	X	X
Federal Agencies	USACE	X		
	USGS			X
	National Park Service			X
	Natural Resources Conservation Service		X	
	USFWS		X	X
Coordinating Bodies	GSLAC		X	
	GSL Technical Team		X	X

4.2 Research and Management

4.2.1 Current Coordination

Research and management issues are currently addressed through the GSL Technical Team, which is facilitated by FFSL. As stated in section 1.2.10, the GSL Technical Team comprises academic, federal, state, and special interest representatives. The GSL Technical Team's mission is *to provide guidance and recommendations in the monitoring, management, and research efforts of the Great Salt Lake ecosystem and to provide a forum for the interchange of information on ideas, projects, and programs that affect the activities and natural systems of the Great Salt Lake*. The GSL Technical Team meets four times a year to view research presentations, GSL-related project updates, and to discuss research and funding opportunities. The meetings are open to the public, and as such, not all individuals attending the meetings are directly responsible for resource management or research. Informal coordination also occurs between individual resource managers and researchers outside the GSL Technical Team on a project-specific or case-by-case basis. Recently, the GSL Planning Team, which has provided guidance in the development of this CMP, has facilitated productive coordination not only on the CMP but also on specific management activities. Proposed projects under review by FFSL are noticed through the Governor's Office and Planning and Budget Resource Development Coordinating Committee.

4.2.2 Coordination Needs

The divisions within UDNR and UDEQ that manage GSL resources operate within a range of different mandates. GSL resource managers need to be informed of management actions by other divisions (or federal government agency) to evaluate the effects on "their" resource within the GSL system. Resource managers need a mechanism to communicate resource concerns and/or anticipate changes to the resource associated with a proposed management action.

Resource management and research are important pieces in the context of coordination. Within GSL resource management, managers need to understand how actions can affect a range of resources managed by others. For those state agencies that are required to monitor the resource, optimizing and coordinating equipment and personnel amongst agencies could save considerable time and costs to the state.

Research is also a critical component to understanding impacts associated with projects and management actions on the lake. Currently there is a need to prioritize research efforts that help reduce uncertainty associated with resource management. Research is needed to help resource managers effectively manage specific resources of the GSL ecosystem (e.g., what is the best *Phragmites* management approach? Are nutrients a concern for any of the beneficial uses of GSL?) Research will also be more applicable and efficient if individual scientists partner with other researchers where appropriate to expand the reach and scope of research. Depending on the research topic, coordination between agencies would require greater levels of coordination than others based on their complexity and the range of resources the proposed research would have (e.g., mercury: fate and transport, biological processing, impacts to sensitive species, and associated health concerns). Throughout the planning process, it was determined that there were several future research needs in relations to GSL; several were identified and are listed in Appendix E.

4.3 Permitting

4.3.1 Current Conditions

Currently, the permitting agencies of GSL are typically operating in separate "silos." Communication between agency staff that is responsible for permitting is minimal. The permitting staff does not necessarily overlap or coordinate with resource managers within or outside of their respective divisions. Individuals who are responsible for permit review are not involved in the GSL Technical Team. This lack of coordination has led to permitting actions on behalf of one division that conflict with another division.

4.3.2 Permitting Coordination Needs

To ascertain the level of coordination needed, FFSL has developed a table to determine where the permit activities intersect (Table 4.2). Permitting relationships between divisions need to be established to determine when permits need to be obtained (e.g., concurrently or proceeding one another). That is to say, would one division or the applicant themselves benefit from completing a permit from one division (or federal agency) prior to the submission to another agency? The information obtained from the previous permitting process could support the future permitting needs and lead to greater efficiency within the permitting process. Within the State of Utah government agencies, there is also a need for a more efficient and streamlined permitting/application process. This is in support of Governor Herbert's "business friendly" initiative.

Table 4.2. *Agency Permitting Responsibilities*

Agency	Permit	Activity: Mineral Extraction	Discharge to GSL across State Lands	Dike or Causeway Modification	Marinas/Boating Activity	Brine Shrimp/Biological Resources Harvesting	Grazing Activities on State Lands	Filming/Professional Photography	Extraction of Resource other than Bio/Minerals (mud, sand, gravel, etc.)	Invasives Treatment
FFSL	General permit			X[†]	X					
	Materials permit								X	
	Special use lease agreement				X[‡]					
	Easement	X	X	X						
	Right-of-entry	X*						X		
	Minerals lease	X								
	Royalty agreement	X				X			X	
	Letter of authorization									X
	Grazing permit						X			
	Bioprospecting registration					X				
DOGM	Application for permit to drill (oil and gas)	X								
	Notice of intention (minerals)	X								
DWQ	Utah pollutant discharge elimination system, general and stormwater permit with an antidegradation review	X	X							
	401 certification	X		X	X			X		
DAQ	Title V permit	X								X[¶]

Table 4.2. *Agency Permitting Responsibilities*

Agency	Permit	Activity								
		Mineral Extraction	Discharge to GSL across State Lands	Dike or Causeway Modification	Marinas/Boating Activity	Brine Shrimp/Biological Resources Harvesting	Grazing Activities on State Lands	Filming/Professional Photography	Extraction of Resource other than Bio/Minerals (mud, sand, gravel, etc.)	Invasives Treatment
USACE	Section 10/404 permit	X		X	X					
DSPR	–				X			X[§]		
DWR	–					X				X

Notes:

*Rights-of-entry have been issued for some mineral/salt extraction operations where the evaporation pond is located on adjacent, upland, private property and the operator extends piping and a pump to the water's edge to extract brine. These operations tend to be smaller, seasonal, and have short-term easements with private property owners, which limit the ability of the FFSL to issue an easement that involves longer-term use.

[†] A general permit would be issued to a government agency wishing to extend a causeway or dike on GSL (e.g., general permit issued to DSPR for causeway from Antelope Island to main shoreline).

[‡] General permits are issued to marinas operated by government agencies (e.g., DSPR). Special-use lease agreements are issued for marinas operated by private or nongovernmental entities (e.g., Black Rock, which is undeveloped to date).

[§] DSPR would also need to issue authorization/permission for filming within state parks or state park marinas.

[¶] If invasive weed treatment involves burning, DAQ must authorize.

4.4 Proposed GSL Coordinating Framework

As mentioned previously, UTAH CODE § 65A-10-8 states that FFSL is responsible for coordinating activities of the various divisions within DNR with respect to GSL. To accomplish this coordination, FFSL plans to retain many of the GSL Planning Team members as a GSL Coordinating Committee. This team, comprising primarily DNR and DEQ representatives, will review proposed actions on GSL and provide comment and advice on resource or permitting issues related to the action. The most critical part of the coordination framework is the notification of proposed actions on GSL. In the past, notifications from one division to another about proposed actions or permits on sovereign lands have been sporadic at best. Noticing of proposed projects by FFSL will continue on the Resource Development Coordinating Committee website. However FFSL is interested in coordinating on a proposed project before it gets posted on the Resource Development Coordinating Committee website. The current plan is for FFSL to be notified when another division receives an application for an action on sovereign land. In turn, FFSL will send a summary of the proposed action to the GSL Coordinating Committee for review and comment. Meetings of the committee will take place quarterly, unless a member calls a supplemental meeting for a proposed action. FFSL is optimistic that the Coordinating Committee will provide a sufficient level of feedback for the division to make informed decisions affecting GSL and its resources.

Table 4.3. *Great Salt Lake Coordination Spheres*

Agency		Permitting and Compliance	Management	Current and Past Research Initiatives
UDNR	FFSL	Activities on sovereign land below the GSL meander line	Unimpounded wetlands	Fund research opportunities on topical issues related to GSL each year
	DOGM	Oil, gas, and mineral exploration and extraction in and around GSL		
	DSPR	Boat slip permits at GSL UDNR Marinas	Marinas, campgrounds, and beach areas around GSL	
	DWRi	Right to withdrawal water from GSL and its tributaries Groundwater diversion permits		
	DWRe		Operation of pumps from GSL to West Desert when lake reaches high levels	Tributary and groundwater flow to GSL Interbay circulation and salt balance models
	DWR	Hunting and fishing permits	Brine shrimp industry WMA program Nongame bird conservation	GSLEP: brine shrimp ecology, avian biology
	UGS			Wetland mapping Wetland condition assessment Lake elevation and water chemistry Salt balance
UDEQ	DWQ	Utah Pollutant Discharge Elimination System permits to GSL Antidegradation 401 certification		Selenium and mercury dynamics related to GSL beneficial uses Nutrient concerns, primarily in Farmington Bay Development of numeric criteria Water quality baseline sampling Development of nutrient criteria in the Willard Spur of Bear River Bay

Table 4.3. *Great Salt Lake Coordination Spheres*

Agency		Permitting and Compliance	Management	Current and Past Research Initiatives
	DAQ	Major source permits for sources near the GSL		Fugitive dust sources along the Wasatch Front including open areas around GSL
Federal Agencies	USACE	CWA 404 permits for activities in jurisdictional waters		Lake dynamics as necessary for National Environmental Policy Act analyses
	USGS			Lake elevation and morphometry Lake biogeochemistry (including mercury and selenium)
	USFWS		Bear River Migratory Bird Refuge	Contaminant research
	National Park Service		Golden Spike National Monument	
	Natural Resources Conservation Service		Wildlife management on private agricultural lands	

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Appendix A. Great Salt Lake Lake Level Matrix

GSL LAKE LEVEL MATRIX

1-Mar-13

Zone boundary transition

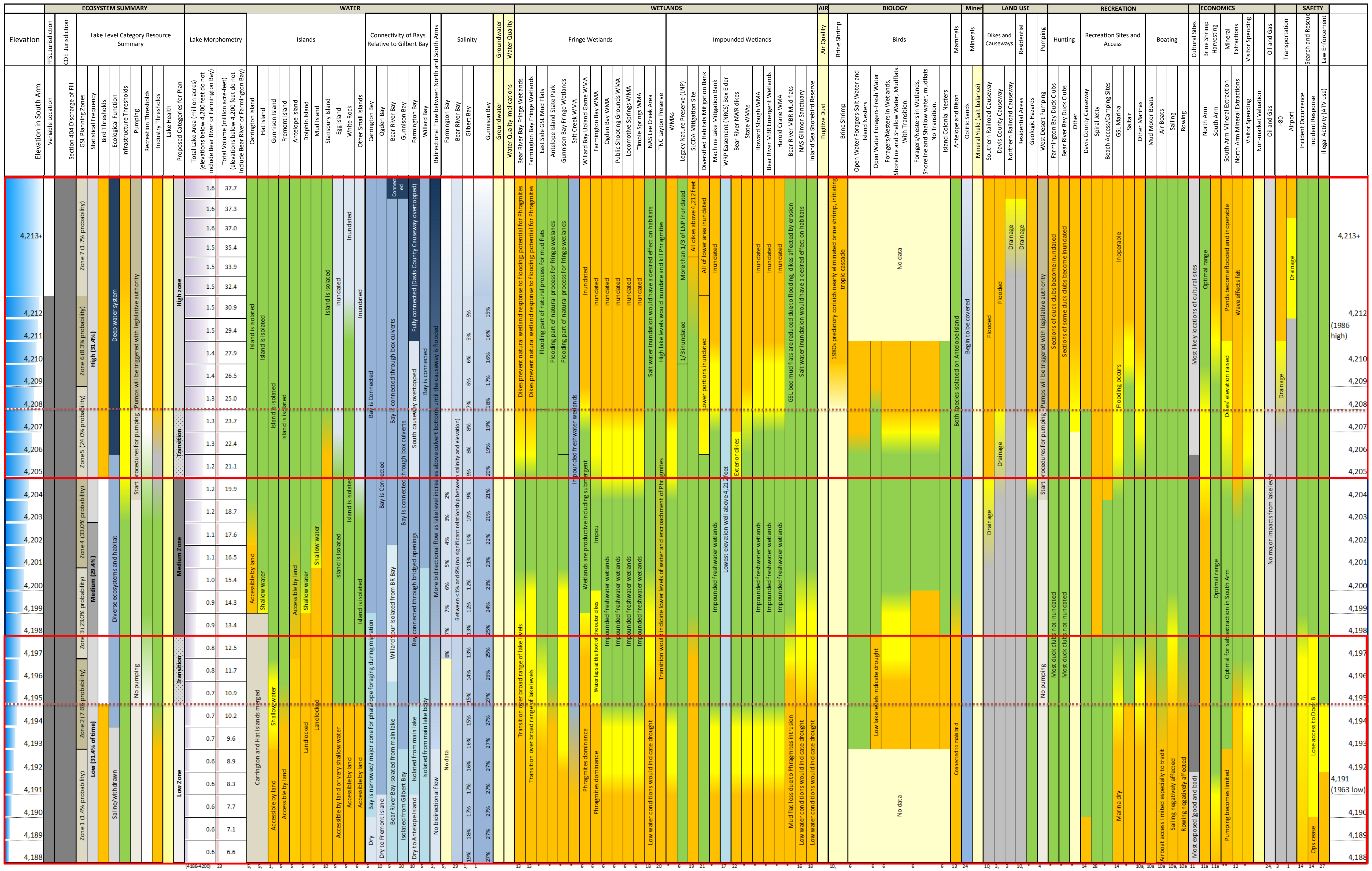
Zone boundary

Beneficial for resource — transition — Adverse for resource

Gray scale is descriptive only to show differences in categories etc.

Blue scale represents value-neutral changes in lake characteristics

Incomplete data or information gap



* "The lake level values associated with this resource are based on collective knowledge and judgment of the GSLCMP Planning Team."

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Appendix B. Summary of Public Involvement

APPENDIX B. SUMMARY OF PUBLIC INVOLVEMENT

FFSL submitted a notice of intent to initiate the CMP revision process to the Resource Development Coordinating Committee in April 2010. Following that submittal, FFSL and SWCA conducted three rounds of public involvement meetings: 1) at scoping, 2) release of the draft GSL CMP, and 3) release of the final GSL CMP. A summary of these three public involvement periods is provided below.

1. In August 2010, FFSL and SWCA conducted one scoping meeting in each of the five affected counties to solicit public and agency concerns and comments (Table B.1).

Table B.1. *Formal Scoping Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
August 10, 2010	10:00 a.m.–1:00 p.m.	Ogden, Utah	2380 Washington Blvd
August 17, 2010	10:00 a.m.–1:00 p.m.	Farmington, Utah	28 East State Street
August 17, 2010	4:00–7:00 p.m.	Salt Lake City, Utah	2001 South State Street
August 24, 2010	3:00–6:00 p.m.	Tooele, Utah	47 South Main Street
August 31, 2010	9:00 a.m.–Noon	Brigham City, Utah	01 South Main Street

2. In May 2011, FFSL and SWCA conducted one public meeting in each of the five counties that surround GSL to solicit public and agency feedback on the draft GSL CMP (Table B.2).

Table B.2. *Draft Great Salt Lake Comprehensive Management Plan Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
May 12, 2011	6:00–8:00 p.m.	Brigham City, Utah	01 South Main Street
May 17, 2011	6:00–8:00 p.m.	Ogden, Utah	2380 Washington Blvd.
May 18, 2011	6:00–8:00 p.m.	Farmington, Utah	28 East State Street
May 19, 2011	6:00–8:00 p.m.	Tooele, Utah	47 South Main Street
May 24, 2011	6:00–8:00 p.m.	Salt Lake City, Utah	1594 West North Temple

3. In March 2012, FFSL and SWCA conducted one public meeting in each of the five counties that surround the GSL to solicit public and agency feedback on the final GSL CMP (Table B.3).

Table B.3. *Draft Final Great Salt Lake Comprehensive Management Plan Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
March 20, 2012	6:00–8:00 p.m.	Clearfield, Utah	562 South 1000 East
March 21, 2012	6:00–8:00 p.m.	Tooele, Utah	47 South Main Street
March 22, 2012	6:00–8:00 p.m.	Salt Lake City, Utah	1575 West 1000 North
March 27, 2012	6:00–8:00 p.m.	Brigham City, Utah	26 East Forest Street
March 28, 2012	6:00–8:00 p.m.	Ogden, Utah	2464 Jefferson Avenue

Meeting Design

The public involvement meetings combined formal presentation and open house formats. At each meeting, SWCA's project manager provided a brief project overview or presentation. Following this informational session, an open house meeting was conducted in a meeting space within the same building. Attendees were greeted and asked to sign in, as well as informed about the meeting format and given the option of taking a business card with the project website and contact information and/or a scoping comment form. Attendees were informed about ways to submit comments and encouraged to ask questions of SWCA's public involvement staff and resource specialists from the GSL Planning Team (if present).

Informational display boards were also arranged around the meeting room to provide the following background information:

- Explanation of the plan revision process and the general timeline and sequence of events
- Description of the general need for a plan revision and responsible entities
- Definition of sovereign lands, public trust, and multiple-use/sustainable yield
- Map and list of potential resource issues
- Opportunities for public comment and a description of available comment methods
- Description of the mineral leasing process
- Lake Level Matrix

Meeting Advertising

Pursuant to FFSL requirements, public involvement meetings were advertised in a variety of formats (Table B.4) prior to their scheduled dates. In each format, the advertisements provided logistics, explained the purpose of the scoping meetings, gave the schedule for the public and agency comment period, outlined additional ways to comment, and provided methods of obtaining additional information.

Stakeholder Meetings

During the revision process, two rounds of stakeholder meetings also took place (one in January 2011 and one in November 2011). The objective of the first stakeholder meeting was to preview and gather comment on the GSL Lake Level Matrix. The objective of the second meeting was to preview and comment on the draft management strategies. The comments gathered at the stakeholder meetings were incorporated into the document, as appropriate. A summary of the public meetings held to date is provided in Table B.5.

Table B-4. *Advertising of Public Meetings*

Media Notices and Other Forms of Advertising
Media notice releases for the scoping period were emailed on July 30, 2010, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader* Media notice releases for the draft GSL CMP were emailed on April 19, 2011, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader* Media notice releases for the draft final GSL CMP were emailed on March 7, 2012, to the following: • *Davis County Clipper* • *Box Elder News Journal* • *Deseret News* • *Ogden Standard-Examiner* • *Salt Lake Tribune* • *Tooele Transcript-Bulletin* • *The Leader*
Meeting information was posted on the project website, www.gslplanning.utah.gov on July 30, 2010.
The draft GSL CMP was posted on the project website, www.gslplanning.utah.gov on May 2, 2011.
The final GSL CMP was posted on the project website, www.gslplanning.utah.gov on March 7, 2012.
Postcards and Other Invitations
Postcards announcing the scoping meetings were sent to those on the mailing list on August 2, 2010. These comprised the following: • UDNR staff identified as having an interest in the project • Prior and current GSL Planning Team members • Nongovernmental organizations identified as having a possible interest in the project • Local and state agencies identified as having jurisdictional authority in the project • Residents who had attended prior plan meetings • Members of the general public who signed up for updates via the project website • Members of the press • All landowners adjacent to the meander line within the affected counties
A meeting invitation for the scoping meetings was emailed to those on the project mailing list for whom email addresses were provided or were obtainable on August 2, 2010.
A scoping meeting announcement was posted on the following listserves: • GSL Technical Team • Jordan River Watershed Council • South Shore Cooperative Weed Management Area
A project poster was displayed at the FRIENDS of GSL Issues Forum April 28–30, 2010.

Table B-4. *Advertising of Public Meetings*

A meeting invitation for the draft GSL CMP was emailed to the 416 individuals on the project mailing list for whom email addresses were provided or were obtainable as of April 19, 2011.

Postcards announcing the draft GSL CMP meetings were sent to the 567 individuals on the project mailing list for whom mailing addresses were provided or were obtainable as of April 19, 2011. These comprised the following:

- UDNR staff identified as having an interest in the project
- Prior and current GSL Planning Team members
- Nongovernmental organizations identified as having a possible interest in the project
- Local and state agencies identified as having jurisdictional authority in the project
- Residents who had attended prior plan meetings
- Members of the general public who signed up for updates via the project website
- Members of the press
- All landowners adjacent to the meander line within the affected counties

A meeting invitation for the draft final GSL CMP was emailed to the 416 individuals on the project mailing list for whom email addresses were provided or were obtainable as of March 7, 2012.

Postcards announcing the draft final GSL CMP meetings were sent to the 638 individuals on the project mailing list for whom mailing addresses were provided or were obtainable as of March 7, 2012. These comprised the following:

- UDNR staff identified as having an interest in the project
- Prior and current GSL Planning Team members
- Nongovernmental organizations identified as having a possible interest in the project
- Local and state agencies identified as having jurisdictional authority in the project
- Residents who had attended prior plan meetings
- Members of the general public who signed up for updates via the project website
- Members of the press
- All landowners adjacent to the meander line within the affected counties

Table B.5. *Meeting Dates, Times, and Locations*

Date	Time	City, State	Address
January 4, 2011	2:00–4:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South
January 6, 2011	2:00–4:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South
November 1, 2011	10:00 a.m.–Noon	Salt Lake City, Utah	SWCA, 257 East 200 South
November 3, 2011	1:00–3:00 p.m.	Salt Lake City, Utah	SWCA, 257 East 200 South

Methods for Public and Agency Comment

Members of the public and representatives of agencies were given several methods for providing comments:

- Comments could be recorded on comment forms at the scoping meetings. Comment forms were available throughout the meeting room, and attendees could write and submit comments at that time.
- Comments could be submitted online at www.gslplanning.utah.gov.
- Individual letters and comment forms could be mailed via U.S. Postal Service to Laura Vernon, SWCA project manager, or Laura Ault, FFSL project manager.

- Individual letters and comment forms could be emailed to Laura Vernon, SWCA project manager, or Laura Ault, FFSL project manager.

Public Comment and Content Analysis

Public comments were gathered during three rounds of public comment periods and during the stakeholder meeting mentioned above. The comments gathered throughout the planning process were considered in the decision-making process and shaped the final CMP. Public comment summary reports were produced for each round of comment periods and are part of the project record. FFSL has provided public comment analysis and response to comments on the draft final CMP and MLP in the following section.

Comment Analysis Approach

FFSL received 225 public comment submissions on the Draft Final CMP and MLP. From the 225 comment letters, 1,211 individual comments were extracted for review of acceptance or non-acceptance. All public comments received were coded by resource or section of the plan and as substantive, non-substantive, or out-of-scope. Comments pertaining to the proposed expansion of the GSL Minerals Evaporation ponds were accepted but are out of the scope of this plan and will not be responded to. Impacts associated with the GSL Minerals Expansion are being analyzed in an Environmental Impact Statement led by the US Army Corps of Engineers. All Draft Final GSL CMP substantive comments were considered in the revision of the Final GSL CMP.

Due to the large number of public comments received on the CMP and MLP, a process was devised to group and respond to similar public concerns. All comments are organized by commenter letter and comment numbers (e.g. 111.4).Substantive, comments have been summarized into public concern statements and responded to below. Each of the associated comments attributed to the public concern statement can be found in their entirety in the GSL CMP Comment Table. Editorial and technical comments have been reviewed individually and changes to the CMP and MLP have been made at the discretion of FFSL.A list of all commentors on the Draft Final CMP and MLP proceed the following Response to Comments section below.

Introduction

PUBLIC CONCERN 1

FFSL should balance sustainability and ecological health with multiple use principles and this balance should be reflected throughout the GSL CMP. Further, FFSLFFSL should recognize that these are principles that are widely shared by GSL managers and stakeholders. FFSL should address project proposals using environmental regulations rather than the precautionary principle.

Associated Comments: 132.5, 132.6, 132.7, 149.2, 149.30, 150.1, 150.4, 150.5, 151.33, 160.2, 177.4, 177.5, 178.2, 185.8, 217.4, 223.1.

Response: The vision statement on page xv was developed in consultation with the Great Salt Lake Planning Team assembled to oversee the development of the GSL CMP. The vision statement accurately captures FFSL's philosophy for multiple use management. FFSL is satisfied that the resource specific sections of the CMP are consistent with the vision statement and the division's multiple use mandate. The GSL CMP does not address specific project impacts but lays the foundation for such evaluation in a collaborative manner with other agencies.

PUBLIC CONCERN 2

FFSL should not elevate the Public Trust Doctrine above statutorily mandated policy criteria. FFSL should ensure that the CMP complies with its legislative mandate. The CMP as currently drafted outlines a management process that is inconsistent and does not fulfill the FFSL's public trust obligations. (148.2, 148.14, 148.21, 150.3, 151.15, 151.29, 194.8, 149.17, 151.2, 151.115, 150.2, 150.15, 150.16, 150.17, 151.30, 198.2, 198.3)

Response: The legal parameters governing FFSL and the Great Salt Lake Comprehensive Management Plan are fairly well defined. Great Salt Lake is sovereign land and therefore subject to the laws relating to those lands including applicable constitutional provisions, statutes, regulations, and case law.

Article XX Section 1 of the Utah Constitution states, "All lands that have been, or may hereafter be granted to the State by Congress, and all lands acquired by gift, grant or devise, from any person or corporation, or that may otherwise be acquired, are hereby accepted, and, except as provided in Section 2 of this Article [relating to school and institutional trust lands], are declared to be the public lands of the state; and shall be held in trust for the people, to be disposed of as may be provided by law, for the respective purposes for which they have been or may be granted, donated, devised or otherwise acquired." The State of Utah obtained ownership of Great Salt Lake through the Equal Footing doctrine. *Utah v. United States*, 403 U.S. 9 (1971).

The Utah legislature has adopted statutes that provide guidance to FFSL on its management activities generally, and also specifically with regard to Great Salt Lake. FFSL statutes govern the sale, exchange, and lease of state lands (Utah Code § 65A-7-1 *et seq*.); mineral leases on state lands (Utah Code § 65A-4-3, Utah Code § 65A-6-1 *et seq*.); management of sovereign lands (Utah Code § 65A-10-1 *et seq*.); management of range resources on state lands (Utah Code § 65A-9-1 *et seq*.); and flood control and prevention on state lands (Utah Code § 65A-11-1 *et seq*.). Furthermore, FFSL statutes proscribe certain activities on state lands (Utah Code § 65A-3-1 *et seq*.) and provide for forest management and fire control on state lands (Utah Code § 65A-8-1 *et seq*., Utah Code § 65A-8a-1 *et seq*.).

Statutes provide that "[FFSL] is the executive authority for the management of sovereign lands, and the state's mineral estates on lands other than school and institutional trust land." (Utah Code § 65A-1-4); that "[FFSL] shall administer state lands under comprehensive land management programs using multiple-use sustained yield principles." (Utah Code § 65A-2-1); and that "[FFSL] is the management authority for sovereign lands, and may exchange, sell, or lease sovereign lands but only in the quantities and for the purposes as serve the public interest and do not interfere with the public trust." (Utah Code § 65A-10-1).

In regard to Great Salt Lake, through Utah Code § 65A-10-8, the Utah legislature has granted FFSL the following powers and duties:

- Prepare a comprehensive plan for Great Salt Lake which recognizes the following policies: (a) develop strategies to deal with a fluctuating lake level; (b) encourage development of the lake in a manner which will preserve the lake, encourage availability of brines to lake extraction industries, protect wildlife, and protect recreational facilities; (c) maintain the lake's flood plain as a hazard zone; (d) promote water quality management for the lake and its tributary streams;(e) promote the development of lake brines, minerals, chemicals, and petro-chemicals to aid the state's economy; (f) encourage the use of appropriate areas for extraction of brine, minerals, chemicals, and petro-chemicals; (g) maintain the lake and the marshes as important to the waterfowl flyway system; (h) encourage the development of an integrated industrial complex; (i) promote and maintain recreation areas on and surrounding the lake; (j) encourage safe boating use of the lake; (k) maintain and protect state, federal, and private marshlands, rookeries, and wildlife refuges; and (l) provide public access to the lake for recreation, hunting, and fishing. Utah Code § 65A-10-8(1).

- Employ personnel and purchase equipment and supplies authorized by the legislature through appropriations. Utah Code § 65A-10-8(2).
- Initiate studies of the lake and its resources. Utah Code § 65A-10-8(3).
- Publish scientific and technical information concerning the lake. Utah Code § 65A-10-8(4).
- Define the lake's flood plain. Utah Code § 65A-10-8(5).
- Qualify for, accept, and administer grants, gifts, or other funds from the federal government and other sources, for carrying out any functions related to Utah Code § 65A-10. Utah Code § 65A-10-8(6).
- Determine the need for public works and utilities for the lake area. Utah Code § 65A-10-8(7).
- Implement the comprehensive plan through state and local entities or agencies. Utah Code § 65A-10-8(8).
- Coordinate the activities of various divisions with the DNR with respect to the lake. Utah Code § 65A-10-8(9).
- Perform all other acts reasonably necessary to carry out the purposes and provisions of Utah Code Ann. § 65A-10. Utah Code § 65A-10-8(10).
- Retain and encourage the continued activity of the Great Salt Lake technical team. Utah Code § 65A-10-8(11).

FFSL's rules provide further guidance to management of sovereign lands. Utah Admin. Code R652-2-200 states,

> "The state of Utah recognizes and declares that the beds of navigable waters within the state are owned by the state and are among the basic resources of the state, and that there exists, and has existed since statehood, a public trust over and upon the beds of these waters. It is also recognized that the public health, interest, safety, and welfare require that all uses on, beneath or above the beds of navigable lakes and streams of the state be regulated, so that the protection of navigation, fish and wildlife habitat, aquatic beauty, public recreation, and water quality will be given due consideration and balanced against the navigational or economic necessity or justification for, or benefit to be derived from, any proposed use."

This regulation indicates the balancing that FFSL considers when determining whether or not to allow proposed uses of sovereign land resources. R652-70-100 states that the R652-70 rules implement "Article XX of the Utah Constitution, and Section 65A-10-1." All uses of sovereign land are required to be consistent with the Utah Constitution, governing statutes and rules, as well as common law principles including the public trust doctrine.

FFSL is not aware of binding legal precedent interpreting the public trust doctrine in Utah, nor is FFSL aware of legal precedent interpreting FFSL's statutory framework. All uses of sovereign land at Great Salt Lake are required to comply with governing constitutional provisions, statutes, regulations, and applicable legal doctrines including the public trust doctrine. FFSL asserts that public trust doctrine does not conflict with other applicable law and that the plan does not inappropriately elevate any legal doctrine or principle over any other. Rather, the plan is entirely consistent with all applicable law.

PUBLIC CONCERN 3

FFSL should acknowledge that the CMP is not a rule promulgated under the Utah Rulemaking Act. (148.3, 148.13, 148.18, 148.19, 148.20)

Response: The CMP is not a rule promulgated under the Utah Rulemaking Act (Chapter 3 of Section 63G). Comprehensive Management Plans are defined as "plans prepared for sovereign lands that guide the implementation of sovereign land management objectives." Utah Admin. Code R652-1-200. These sovereign land management objectives are identified in the FFSL's statutes and rules. The Utah Rulemaking defines a rule as, "an agency's written statement that: (i) is explicitly or implicitly required by state or federal statute or other applicable law; (ii) implements or interprets a state or federal legal mandate; (iii) applies to a class of persons or another agency." Utah Code Ann. § 63G-3-102. R652-90-1000 states, "[FFSL] shall follow the management direction, policeis and land use proposals presented in comprehensive management plans." As indicated by this rule, FFSL has obligated itself to follow the CMP, but the CMP itself is not a rule promulgated under the Utah Rulemaking Act.

PUBLIC CONCERN 4

FFSL should acknowledge that the following resource sections are not required for the GSL CMP: Paleontological Resources, Visual Resources, Land Use Management, Agriculture, and Cultural Resources. They are beyond the legislative intent of the GSL CMP. (151.94)(151.11, 151.95, 151.134))(151.10, 151.133, 151.93)(151.8)(151.12)

Response: The GSL CMP aims to document all of the resources within the meander line of GSL including those that FFSL is not specifically tasked with managing. The final plan clarifies those resources that are managed by other agencies, including SHPO, municipalities, and UGS.

PUBLIC CONCERN 5

FFSL should acknowledge that the CMP is not comprehensive unless it has commitment from other agencies. (223.2)

Response: The title of the plan is dictated by Utah code. In addition, the GSL Planning Team assembled to oversee the development of the plan included representatives from all of the divisions in the Department of Natural Resources and two divisions in the Department of Environmental Quality.

Lake Level Approach

PUBLIC CONCERN 6

FFSL should acknowledge that both high and low lake levels are concerning to the public, industry, and impact GSL resources. Additional planning is necessary to protect industry from high lake levels. (151.21, 153.11)(160.8, 160.9, 160.12, 160.19, 160.24)

Response: The GSL CMP addresses both high and low lake levels throughout the management strategies section. Additional language has been added to 1.1.3 of the final plan to clarify that both high and low lake levels are of concern to the public. FFSL is not responsible for protecting infrastructure during high lake levels. The use of pumping to protect infrastructure at high lake levels is managed by the Division of Water Resources under the direction of the legislature. This is discussed in Table 3.2 under the objective "manage at extremely high and low lake levels to reduce impacts to ecosystems, industry, and infrastructure."

PUBLIC CONCERN 7

FFSL should provide more information on the methodology used for the "Lake Level Effects" sections and improve the legibility of the Lake Level Matrix. FFSL should continue to refine the Lake Level Matrix as more data becomes available. (168.2)(149.22, 149.32, 177.8)(132.11, 148.31)(174.55)

Response: A high resolution version of the Lake Level Matrix will be made available to the public with the release of the final GSL CMP. In addition, a discussion on methodology used to develop the matrix was added to section 1.1.3 and the references used in the development of the matrix was added to this section in addition to be included in the matrix figure itself.

Ecosystem

PUBLIC CONCERN 8

FFSL should protect the health of the GSL ecosystem, its importance in the Pacific Flyway, and acknowledge that ecological health makes GSL's beneficial uses possible. FFSL should consider adopting into the CMP the benchmarks for GSL health contained in the "Definition and Assessment of Great Salt Lake Health" report (GSL Health Report) recently commissioned by the GSL Advisory Council. Further, FFSL should consult, and encourage other agencies to consult, the GSL Health Report when considering proposals. FFSL should modify its definition of a "healthy ecosystem" from "one that existed before significant anthropogenic impacts" to a definition that recognizes the unique ecosystems that have developed as a result of physical modifications to the system including those that support industry, waterfowl management, and transportation. Such a definition is developed in the GSL Health Report. FFSL should conduct research to identify key ecological targets or benchmarks for the health and sustainability of GSL. (185.1, 183.8, 8.3, 101.3, 106.4, 112.1, 220.3, 132.2,132.3,151.31,153.19, 153.20, 177.2, 177.3)(168.8)(148.46)(132.6, 132.7)(151.35)(7.3; 65.2; 158.2)(221.2)(185.6)

Response: FFSL recognizes that protecting the health of the GSL ecosystem is an important objective of managing the lake's resources for multiple uses. FFSL supports the incorporating the findings of the GSL Health Report into management of the lake. Unfortunately, the findings of the GSL Health Report could not be incorporated in the GSL CMP due to the timing of the report's release. There are insufficient time and funds to modify the plan to incorporate the GSL Health Report during this revision cycle. FFSL will consider the GSL Health Report and updates to it in future management plans. A note was added to the plan (Sections 1.2.9 and 2.2.3) that references additional data and reports, including the GSL Health Report, published after the drafting of the GSL CMP.

PUBLIC CONCERN 9

FFSL should clarify the term 'sustainable' and 'sustainability', develop a definition specific to Great Salt Lake that includes protection of the entire system not only specific resources in the lake, and use it consistently throughout the plan including in sections 2.2.5, section 3.3, and the vision statement. (132.17, 177.6, 177.17, 132.17)

Response: FFSL has broadened the definition of sustainable to include both the overall complex lake system and specific resources within the lake. The definition is referred to consistently throughout the final GSL CMP.

PUBLIC CONCERN 10

FFSL should remove all references to "substantial impairment" from the CMP or outline how it intends to use that term in a manner consistent with Utah Code Ann. § 65A-10-1. (148.5)

Response: The "substantial impairment" standard is similar, if not identical, to the "interference" standard stated in Utah Code Ann. § 65A-10-1. The "substantial impairment" standard was articulated by the United States Supreme Court in *Illinois Central R.R. Co. v. Illinois*, 146 U.S. 387 (1892).

PUBLIC CONCERN 11

Section 2.2.5 should be revised to be consistent with the vision statement that frames the philosophy of the GSCLMP. Specifically, the statement regarding industry and political opposition to the precautionary approach should be removed and the use of the precautionary principle in managing for multiple uses should be better explained. FFSL should focus on monitoring and adaptation as a strategy to protect the ecosystem and account for uncertainty associated with impacts from natural resource development. FFSL should clarify what GSL resources it thinks will be consumed by growing populations. (151.38, 151.33, 177.5, 151.37, 177.6)(151.35)160.24

Response: FFSL recognizes the need to balance sustainable use of natural resources with other uses of the lake in an effort to protect the long-term health of the ecosystem and the economies dependent upon it. The statement "There is often industry and political opposition to the precautionary approach because it interferes with traditional ways of conducting business and with the scientific process used to provide decision-making rationales" has been removed from the final GSL CMP. Page 2-11 of the draft GSL CMP already includes a lengthy discussion of the importance of monitoring and incorporating uncertainty into planning and decision making.

Water Resources

PUBLIC CONCERN 12

FFSL should develop a comprehensive water management plan for GSL that includes an updated water balance and a discussion on the influence to lake level and circulation of groundwater pumping around GSL, precipitation, climate variation, water extraction and diversions. Further, FFSL should evaluate the effect that additional breaches in the Southern Causeway would have on the lake when it is above 4,200 feet. (123.2) (175.4) (191.13, 153.24)(66.15, 66.17)(148.45)(185.4)

Response: FFSL supports updating the water balance and hydrodynamic models for GSL to improve understanding of circulation, linkages between bays, and formation of deep brine layers. If such a tool were available, FFSL would use it for management and planning including analysis of project specific impacts on lake dynamics. As such, FFSL supports GSL Advisory Council's selection of a GSL Hydrodynamic Model as an important research priority deserving of funding in the near future. In addition, the GSL CMP identifies several related research priorities in Appendix D.

PUBLIC CONCERN 13

FFSL should incorporate watershed-level management strategies that account for the complex hydrologic network in the GSL basin into planning and management of GSL as well as all sovereign lands within the GSL watershed. These strategies should acknowledge the impact that surface water inflows have on water quality and water quantity in GSL both of which are affected by activities in the GSL watershed. Water quality and quantity are critical factors for the sustainable use of GSL resources and protection of ecosystem health. FFSL should actively advocate for good management of water quality and quantity upstream in the GSL basin and against upstream projects that degrade water quality and/or quantity to GSL. (153.8, 153.13, 153.59, 153.67, 185.2, 220.1, 153.9, 153.10, 153.34) (151.120, 153.57)(153.16)(123.4)(194.6)(148.47)

Response: FFSL does not have management authority over areas above the meander line. Nonetheless, FFSL supports development of a watershed wide hydrologic model that would allow FFSL and other agencies to evaluate linkages between actions in the watershed and GSL including those related to water quality and quantity. FFSL would use such a tool in GSL management and planning including analysis of project specific impacts and to better coordinate with agencies that do have management authority in the watershed. As such, FFSL supports GSL Advisory Council's selection of a Hydrologic Model of the GSL Basin as an important research priority deserving of funding. Several related research priorities are identified in Appendix D

FFSL does not have management authority over water quality in Great Salt Lake. However, FFSL supports UDEQ's ongoing efforts to develop water quality standards for GSL. Reference to this effort has been added to the water quality section 3.6 and the coordination section (4.0).

Lake Elevation

PUBLIC CONCERN 14

FFSL should acknowledge that GSL elevation is naturally fluctuating. (217.1, 168.4, 216.1)

Response: The natural fluctuation of GSL is discussed in Section 2.3.1.4.1 "Natural Fluctuations of Lake Level". The plan does not seek to manage the lake at a single elevation but rather to manage GSL resources appropriately at varying lake levels. This is reflected in the discussion of lake level management in Section 1.1.3.

PUBLIC CONCERN 15

FFSL should consider conducting morphometric analyses and developing hypsographic curves for GSL. (123.5)

Response: FFSL supports collection of more refined hypsographic curve data. The need for more refined bathymetry data is identified as an important research need in Appendix D. Any additional or improved hypsographic data will be considered in future updates to the Lake Level Matrix and future revisions of the GSL CMP.

PUBLIC CONCERN 16

FFSL should remove reference to lake elevation models that are not necessarily useful in predicting lake level into the future. (153.28, 151.51)

Response: The discussion of existing lake elevation models has been revised from the 2000 CMP to show that there has been evaluation of different models that may or may not be appropriate for the lake. The models are not used nor endorsed by FFSL.

Water Rights

PUBLIC CONCERN 17

FFSL should make it clear in the CMP that existing water rights on GSL will be protected. (160.21)

Response: FFSL does not have authority to regulate water rights. This authority resides with the Division of Water Rights as stated in Section 1.4.4. A more explicit statement about these modifications was added to the final GSL CMP.

PUBLIC CONCERN 18

FFSL should remove the CMP's discussion of existing water rights in the GSL Basin. (151.54)

Response: Water use in the basin directly affects the amount of water delivered to the GSL. Section 2 of the plan describes the resources of GSL and the quantity of water delivered to GSL is relevant to this section.

Water Quantity

PUBLIC CONCERN 19

FFSL should provide more detail on the relationship between groundwater and GSL. Specifically, FFSL should identify the areas where groundwater pumping could result in altered hydrology to wetlands and saline intrusion thereby threatening the health of wetlands. (66.15, 66.17,66.25)(151.90)

Response: The influence of groundwater is discussed in subsections of 2.3.1.2. The need for additional research on groundwater and wetlands in relation to GSL is also mentioned in 2.4.11.

Potential impacts to wetlands as a result of groundwater pumping would be explored by FFSL should a proposal to do such activities be submitted to DNR and/or DEQ. Coordination regarding groundwater impacts would occur in the GSL Coordinating Committee.

Water Quality

PUBLIC CONCERN 20

FFSL should acknowledge that more protection of water quality is needed to protect GSL. FFSL should support more restrictive pollution guidelines and conduct a comprehensive study of what contaminants are found in GSL. (114.1, 137.1, 175.8, 191.12, 114.2, 175.6, 175.7, 175.9, 191.6)

Response: FFSL defers to UDEQ for management of pollutant discharge to and water quality in GSL. As such, FFSL supports UDEQ's ongoing efforts to develop water quality standards for GSL. FFSL supports the need for more research related to contaminants to GSL as identified in Appendix D.

PUBLIC CONCERN 21

FFSL should explain why GSL is so uniquely affected by air deposition of mercury. (151.65)

Response: The most up-to-date information available on mercury deposition to GSL was incorporated into the plan. Mercury dynamics are the subject of on-going research and future plans will be updated with additional research as it becomes available.

PUBLIC CONCERN 22

FFSL should explain why the CMP's mercury section did not use Utah Division of Water Quality analyses conducted after 2008. (151.66)

Response: The most recent mercury data available from DWQ was collected in 2008 and released in a report in 2011. FFSL confirmed with DWQ in October 2012 that there are no additional or more recent data available on this topic.

PUBLIC CONCERN 23

FFSL should acknowledge that selenium levels in GSL are below levels of concern. (177.14)

Response: This is noted in the last paragraph of section 2.3.4.5.1.

PUBLIC CONCERN 24

FFSL should develop management strategies to deal with the degraded state of Farmington Bay and incorporate more data and recent publications in the description of the water quality in and ecology of Farmington Bay. (123.6) 123.12, 123.15)

Response: Additional data on the role of salinity in nutrient dynamics, observed cyanobacteria concentrations, and observed cyanotoxin concentrations in Farmington Bay were added to the nutrient section of the final plan. Data that have not been published through a peer-reviewed process were noted as "unpublished data."

Salinity

PUBLIC CONCERN 25

FFSL should support a new, updated salt balance model for GSL and use the model to evaluate the impacts of new leases on GSL. The salt balance model should also be used to determine how the amount of salt extracted from GSL each year by the mineral extraction industry compares to the amount delivered from its tributaries (132.16)(66.19)(160.4)

Response: FFSL supports updating the salt balance for GSL as part of a hydrodynamic model for the lake. FFSL recognizes that an updated salt balance model would improve the management of minerals in GSL by understanding their flux throughout the lake and assessing low lake level effects on salt movement between the North and South Arms. FFSL would use such a tool in GSL management and planning including analysis of project specific impacts. FFSL supports GSL Advisory Council's selection of "Updating the salt balance for GSL and development of planning horizon for mineral extraction" as an important research priority deserving of funding in the next few years. Several related research priorities are identified in Appendix D. The most recent information on salt balance indicates that there is a slight imbalance between salt delivery and salt withdrawn as described in section 2.3.2.3.

PUBLIC CONCERN 26

FFSL should acknowledge that the artificially higher salinities in Gunnison Bay are problematic for the GSL ecosystem and steps are needed to restore the salinity balance between the north and south arms of GSL. FFSL should clarify whether it will develop a plan to equalize salinity in the lake to pre-causeway conditions. (69.4, 139.6, 140.1, 160.27, 219.1, 148.58, 219.2).

Response: FFSL manages the GSL based on its current physical condition, including modifications that have resulted in the development of altered ecosystems. FFSL is not aware of any research indicating what the ideal salinity would be for GSL. Rather FFSL recognizes that salinity fluctuates with lake level. FFSL manages the lake to minimize impacts to all lake resources in the context of natural fluctuations and existing physical structures including dikes, causeways, and impounded wetlands. FFSL supports future efforts to evaluate the salinity balance and identify optimal salinity ranges for given circumstances.

Wetlands

PUBLIC CONCERN 27

FFSL should acknowledge that GSL was recently nominated for designation as a Wetlands of International Significance under the Ramsar Convention, but Utah Division of Natural Resources did not endorse the nomination. (174.26)

Response: Section 2.7.8.1 of the final report reflects that the lake has been nominated for this status.

Air Quality

PUBLIC CONCERN 28

FFSL should address dust production from exposed GSL shoreline. FFSL should consider the research assessing the affect that dust has on the rate of snow melt in the Wasatch, and how this affects lake levels. (66.16)(132.12, 174.75, 114.3, 143.1, 219.6, 174.76, 183.10, 124.5, 177.7)

Response: FFSL does not have regulatory authority over dust production. FFSL will consult with the DAQ when the lake level is low to develop management strategies to reduce windblown dust, as described in Section 3.6. Discussion of dust on snow melt rates in the Wasatch Mountains is outside of the scope of the GSL CMP.

PUBLIC CONCERN 29

FFSL should not single out mineral extraction industries for additional air emission scrutiny. (151.6, 151.68, 151.121, 153.40, 153.58, 151.121)

Response: As described in Section 2.5.2, only those emissions from industries that are directly reliant on GSL and/or are permitted by FFSL were included in the analysis. The section describes the relative contribution of GSL dependent industries on overall air quality issues along the Wasatch Front. All other emissions are beyond the scope of the GSL CMP.

Climate

PUBLIC CONCERN 30

FFSL should consider the effect that climate change will have on lake elevation. FFSL should acknowledge that there is scientific uncertainty about how Utah will be affected by climate change. (151.7, 151.69, 153.41, 151.22)(114.4, 185.5)

Response: The final plan includes more discussion on the scientific uncertainty associated with the report published by the Governor's Blue-Ribbon Advisory Council on Climate Change. This scientific uncertainty extends to impacts on GSL itself. Should additional research be available in the future, it will be considered during future revisions of the plan and could be incorporated. FFSL supports development of hydrologic and hydrodynamic model that could incorporate analysis of climate change impacts on GSL.

PUBLIC CONCERN 31

FFSL should provide an accurate portrayal of the contribution that GSL "lake effect" precipitation provides to the local climate. The phrase "small but detectable role" should be removed. (132.13, 151.71)

Response: The phrase 'small but detectable' was removed from the final plan and the section will simply report the 10% value.

PUBLIC CONCERN 32

FFSL should remove the preliminary analysis on ocean acidification. (151.70)

Response: This section was deleted from the final plan.

Biology

PUBLIC CONCERN 33

FFSL should develop more specific management strategies to address the *Phragmites* problem at GSL including improved coordination between agencies and improving the process for obtaining a permit for *Phragmites* control. (2.3, 63.4, 66.21; 63.5)

Response: FFSL is currently in the process of developing a Sovereign Lands Invasive Species Guidance Document that includes more specific strategies to manage *Phragmites* around GSL. FFSL will work to improve the permitting process including better coordination with other agencies. This is now indicated in coordination section of the plan.

PUBLIC CONCERN 34

FFSL should provide more discussion of the management of brine shrimp in terms of bird consumption, prey base, salinity tolerance, population and harvest figures, and long-term protection of the population. (149.33; 151.34)(212.1)

Response: FFSL used the most recent data provided at the time of the drafting of the GSL CMP. UDWR including representatives that manage brine shrimp and birds were members of the planning team consulted during the drafting of the GSL CMP. All relevant data provided during that period was included in the GSL CMP. FFSL will consider additional brine shrimp data in future revisions of the GSL CMP. Finally, a new section was added to the plan that references additional data and reports published after the drafting of the GSL CMP.

PUBLIC CONCERN 35

FFSL should rely upon objective and authoritative facts when stating conclusions about brine shrimp harvest in the CMP. Noting that brine shrimping was best in the Gunnison Bay before the Causeway construction based on a conversation with EPA's Kleeman is not supported by any objective facts. (153.29, 151.53).

Response: This statement was deleted from the final plan.

PUBLIC CONCERN 36

FFSL should acknowledge that the presence of fish in GSL is minimal but that fish can persist in areas of GSL during periods of low lake levels as well as high lake levels. FFSL should explain if there are any native species of fish in GSL whose abundance would increase at higher lake levels. (151.77, 151.78, 174.24, 174.18)

Response: Fish in GSL and surrounding wetlands are discussed is section 2.7.7. FFSL recognizes that additional research on fish populations is needed to better understand the role of fish in the ecosystem. This was added to the list of research priorities in Appendix D of the final GSL CMP.

PUBLIC CONCERN 37

FFSL should acknowledge that GSL mineral extraction industries sometimes contribute to bird numbers by providing habitat for brine shrimp in extraction ponds, especially during periods of high lake levels. (151.34)

Response: No data related to the role of mineral extraction ponds in providing brine shrimp habitat was received during the drafting stage of the GSL CMP. Should such data be provided in the future, it could be considered in future revisions.

PUBLIC CONCERN 38

FFSL should clarify management goals related to isolated nesting habitat to explain why protection of rookeries from natural predators at low lake levels is an appropriate management objective. FFSL should also eliminate the word 'unnecessary' in the management strategy related to disturbance to nesting habitat. (151.49) (151.126)(168.15)

Response: FFSL acknowledges that naturally occurring low lake levels would result in an increase of predators to GSL islands. Human modifications to GSL and human habitation around the lake have the potential to increase the frequency at which predation occurs. DNR is interested maintaining the isolated islands of GSL and providing critical habitat for birds of national and regional significance, including the American White Pelican. The word 'unnecessary' was removed from the related management strategy.

Minerals and Hydrocarbons

PUBLIC CONCERN 39

FFSL should aim to maintain and provide certainty for the continued operation of mineral extraction industries at GSL and to increase the utilization of GSL minerals. Specifically, FFSL should renew existing mineral leases if they do not involve expansion of the authorized use before new leases are permitted on GSL. Further, FFSL should continue leasing arrangements into perpetuity unless they are renegotiated at their normal term. FFSL should allow existing mineral lessees to extend intake canals when necessary at low lake levels without requiring additional permits. (160.10) (160.22) (160.14)(151.5) (160.5, 160.17, 160.18, 216.2)

Response: The GSL CMP balances the requirement to promote the development of minerals outlined in Utah Code § 65A-10-8 with the multiple use mandate described in Utah Code § 65A-2-1 which states that FFSL shall use "multiple-use, sustained-yield principles." FFSL is satisfied with the balance represented in the GSL CMP between mineral development and other uses of GSL.

PUBLIC CONCERN 40

The plan as currently drafted is biased towards expansion of mineral evaporation ponds. FFSL should consider removing existing evaporation ponds from GSL and limiting mineral development on the west side of GSL. (219.7)(169.2)(144.1)(139.4)

Response: The GSL CMP balances the requirement to promote the development of minerals outlined in Rule 65-8-10-A with the multiple use mandate described in 65A-2-1 which states that FFSL shall use "multiple-use, sustained-yield principles." FFSL is satisfied with the balance represented in the GSL CMP between mineral development and other uses of GSL.

PUBLIC CONCERN 41

FFSL should release all available data, and conduct research to supplement the data, on the rate of mineral extraction from GSL and the potential for airborne pollution following evaporation from industrial ponds. (149.18)

Response: The GSL CMP is not the appropriate document to disclose extraction rates of specific mineral operations. Royalty data are available in aggregate form provided that they cannot be used to identify a particular operator. Emissions associated with GSL industry are maintained by the Division of Air Quality and are summarized in section 2.5 of the plan.

PUBLIC CONCERN 42

FFSL should provide more information about the potential for spills from evaporation and tailings ponds, as well as any mitigation plans on file. Further, FFSL should monitor dumping at GSL. (175.11)(149.19)

Response: A hazardous waste and remediation section has been be added to Section 2.9.7, which will be retitled "Hazards." This section includes a summary of spill prevention, hazardous waste management, and remediation for mineral operators that are required by the Division of Oil, Gas, and Mining.

Land Use

PUBLIC CONCERN 43

FFSL should identify in detail the areas of the lake that are appropriate for different uses. Specifically, FFSL should consider designating more areas of GSL as restricted from further development and give preference to existing uses that have demonstrated their ability to sustainably function within GSL. FFSL should protect the Bear River Migratory Bird Refuge, Bear River Bay, and Gunnison Island's nesting American white pelicans from industrial activities. (8.1)(160.13)(112.2, 148.59, 178.3, 139.4, 183.9)(63.6)

Response: FFSL is satisfied with the level of detail in the classification of mineral development areas. Other proposed uses will be handled on a case-by-case basis with site-specific analyses as determined appropriate by the FFSL Director.

PUBLIC CONCERN 44

FFSL should expand the CMP's land use objective related to diking and causeways to include recognition of how human modifications to GSL impact all resources. (151.128)

Response: The management objective was revised to read "Recognize how human modifications to GSL impact GSL resources."

PUBLIC CONCERN 45

should independently confirm the FEMA information in the CMP regarding lake elevation and structures that are subject to further inundation. (66.20)

Response: FFSL supports FEMA's designation of the 100-year floodplain at 4,217. Since FFSL does not have jurisdiction to lands above the meander line (no higher than 4,212 feet), exact confirmation of the 4,217 elevation would have little relevance in FFSL's management of the lake bed.

PUBLIC CONCERN 46

FFSL should modify its description of Class 1 category areas to include values other than resource development and eliminate the Class 3 category for GSL. (168.6)(185.3)

Response: FFSL does not have the authority to change the wording of the classifications or eliminate classifications in the GSL CMP. These definitions are determined in Rule R652-70-200. Sovereign Lands Classifications and are described in more detail in Section 2.9.3.1.

PUBLIC CONCERN 47

FFSL should explain how evaporation ponds would be reclaimed and restored. FFSL should require full restoration to at least the physical/hydrologic conditions of the site before approving projects that require major alteration of the lake bed. (132.23)(124.9, 191.15)

Response: As part of the site-specific planning required for future proposals, a work plan and reclamation plan for proposed evaporation ponds would be required by DOGM and reviewed by FFSL. Issues such as spill prevention, hazardous waste management and site reclamation would be addressed in the mining permit issued by DOGM. FFSL will coordinate with DOGM and DEQ to ensure that new projects include a Mining and Reclamation Plan that supports the sustainability of GSL resources.

PUBLIC CONCERN 48

FFSL should consider the potential effects that noise from encroaching development or transportation could have on GSL. (66.3)

Response: A discussion of noise impacts to GSL resources was added to the final plan.

PUBLIC CONCERN 49

FFSL should educate communities adjacent to GSL about the dangers of building below 4,217’ due to future potentials for high lake elevations. (168.5)

Response: Notifying residents and developers about flood risk associated with high lake levels has been added to the management strategies for land use in the final plan.

Visual Resources

PUBLIC CONCERN 50

FFSL should address potential impacts to GSL visual resources at both high and low lake elevations. (153.50)

Response: Additional discussion was added to section 2.10.1 to acknowledge visual resources that would be impacted at high lake levels.

PUBLIC CONCERN 51

FFSL should consider the visual impact of tailings ponds at GSL. (191.7)

Response: Visual impacts of tailing ponds at GSL was added to the visual resources section of the final plan.

Recreation

PUBLIC CONCERN 52

FFSL should develop a more specific plan to balance recreation uses and other GSL uses and should eliminate discussion on recreation outside of the meander line, such as skiing. Specifically, the plan should outline how to balance industrial development along the shores of GSL with recreation uses. FFSL should consider how mineral leasing on the west side of GSL would affect recreational and commercial boating. (219.3)(151.136, 2.4, 151.131)(63.7)

Response: Reference to skiing was included due to the fact that the lake effect snow is suggested to enhance snow totals in the Wasatch Mountains and have an potential impact on recreation and visitor spending in Utah. The west shore of GSL is not used for recreational boating. FFSL is satisfied with the management strategies developed to support other recreation on GSL.

PUBLIC CONCERN 53

FFSL should acknowledge the potential impacts to recreation caused by low lake elevations. These impacts include reduced airport access to Bear River Bay, Ogden Bay, and Farmington Bay; reduced recreational waterfowl hunting; and reduced ability to enjoy the lake through sailing. (162.10, 185.9, 220.2, 221.1, 222.1)

Response: The recreation impacts of low lake level are discussed in section 2.11.3.1 including impacts to air boating and sailing.

Economics

PUBLIC CONCERN 54

The GSL CMP should be based on the most up to date information available on economic value. FFSL should revise the economic section of the GSL CMP to incorporate the economic study "Economic significance of the Great Salt Lake to the State of Utah" (GSL Economic Report) commissioned by the GSL Advisory Council and completed by Bioeconomics in January 2012. The GSL Economic Report is more recent, accurate, and comprehensive than the literature and data used in the GSL CMP. (194.5)(151.96, 151.97, 151.100, 151.101, 153.51, 153.52, 151.98)(153.53, 132.15)(148.46)(151.108, 151.109)(66.18)(151.135)(151.102, 151.103)

Response: FFSL recognizes the importance of good economic data in managing GSL. FFSL supports the incorporating the findings of the GSL Economic Report into management of the lake. Unfortunately, the findings of the GSL Economic Report could not be incorporated in the GSL CMP due to the timing of the report's release. There are insufficient time and funds to modify the plan to incorporate the GSL Economic Report during this revision cycle. FFSL will consider the GSL Economic Report and updates to it in future management plans and future management decisions. This is noted in Section 1.2.9 and 2.14. Any errors reported in the section have been corrected in the final plan.

PUBLIC CONCERN 55

FFSL should rework the economic section to acknowledge values that are currently not captured, eliminate sections that are no longer significant, and provide an appropriate amount of attention to GSL industries that have the greatest economic impact. The GSL CMP should acknowledge the economic value of GSL's contribution to rainfall and snowpack and the intrinsic value of GSL. However, salvage and manufactured wood does not have sufficient economic value to deserve its own section. The current section on "Quality of Life" does not present an objective quantitative assessment of economic value of the impact of GSL on quality of life and such an analysis is outside of the mandate of the GSL CMP. Further, too much attention is paid to the value of tourism while there is insufficient information on the value of industry. (151.14, 151.135)(66.22)(66.18)(150.14, 151.13, 151.105, 151.106, 151.104)(151.103)

Response: FFSL used the most recent economic data available at the time that the GSL CMP was drafted. Due to limited time and funds, no additional data subsequently produced can be incorporated into the plan during this revision cycle. FFSL plans to consider additional research on other economic values of the lake during future plan revisions. A recently completed report on the economic impact of lake effect snowfall can be found in Section 2.14.1. While the manufacturing of salvaged and manufactured wood is not a substantial economic GSL resource, the industry will remain included to show the range of past and present GSL uses. The Quality of Life section provides an important qualitative examination of how the GSL impacts local residents and visitors to the area. While managing for quality of life is not a specific mandate of FFSL we are responsible for understanding how GSL impacts local communities on qualitative and quantitative levels.

PUBLIC CONCERN 56

FFSL should develop a more robust and integrated economic development plan for GSL that includes ensuring that mineral, gas, and oil leases provide fair compensation to the State based on the resources they impact and cost-benefit analyses of specific mineral extraction operations and impacts to other industries and economic entities. FFSL should discuss how to encourage the development of an integrated industrial complex to optimize the production and economic output associated with GSL resources, as required by 65A-10-8 (1)(h). (151.3) (66.9)(101.5, 112.3, 178.4)

Response:

The lease and royalty rates on mineral extraction operations were established at the time their lease agreement. Future leases would be subject to adjusted royalty rates. Readjustment of royalty rates would be possible as deemed appropriate by FFSL as a result of relevant analysis and a change in rule. FFSL manages GSL for a range of uses required by 65A-10-8 and does not promote a hierarchy of uses on GSL.

PUBLIC CONCERN 57

FFSL should consider how lake level affects the economics of mineral extraction. (151.127)

Response: Information on lake level impacts to mineral extraction industries was taken into account during the planning process and can be found in Section 2.8.2.6. Future research on the impacts of lake level to mineral extraction industries may be developed and incorporated into the GSL Lake Level Matrix and future GSL CMP revisions.

PUBLIC CONCERN 58

FFSL should support research to estimate the value of ecosystem services provided by GSL to migratory bird populations including the value of the Gunnison Island rookery, over-wintering bald eagles, brine shrimp, invertebrates, and green algae. (191.17; 191.18; 196.3; 191.8)

Response: FFSL supports research on the value of ecosystem services. This is a research item identified in Appendix D of the document and is included in the management strategies for the economic section of the plan.

Management Strategies

PUBLIC CONCERN 59

FFSL should revise its management objectives to be more useful and specific in guiding management of GSL, rather than just understanding the GSL ecosystem. As such, FFSL should remove superfluous management objectives from the CMP and ensure that the CMP is guided by established priorities and principles. FFSL should include discussion of future plans for framing and developing policies in the CMP. (66.10)(151.16)(151.118, 151.114)(151.113, 151.125)

Response: The management objectives and strategies in the plan reflect the lack of direct management authority that FFSL has for many specific resources in GSL. The GSL CMP revision aims to clarify

FFSL's authority and identify new opportunities for improved coordination between agencies to improve overall management of GSL.

PUBLIC CONCERN 60

FFSL should consider waiting until GSL elevation reaches 4,210 feet before using the West Desert Pumping Project to protect the long-term health of GSL. (168.11)

Response: FFSL assumed the level of 4,208 because this is the level at which the DWRe, the agency tasked with managing the pumps, would ask for legislative approval to begin pumping. The final decision to begin pumping lies with the legislature and the DWRe not with FFSL.

PUBLIC CONCERN 61

FFSL should specify what management actions would be taken under each lake elevation scenario. (160.6, 160.26)

Response: Management actions that would be taken at low, medium, and high lake levels are described in Section 3.6. The title of this section was revised to read "Lake Management at Varying Lake Levels."

PUBLIC CONCERN 62

FFSL should restrict pumping of GSL water for mineral extraction operations with current leases, not just new leases, when the lake elevation drops below a certain elevation. (100.4, 100.5, 100.6, 100.7, 100.8, 162.8, 149.29, 100.10, 66.8, 127.3, 141.1, 222.2, 148.30, 162.2, 162.3, 162.4, 162.5, 168.3, 168.9, 175.12, 198.8)

Response: Absent highly unusual circumstances, FFSL does not have the authority to amend existing leases on existing operations unless the operator seeks a modification of an existing lease or if a lease is up for renewal. Existing water withdrawals are managed by the DWRi.

PUBLIC CONCERN 63

FFSL should not restrict GSL industries when lake elevations are low. (217.2, 153.56, 160.7, 160.16, 160.20, 179.13)

Response: FFSL is required to manage the lake for multiple resource uses. Lake levels below the threshold identified in the GSL CMP clearly impacts multiple resources as well as some industry. These impacts are summarized in the Lake Level Matrix and in the management strategies Table 3.7.

PUBLIC CONCERN 64

FFSL should increase the lake level threshold at which actions are taken to reduce lake withdrawals and increase flow to the lake. Specifically, an elevation of 4,195 is more protective of all GSL resources. Critical biological resources within the GSL ecosystem could be impacted if the surface elevation of Gilbert Bay drops below 4,193 feet, and many of these impacts could affect critical links in the GSL food web and are not well understood. Further, Gunnison Island is accessible to predators when GSL lake falls below 4,193 feet, and the biological importance of Gunnison Island is increased at GSL elevations above 4,195 feet. In addition, impacts to stromatolites, an important habitat for brine flies found in shallow areas of the lake, are impacted at levels at and below 4,193. (162.9)(162.7)(162.6)(153.21, 153.27)(162.1)(66.7, 100.1, 100.2, 100.3, 139.3, 148.32, 148.34, 148.35, 148.36, 149.27, 149.28, 168.10)(155.1)

Response: The threshold was kept at 4,193 but the point during the year at which to measure the elevation was changed from June (generally the peak elevation) to October 15 (generally the lowest elevation). Should the lake level elevation be 4,193 in the south arm on October 15, new lessee may be required to modify or cease pumping operations until June 15 of the following year or until the lake reaches 4,194 whichever is later.

PUBLIC CONCERN 65

FFSL should work with other agencies to develop the lake level threshold identified in the GSL CMP into a formal conservation pool with an in-lake water right assigned to the lake. FFSL should acknowledge that the CMP cannot protect GSL until the in-lake water rights are recognized. (148.27; 223.3)(2.2, 5.2, 66.4, 66.5, 101.10, 139.5)

Response: According to Utah Code § 73-1-1 "All waters in the state…are …the property of the public." Under the Prior Appropriation system, the system of water allocation used in Utah, a right to use a specific quantity of water can be obtained by placing a quantity of water to beneficial use and by applying for a water right. *See* Utah Code § 73-3-1. Thus, although the water in the state belongs to the public, the right to use a specific quantity of water within a specific water source can be held by a private person. FFSL has no control over water rights. Rather, the State Engineer is responsible to administer the system of water rights allocation in the State of Utah (Utah Code § 73-2-1(3)(a)). The State Engineer's agency, DWRi (Utah Code § 73-2-1.2), is a sister agency to FFSL. Coordination with DWRi and the State Engineer will occur regarding new project proposals and lake-level specific resource concerns.

No statute specifically authorizes a conservation pool at Great Salt Lake or any other navigable body of water in the state. The Division is conceptually not opposed to a privately-funded conservation pool at Great Salt Lake if possible according to existing statutes. Furthermore, the Division is not opposed to a state agency possessing an in-lake water right if authorized by existing law.

In the 2013 CMP, FFSL is proposing implementing management strategies for various lake levels including a restriction on new leases or expansions of existing leases when the lake elevation goes below a certain identified threshold.

PUBLIC CONCERN 66

FFSL should acknowledge that suspending new leases when GSL reaches 4,193 feet is unlikely to stop a downward trend in lake elevation since existing leases would still be active. (219.5)

Response: FFSL does acknowledge that suspending new leases would not stop a downward trend, but the management action is one tool that seeks to minimize the adverse impacts to GSL resources at low lake levels. Further, as mentioned in Public Concern Statement 64 the time of year that FFSL will evaluate lake level elevation has been changed from the average annual high to the average annual low in order to minimize adverse impacts from lower lake elevations. .

Coordination

PUBLIC CONCERN 67

FFSL should increase coordination efforts with other interested branches of government, nongovernmental organizations, and the public. (106.2, 106.3, 123.3, 132.22, 178.1)

Response: Coordination between agencies is outlined in Section 4 of the GSL CMP.

PUBLIC CONCERN 68

FFSL should examine the already existing GSL management groups before recommending the creation of another group. (151.137, 153.61)

Response: The proposed Great Salt Lake Coordinating Committee brought forth in Chapter 4 of the Draft Final CMP is not a newly created group. It will be an extension of the GSL CMP Planning Team that was established in 2010. Representatives from the DNR and DEQ have expressed continued interest in the interagency coordination that has been occurring at the Planning Team meetings over the last two years.

PUBLIC CONCERN 69

FFSL should outline how site-specific analyses for proposed projects will be completed in the future including an analysis of cumulative effects on all GSL resources and the role of Resource Development Coordinating Committee in the permitting process. Further, FFSL should clearly state what criteria state agencies will be using to make permitting and other project specific decisions beyond expanding the existing coordination/information sharing processes. (132.4, 132.19)(132.21, 94.2, 148.15, 198.4, 148.33)(148.60, 124.8, 124.10, 183.4, 196.2, 219.8, 191.10, 101.1, 178.8)(153.18)(101.9, 132.9, 168.17, 194.4)(196.1)(198.7)(68.61)(149.9)

Response: FFSL is responsible for analyzing proposed projects according to R652-90 and applicable rules, statues and other laws. The level of site-specific analyses is currently being determined on a case-by-case basis at the Director's discretion. Future site-specific analyses will be subject to changes in R652-90. Future projects will also be reviewed by the Great Salt Lake Coordinating Committee in order to understand impacts to a range of GSL resources.

PUBLIC CONCERN 70

FFSL should consider developing a technological approach to exchanging information with coordinating agencies. (66.13)

Response: FFSL will continue coordination with the Great Salt Lake Coordinating Committee as it has done throughout the two year planning process – via email and face-to-face meetings. FFSL also supports the continued use of Resource Development Coordinating Committee as an electronic mechanism for sharing information and soliciting comments on permit applications and other proposals within the state system. This has been added to Section 4 of the final GSL CMP.

PUBLIC CONCERN 71

FFSL should include a narrative in the CMP about the role of the GSL Advisory Council. (68.59)

Response: A discussion of the role of the GSL Advisory Council was added to section 4.1 of the final plan.

PUBLIC CONCERN 72

The coordination section of the GSL CMP seems to seek reassignment or ceding of some FFSL responsibility to other agencies. (151.116, 185.7)

Response: The coordination framework outlined in Section 4 documents existing mandates and relationships between agencies. Although, this section is the first place to document these relationships in one place, the plan does not seek to change management authority over GSL resources. Rather it aims to improve coordination between agencies with varied management, research, and permitting authority over GSL and its resources.

PUBLIC CONCERN 73

FFSL should state its permitting process and requirements with as little uncertainty as possible and should clarify the relationship between the CMP and the MLP. (148.4)(160.11, 198.6, 148.8)

Response: The MLP provides a more-detailed look into mineral extraction as a resource when compared to the CMP. It is intended to be used as a companion guide to the CMP. The MLP offers a more in-depth look at FFSL's management direction with regard to mineral extraction when compared to the CMP. When considering the fundamental guidance on mineral extraction, the CMP provides sufficient level of detail. When considering FFSL management direction in a greater level of detail, the MLP will be used. Additional detail on management guidance and permitting processes will be incorporated into future MLP revisions, as appropriate. At this time the permitting process for each application is handled on a case-by-case basis at the discretion of the FFSL Director.

Public Involvement

PUBLIC CONCERN 74

FFSL should have a clearly defined public participation process including a discussion on how public comments framed the final GSL CMP. FFSL should list the public meetings and public comment periods that occurred during the planning process. FFSL should notify the public where to find updates and/or updated data regarding the CMP when that information becomes available. (168.1)(126.1)(70.1) (139.2, 148.12, 198.5, 168.18, 192.1)(153.3)

Response: The public involvement process is documented in Appendix E of the GSL CMP. Public comment periods, meetings, and the location of future updates have been updated in Appendix E of the final plan.

PUBLIC CONCERN 75

FFSL should allow the public and all stakeholders to review and comment on decisions that affect the health and future of GSL. (94.3, 149.5, 149.6, 178.7) (192.2, 192.3, 160.23, 160.25, 151.1)

Response: The new coordination plan outlined in Section 4 involves coordination with agencies that represent the public and stakeholders. In addition, FFSL will continue to comply with public involvement requirements for specific permitting actions, as required by R652-90. These are outlined in Section 4 of the final plan.

PUBLIC CONCERN 76

FFSL should extend the public comment period and/or hold additional public meetings. (70.2, 140.3, 176.1)

Response: FFSL already extended the public comment period by 30 days. FFSL is satisfied with the public involvement process conducted during the drafting of the GSL CMP and additional delays to its finalization are not acceptable.

Table B.6. *Commenters on the Draft Final CMP and MLP*

Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
1	Stephanie	Young	slymerzel@aol.com	723 9th Ave	Salt Lake City	UT	84103	–
2	Debra	Johnson	–	615 W 9400 S Ste 116	Sandy	UT	84070	–
3	Louise	Brown	luckylou@allwest.net	PO Box 643	Kamas	UT	84036	–
4	J	Tanner	–	5760 Stoneflower	Kearns	UT		–
5	Wade	Brown	–	8324 W. Danbury Dr.	Magna	UT	84044	–
6	Nick	Brown	–	8324 W. Danbury Dr.	Magna	UT	84044	–
7	Tim	Rhodes	rhodes@xmission.com	2002 Imperial St	Salt Lake City	UT	84105	–
8	Sylvia	Wilcox	–	2689 Imperial St.	Salt Lake City	UT	84106	–
9	Wade	Brown	–	8324 W. Danbury Dr.	Magna	UT	84044	–
10	Nick	Brown	–	8324 W. Danbury Dr.	Magna	UT	84044	–
11	Vernona	Pace	–	4853 Cherrywood Ln	Salt Lake City	UT	84120	–
12	Sylvia	Wilcox	–	2689 Imperial St.	Salt Lake City	UT	84106	–
13	Alex	Toller	–	701 E 2nd Ave	Salt Lake City	UT	84103	–
14	Andrew	Lloyd	–	5832 S Westbench Dr	Kearns	UT	84118	–
15	Zoe	LeCheminant	–	3525 W. 7520 S.	West Jordan	UT	84084	–
16	Tony	Johnston	–	9757 S. 1650 W.	South Jordan	UT	84095	–
17	Laura	Romney	–	2437 Countryside Lane	West Jordan	UT	84084	–
18	Carole	Sexton	–	9075 S. 700 E. Apt. 326	Sandy	UT	84070	–
19	Bob	Romney	–	1494 S. West Temple	Salt Lake City	UT	84115	–
20	Doug	Pearson	–	5932 Allores Ct.	Herriman	UT	84096	–
21	Kelly	Asay	–	5031 W. Highwood Dr.	Kearns	UT	84118	–
22	Dena	Robinson	–	5032 W. Highwood Dr.	Kearns	UT	84118	–
23	Kyle	Stevens	–	5168 W. 4100 S.	West Valley City	UT	84120	–
24	Eric	Tvedtnes	–	2382 Jordan Meadows Lane	West Jordan	UT	84084	–
25	Bret	Beckstead	–	3213 Larkin	West Valley City	UT	84120	–
26	Tyler	Beckstead	–	7549 South 2160 East	Salt Lake City	UT	84121	–
27	Sylvia	Gray	–	666 Ninth Avenue	Salt Lake City	UT	84103	–
28	Rocky	Robinson	–	5032 W. Highwood Dr.	Kearns	UT	84118	–
29	Anon	Anon	–	–	–	–	–	–
30	Gary	Lloyd	–	8553 Johnson Way Drive	Sandy	UT	84094	–
31	Burh	Sinsi	–	623 Marin Way	Saratoga	UT	84045	–
32	Mike	Asani	–	5031 W. Highwood Dr.	Kearns	UT	84118	–
33	Pat	Burns	–	6843 S. Clover Circle	West Jordan	UT	84084	–
34	Todd	Kaumo	–	1479 California Ave	Salt Lake City	UT	84104	–

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Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
35	Jeredee	Gibson	–	PO Box 1306	Bountiful	UT	84011	–
36	John	Gibson	–	PO Box 1306	Bountiful	UT	84011	–
37	Cameron	Reynolds	–	PO Box 1306	Bountiful	UT	84011	–
38	Tim	Rhodes	–	2002 Imperial St	Salt Lake City	UT	84105	–
39	Carole	Sexton	–	9075 S. 700 E. Apt. 326	Sandy	UT	84070	–
40	Andrew	Lloyd	–	5832 S. Westbench Dr	Kearns	UT	84118	–
41	Todd	Kaumo	–	1479 California Ave	Salt Lake City	UT	84104	–
42	Amanda	Martin	–	664 S. Grand	Salt Lake City	UT	84102	–
43	P	Burns	–	6843 S. Clover Circle	West Jordan	UT	84084	–
44	Dena	Robinson	–	5032 W. Highwood Dr.	Kearns	UT	84118	–
45	Laura	Romney	–	2437 W. Countryside Ln	West Jordan	UT	84084	–
46	Bob	Romney	–	1494 S. West Temple	Salt Lake City	UT	84115	–
47	Dave	Pearson	–	5932 Allores Ct.	Herriman	UT	84096	–
48	Kelly	Asay	–	5031 Highwood Dr.	Kearns	UT	84118	–
49	Mike	Asay	–	5031 Highwood Dr.	Kearns	UT	84118	–
50	Tony	Johnston	–	9757 S. 1650 W.	South Jordan	UT	84095	–
51	Tyler	Beckstead	–	7549 South 2160 East	Salt Lake City	UT	84121	–
52	Bret	Beckstead	–	3213 Larkin	West Valley City	UT	84120	–
53	Burh	Sinsi	–	623 Marin Way	West Valley City	UT	84045	–
54	Zac	LeCheminant	–	3525 W. 7520 S.	West Jordan	UT	84084	–
55	Eric	Tvedtnes	–	2382 Jordan Meadows Lane	West Jordan	UT	84084	–
56	Gary	Lloyd	–	8553 Johnson Way Drive	Sandy	UT	84094	–
57	Anon	Anon	–					–
58	Kyle	Stevens	–	5168 W. 4100 S.	West Valley City	UT	84120	–
59	Rocky	Robinson	–	5032 W. Highwood Dr.	Kearns	UT	84118	–
60	John	Gibson	–	PO Box 1306	Bountiful	UT	84011	–
61	Cameron	Reynolds	–	PO Box 1306	Bountiful	UT	84011	–
62	Jeredee	Gibson	–	PO Box 1306	Bountiful	UT	84011	–
63	J. Thomas	Bowen	–	925 Executive Park Drive, Ste B	Salt Lake City	UT	84117	–
64	Bob	Brister	–	1102 S. 800 E. #A	Salt Lake City	UT	84105	–
65	Bryant	Olsen	bryant_olsen@yahoo.com	688 E. 700 S. #105	Salt Lake City	UT	84102	–
66	Elizabeth	Menzies	menzies.miranda@googlemail.com	–	–	–	–	–
67	Sarah	Powell	sarahlovesparrots@gmail.com	–	–	–	–	–
68	Jennifer	Sullivan	–	–	–	–	–	State of Utah; Dept of Natural Resources Division of Forestry, Fire and State Lands

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69	William	Gray	cyberflora@xmission.com	666 Ninth Avenue	Salt Lake City	UT	84103	–
70	Shirley	Gorospe		PO Box 188	West Jordan	UT	84081	–
71	Amberlynn	Sauter	Amberlynn.Sauter@gmail.com	–	–	–	–	–
72	Jill	Rolstad	rolstadjill@gmail.com	–	–	–	–	–
73	Dale	Majors	dale@bikewagon.com	–	–	–	–	–
74	Rachel	Lee	rachellee2@mail.weber.edu	–	–	–	–	–
75	Dave	Turner	turnds@xmission.com	–	–	–	–	–
76	Chris	Riches	Chris.Riches@imail.org	–	–	–	–	–
77	Jay	Todd	jaja64@msn.com	4987 South Fairbrook Lane	Holladay	UT	84117	–
78	Nicole	Anderson	nma9999@xmission.com	–	–	–	–	–
79	Jennifer	Sullivan	–	1780 North Research Parkway Ste 104	North Logan	UT	84341	Sovereign Lands/National Fire Plan Coordinator Utah Forestry, Fire and State Lands
80	Joe	Havasi	havasij@compassminerals.com	9900 West 109th Street, Ste 600	Overland Park	KS	66210	Compass Minerals
81	Stephanie	Young	slymerzel@aol.com	723 9th Ave	Salt Lake City	UT	84103	–
82	Debra	Johnson		615 W 9400 S Ste 116	Sandy	UT	84070	–
83	Louise	Brown	luckylou@allwest.net	PO Box 643	Kamas	UT	84036	–
84	J	Tanner	–	5760 Stoneflower	Kearns	UT		–
85	Matt	Orwin	–	4792 S Aaron Way	Salt Lake City	UT	84118	–
86	Sherry	Kaumo	–	1479 California Ave	Salt Lake City	UT	84104	–
87	Jeffrey	Himsl	–	10193 Majestic Canyon Rd	Sandy	UT	84092	–
88	Rebecca	Himsl	–	10193 Majestic Canyon Rd	Sandy	UT	84092	–
89	Terry	Brown	–	7235 W 3100 S	Magna	UT	84044	–
90	Michael	Baldassari	–	6906 S 300 W	Midvale	UT	84047	Mechanical Service & Systems, Inc
91	Jo Ellen	Blackham	–	2050 Sands Dr	Salt Lake City	UT	84124	–
92	Verona	Pace	–	4853 Cherrywood Ln	Salt Lake City	UT	84120	–
93	Sheri & Joseph	Morzinski	–	160 E 300 S	Bountiful	UT	84710	–
94	Mary Beth	Whittaker	–	970 E Murray Holladay Rd 2F	Salt Lake City	UT	84117	–
95	Ben	Orwin	–	4792 S Aaron Way	Kearns	UT	84118	–
96	Florien	Wineriter	–	1648 Saint James Pl	Salt Lake City	UT	84121	–
97	Jim	Orwin	–	4792 S Aaron Way	Salt Lake City	UT	84118	–
98	Sandra	Farris	–	–	–	–	–	–
99	Gary	Brimley	–	–	–	–	–	Assistant Regional Engineer; DWRi
100	Carmen	Bailey	–	–	–	–	–	DWR
101	–	–	rmueller04@comcast.net	–	–	–	–	Bridgerland Audubon Society

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Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
102	Chante	McCoy	chante_m@hotmail.com	7815 Prospector Dr.	Salt Lake City	UT	84121	–
103	Richard	Mueller	–	1526 East 2700 North	North Logan	UT	84341	Conservation Chair, Bridgerland Audubon Society
104	Julia	Bottita	juliabottita@gmail.com	–	–	–	–	–
105	Eric	Klotz	ericklotz@utah.gov	1594 West North Temple, Suite 310	Salt Lake City	UT	84114	Section Chief, Water Conservation and Education, DWR
106	Ellen	Bloedel	bloedeleh@comcast.net	–	Cottonwood Heights	UT	–	–
107	Gary	Kleeman	kleeman.gary@epa.gov	1595 Wynkoop St.	Denver	CO	80202	Watershed Team, Utah Coordinator, EPA
108	Jeffrey	Himsl	–	10193 Majestic Canyon Rd	Sandy	UT	84092	–
109	Rebecca	Himsl	–	10193 Majestic Canyon Rd	Sandy	UT	84092	–
110	Kate	Kessler	trailgod@frontiernet.net	–	Moab	UT	–	–
111	Julia	Bottita	juliabottita@gmail.com	–	–	–	–	–
112	Douglas	Stark	–	2698 Wren Rd	Holladay	UT	84117	–
113	John	Hibbs	–	30 N 1900 E, 4B319	Salt Lake City	UT	84132	University of Utah School of Medicine
114	Cris	Cowley	–	6985 Canyon Creek Circle	Cottonwood Heights	UT	84121	Utah Physicians for a Healthy Envionment
115	Aaron	Andrade	–	5620 SE Schiller St	Portland	OR	97206	–
116	Paul	Johnson	pjohnsonlaw@att.net	1990 West 3300 South	Odgen	UT	84401	Mineral Resources International, Inc.
117	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
118	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
119	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
120	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
121	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
122	Jim and Margaret	Suhr	msuhr@decisioninnovations.co	–	–	–	–	–
123	Wayne	Wurtsbaugh	wayne.wurtsbaugh@usu.edu	Watershed Sciences Department/Ecology Center Utah State Univ	Logan	UT	84322-5210	Watershed Sciences Department/Ecology Center Utah State Univ
124	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
125	Wayne	Wurtsbaugh	wayne.wurtsbaugh@usu.edu	Watershed Sciences Department/Ecology Center Utah State Univ	Logan	UT	84322-5210	Watershed Sciences Department/Ecology Center Utah State Univ
126	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
127	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
128	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
129	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
130	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
131	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
132	Chris	Montague	cmontague@TNC.ORG	559 E South Temple	Salt Lake City	UT	84102	The Nature Conservancy

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Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
133	John	Hibbs	John.Hibbs@hsc.utah.edu	–	–	–	–	University of Utah School of Medicine
134	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
135	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
136	Heather	Dove	hdove@xmission.com	2072 Rainbow Point Drive	Salt Lake City	UT	84124	
137	Cris	Cowley	crisgcowley@comcast.net					Utah Physicians for a Healthy Environment
138	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
139	multiple, see letter		lwvut@xmission.com	3804 Highland Drive, Suite 8D	Salt Lake City	UT	84106	The League of Women Voters of Utah and the League of Women Voters of Salt Lake
140	Jen	Taylor (and 125 middle school students at Renaissance Academy)	jtaylor@renacademy.org	–	Lehi	UT		Renaissance Academy
141	Henry	Boland	henry.boland@comcast.net	–	–	–	–	Member, Great Salt Lake Yacht Club
142	Fred	Adler	adler@math.utah.edu	1452 Michigan Avenue	Salt Lake City	UT	84105	–
143	Chanté	McCoy	chante_m@hotmail.com	7815 Prospector Dr.	Salt Lake City	UT	84121	–
144	Rob	Tautges	robtautges@gmail.com	1203 McClelland st #2	Salt Lake City	UT	84105	–
145	multiple, see letter		lwvut@xmission.com	3804 Highland Drive, Suite 8D	Salt Lake City	UT	84106	The League of Women Voters of Utah and the League of Women Voters of Salt Lake
146	Robert	Andrus	robertmiloandrus@hotmail.com	2412 Hunts End Dr.	Sandy	UT	84092	–
147	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
148	Rob	Dubuc		150 South 600 East, Ste 2A	Salt Lake City	UT	84102	Western Resource Advocates
149			conservation@greatsaltlakeaudubon.org	P. O. Box 520867	Salt Lake City	UT	84152-0867	Great Salt Lake Audubon
150	Martin	Banks	mbanks@stoel.com	201 S Main Street., Suite 1100	Salt Lake City	UT	84111	ATI Titanium (on behalf of)
151	Tom	Tripp	ttripp@usmagnesium.com	238 North 2200 West	Salt Lake City	UT	84116	US Magnesium LLC
152	Tom	Tripp	ttripp@usmagnesium.com	238 North 2200 West	Salt Lake City	UT	84116	US Magnesium LLC
153	Joseph	Havasi	havasij@compassminerals.com	9900 West 109th Street, Suite 600	Overland Park	KS	66210	Great Salt Lake Minerals Corporation; Compass Minerals
154	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
155	Charlie	Heinritz	cthstd@comcast.net					
156	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
157	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
158	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
159	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
160	Keith	Morgan	kmorgan@mortonsalt.com					Morton Salt
161	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
162	Carmen	Bailey						Utah Division of Wildlife Resources
163	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC

Table B.6. *Commenters on the Draft Final CMP and MLP*

Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
164	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
165	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
166	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
167	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
168	Lynn	Carroll	bradlynnc@comcast.net	–	–	–	–	Wasatch Audubon Society
169	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
170	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
171	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
172	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
173	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
174	John	Neill	johnneill@utah.gov	4790 S 7500 W	Hooper	UT	84315	Utah Division of Wildlife Resources (GSL Ecosystem Program)
175	Mavourneen	Strozewski	myphotographiczen@gmail.com	–	–	–	–	–
176	Scott	Miller	smiller@thenetmarkgroup.com	4736 So Glencrest Ln	Murray	UT	84107	The NetMark Group
177	Kelly	Payne	paynek@kennecott.com	4700 Daybreak Parkway	South Jordan	UT	84006	Kennecott Utah Copper/Rio Tinto
178	Melanie	Loucks	lou3132@comcast.net	3132 South 2600 East	Salt Lake City	UT	84109	
179	Corey	Anderson	coreyda3@msn.com	–	–	–	–	NorthShore Limited Partnership
180	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
181	Dayle	Record	daylerecord@gmail.com	–	–	–	–	–
182	Charles	Uibel	cuibel@gmail.com	–	–	–	–	–
183	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
184	Dan	Willems	danwillems1@gmail.com	–	Salt Lake City	UT	–	–
185	Gerald	Harwood	gerald.harwood@greatclips.net	–	–	–	–	–
186	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
187	James	Anderson		–	–	–	–	Sailing Solution LLC
188	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
189	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
190	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
191	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
192	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
193	Lance	Fairbanks	primexchange@msn.com	–	–	–	–	Catalyst Consulting
194	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
195	Charles	Uibel	cuibel@gmail.com	–	–	–	–	–
196	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
197	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC

Table B.6. *Commenters on the Draft Final CMP and MLP*

Letter #	First Name	Last Name	Email	Address	City	State	Zip	Organization
198	Steve	Erickson		444 Northmont Way	Salt Lake City	UT	84103	–
199	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
200	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
201	Paul	Johnson	pjohnsonlaw@att.net	1990 West 3300 South	Ogden	UT	84401	Mineral Resources International, Inc.
202	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
203	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
204	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
205	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
206	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
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210	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
211	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
212	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC
213	Jennifer	Sullivan	j_sully@hotmail.com	–	–	–	–	Forestry, Fire and State Lands
214	David	Dewey	dave.dewey@hotmail.com	–	–	–	–	–
215	Hardy	Grover	hardy.grover@gmail.com	–	–	–	–	–
216	Don	Judkins	judkinsdl@gmail.com	1590 N 4150 W	Ogden	UT	84404	–
217	Mark	Reynolds	markkreynolds@yahoo.com	1423 N 3330 W	Clinton	UT	84015	–
218	Kevin	Smith	kevinsmith3206@comcast.net	–		UT		–
219	Jack	Weis	jacweis@gmail.com	–	Salt Lake City	UT	84103	–
220	Peter	Erickson	PETERGALLOWAYERICKSON@MSN.COM		–	UT		
221	James	Ipsen	JCIpsen@comcast.net	–	Salt Lake City	UT	84118	–
222	Henry	Boland	henry.boland@comcast.net	–		UT	–	–
223	Genevieve	Atwood	genevieveatwood@comcast.net	30 U Street	Salt Lake City	UT	84103	–
224	Shirley	Gorospe	greatsaltlakestory@gmail.com	PO Box 188	West Jordan	UT	84084	Backlight Pictures, LLC

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Appendix C. Recently Completed and Ongoing Ecological and Biological Research

APPENDIX C. RECENTLY COMPLETED AND ONGOING ECOLOGICAL AND BIOLOGICAL RESEARCH

- Avian botulism in marshes (Wildlife Society)
- Avian Ecology Laboratory (Weber State)
- Bear River Migratory Bird Refuge bird abundance surveys (USFWS)
- Bioenergetics of the eared grebe (DWR, USU)
- Biology and management of eared grebes (DWR, USU)
- Brine shrimp ecology of GSL (DWR, University of Notre Dame)
- Brine shrimp population and harvest census (DWR)
- Brine shrimp population dynamics (USU)
- Brine shrimp populations and lake limnology (DWR and USGS)
- Canada Goose Banding (DWR)
- Concentration and effect of selenium in California gulls (GSLEP)
- Continuing analysis of phytoplankton nutrient limitation in Farmington Bay and GSL (Central Davis County Sewer Improvement District, Utah)
- Dynamics of mercury in eared grebes (USGS, DWQ)
- Ecology of stromatolitic structures in GSL, Utah
- Evaluation of trace elements in invertebrates in GSL (USFWS)
- Food abundance and energetic carrying capacity for wintering waterfowl (USU)
- Food Chain Ecology on GSL (USU)
- GSL Botulism Study (USU)
- Interactive pathways in wetland ecosystems (USU)
- Intermountain West Coordinated Shorebird Monitoring (USFWS/Intermountain West Joint Venture)
- Limnological control of brine shrimp population dynamics and cyst production in GSL, Utah
- Mechanisms for coexistence of two swan species at varying spatial scales (USU)
- Metal concentration in waterfowl, shorebirds and waterbirds (USU, Weber State)
- Mid-winter eagle count
- North American Waterfowl Management Plan 2011/2012 Revision (USFWS)
- Pacific Flyway duck banding (DWR)
- Pacific Flyway Shorebird Project (Point Reyes Bird Observatory)
- Population status of the eared grebe (DWR)

- Preliminary analyses of selenium bioaccumulation in benthic food webs in GSL, Utah (DWQ)
- Regional wildlife assessment (UDOT)
- Restoring breeding bird population to Bear River Migratory Bird Refuge (USU)
- Salinity model/patterns in GSL (USGS, UDNR, Tooele County)
- Selenium concentration in duck club wetlands (University of Utah)
- Shorebird population status and trends (Intermountain West Joint Venture)
- Snowy plover surveys (Weber State)
- Spatial analyses of trophic linkages between basins in GSL (FFSL)
- Spatial/temporal avian census of GSL (DWR and cooperators)
- Study of the Phytoplankton Floras of GSL (UDEQ)
- Water quality and contaminant research (USFWS and FFSL)
- Wetland function assessment for beneficial related to wildlife (DWQ, EPA)
- Wetland habitat assessment (Ducks Unlimited)

Appendix D. Permitted Discharges to Great Salt Lake

Table D.1. *UDPDES Permits that Discharge to Waters near Great Salt Lake*

UPDES ID No.	Permit Name	Receiving Waters
UT0024210	Air Products and Chemical, Inc.	Stone Creek to State Canal
UT0024805	ATK Launch Systems Inc.	Blue Creek
UT0020311	Town of Bear River	Malad River to Bear River
UT0022365	Brigham City Corp	Box Elder Creek
UT0024392	Central Valley Water Reclamation Facility	Mill Creek to Jordan River
UT0021911	Central Weber Sewer Improvement District	Warren Canal and Weber River
UT0025739	Chamberlain investments	
UT0020931	City of Corinne	Bear River
UT0020303	City of Tremonton	Malad River
UT0025135	Farmers Grain Cooperative	Irrigation ditch
UT0023752	Fresenius Medical Care	Mill Creek
UT0021130	Grantsville City	Blue Lakes to GSL
UT0000051	Kennecott Utah Copper, Llc	002 C-7 Ditch 005 Jordan River 007 C-7 Ditch 009 Pine Canyon 010 Butterfield Creek
UT0025569	Little Mountain Service Area	GSL
UT0021440	Magna Water and Sewer District	Kersey Creek
UT0025577	Oldcastle Precast	Mill Creek
UT0000116	Pacificorp--Gadsby	S L Abatement Canal to City Drain to Sewage Canal to Gilbert Bay
UT0025119	Questar Infocomm-Wasatch Chemical Superfund Site	700 West Ditch
UT0024767	Rubber Engineering	Storm Drain to Mill Creek
UTG640033	Salt Lake City Corporation	Jordan River
UT0024988	Salt Lake City International Airport	City Drain and Surplus Canal
UT0021636	South Davis Sewer District-North Plant	State Canal to Farmington Bay Bird
UT0021628	South Davis Sewer District-South Plant	Jordan River
UT0024384	South Valley Water Reclamation Facility	Jordan River
UT0025241	Stansbury Park Wastewater	Unnamed irrigation ditch to GSL
UP000053	Tartar Gate West	Corrine Wastewater Treatment Facility
UTS0025089	Weir Specialty Pumps	Storm drain to Jordan River

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Appendix E. Future Research Needs

APPENDIX E. FUTURE RESEARCH NEEDS

Throughout the 2013 GSL CMP revision process, efforts to better understand the unique and complex GSL exposed numerous data and knowledge gaps. To effectively manage GSL, FFSL and other agencies need to better understand the lake's ever-changing characteristics. This list is a compilation of research needs identified by the Planning Team and SWCA's resource specialists. The list also includes most recent hot topics identified by the GSL Technical Team.

Long-term planning and resource management benefit from more data and information. The list below discusses the most striking and critical research needs that will further the understanding the aspects of the lake that are directly related to management and planning. The list highlights future research opportunities for federal and state governments, universities, industries, and organizations. It also serves as a foundation from which all agencies and organizations can build on. The list is intended to be a "living" document that can be updated as projects are complete and the need for new research is understood. The list should be updated quarterly by the GSL Coordinating Committee (discussed in section 4.4) or by the GSL Technical Team. A methodology for prioritizing research projects could also be completed by the Coordinating Committee and/or the Technical Team. To inform the agencies and the public about GSL research efforts, this list could be placed on FFSL (and other agency) websites.

1. Water

Water quality:

- Water quality criteria: Identify water quality criteria, assessment methods, and standards that are supportive of GSL beneficial uses.
- Mercury: Further characterize the fate and transport, biological processing, and impacts of mercury on sensitive species and human health.
- Selenium: Further investigate the physical and biological processes that affect the fate and transport of selenium in GSL, including biological factors, interactions with mercury, bioaccumulation, and sequestration in stable molecular forms.
- Define a trophic condition that is supportive of native biota, especially in Farmington and Bear River bays, including thresholds for indicators such as summer chlorophyll *a* concentrations and invertebrate diversity.
- Technology: Evaluate technologies that could be used to reduce or prevent the methylation of mercury in GSL.
- Other toxins: Identify the level of toxins, other than mercury and selenium, in the water column and in the sediment that does not impair populations of significant species. Characterize the current concentrations of toxins throughout the lake. These toxins could include arsenic, cyanotoxins, avian botulism, and endocrine disrupting compounds.

Salt cycle:

- Salt balance: Continue and expand research on the salt cycle and salt balance for GSL. Research could include analysis and quantification of riverine and atmospheric inputs to each bay and total extraction from the lake.

- Salt sinks: Research could also seek to refine data on salt sinks within the GSL system, including amounts of precipitated salt in the North Arm and in evaporation ponds, and amounts of salt in solution in two arms of the lake and DBLs. Investigation of cycling among salt sinks at varying lake conditions and continued collection of brine composition data with specific elemental analysis would be important components of research.

Circulation of GSL:

- Positive and negative implications of increased circulation between bays; water quality and salt balance and interlinkages; more info on sources of nutrients, salt, etc. (currently assumptions).
- Circulation model: Identify through the use of models and monitoring the processes that drive GSL circulation. Characterize how circulation relates to salinity, salt balance, and the sustainable level of extractable ions in each embayment of the lake.
- DBL: Determine the extent to which the DBL would form at varying lake levels and characterize the importance of the DBL in terms of fundamental lake processes including biogeochemical cycling of mercury, nutrients, and selenium.
- Currents: Determine the speed and paths of currents in the South and North arms of the lake. The last scientific study of the South Arm currents was done in 1991. This study was done after the breaching of the causeway in 1984, but there has been no current scientific study done in the North Arm.

Mapping:

- Bathymetry: Create a bathymetry map and topographic map, from the multiple sources available, with at least 1-foot resolution from elevations 4,191 to 4,217 feet. Ideally, new bathymetry data should be collected to accurately estimate volume in each bay at varying lake levels.

2. Wetlands

Water quality:

- Pollutant retention: Identify the mechanisms by which different wetland types immobilize and retain nutrients, toxic pollutants, and sediment from GSL inflows. Quantify how fast, how much, and how long pollutants are retained in the various wetland types found around GSL.
- Water quality indicator: Develop an indicator of water quality appropriate for delivery to wetlands found around GSL.
- Toxicity: Identify the levels at which toxins begin to impair the ecological function of wetlands.

Mapping:

- Wetland types: Develop a current map of wetland types and develop spatial models of the areal extent and the class of wetlands around GSL. Re-mapping every three to five years across a range of lake levels would increase confidence in wetland management options and forecasting scenarios.
- Wetland management units: Identify and map all wetland management units including state WMAs, mitigation banks, preserves, and private hunting clubs.

Hydrography: The main surface water inflows to GSL are regulated rivers and streams, and much of the lake's surface flow first passes through impounded wetlands. However, there are currently no complete, freely available spatial data identifying these flow systems, especially those within and between managed wetlands.

3. Air Quality

- Windblown dust: Identify areas prone to generation of windblown dust and quantify the contribution of windblown dust from exposed mudflats and playas around GSL to air quality violations in Salt Lake, Weber, and Davis counties.

4. Climate

- Climate change: Identify potential impacts of climate change on GSL lake level and water chemistry.

5. Biology

Microbial ecology (including phytoplankton and bioherms)

- Phytoplankton: Identify the maximum and optimal level of phytoplankton in winter and in summer that is supportive of brine shrimp in Gilbert Bay.
- Bioherm function: Characterize the biological component(s) and determine the importance of the bioherms in the lake.
- Bioherm extent: Determine the extent of bioherms that is supportive of the food chain, including attached periphyton, brine flies, and their consumers.
- Microbial diversity: Characterize the types of bacteria, algae, and other microbes that live in the South and North arms of the lake and evaluate how and why they change over season and with varying lake levels and salinity.
- Methylation of mercury: Determine the role of microbes in the methylation of mercury in the lake.
- Nutrient cycling: Evaluate the role of algae, cyanobacteria, and bacteria in the cycling of nutrients in the lake.
- Cyanotoxins: Measure the concentration of cyanotoxins, especially in Farmington Bay, and evaluate impacts to recreation uses.

Plants

- Submerged aquatic vegetation: Characterize the linkage between submerged aquatic vegetation branch density and other measures of support for the food web in impounded wetlands and in the open water of Bear River and Farmington bays.
- *Phragmites*: Identify possible uses for *Phragmites* obtained from the lake (e.g., fuel, fiber) and create incentives for harvest and use.

Invertebrates

- Macroinvertebrates: Characterize and quantify macroinvertebrate populations that are supportive of waterfowl and other waterbirds in the wetlands around GSL.

- Brine fly larvae: Characterize and quantify brine fly larval populations that are sufficient to support waterbirds.
- Terrestrial transfer of toxins: Characterize the terrestrial transfer of toxins that enter the food chain in GSL (e.g., mercury transfer from brine flies, to terrestrial invertebrates, to birds).

Fish

- Forage fish: Identify the quantity and species optimal for supporting fish-eating birds that forage in Farmington and Bear River bays as well as wetlands around GSL.

Birds

- Gunnison Island Rookery: Define and evaluate threats to Gunnison Island as a world-class American white pelican rookery. Define the process (or processes), timeline (or timelines), and work needed to identify alternatives that ensure the viability of the rookery.

6. Minerals and Hydrocarbons

- Mineral balance: Update estimated GSL mineral balances in North and South arms.
- Optimal brine level for extractive industries: Identify optimal brine composition for specific bays in GSL to support all mineral extractors and brine shrimp production.
- Salt deposition: Determine the amount of salt that is deposited on the floor of the North Arm of the lake (see also salt balance under Water).
- Planning horizon for mineral extraction: Define processes for establishing planning horizons for minerals extracted from GSL. Evaluate alternative approaches to estimate mineral balances of GSL. Specifically, define scientific and administrative processes for determining the remaining economically extractable quantity and rates of removal and/or sequestration of minerals from GSL; the quantity and rate of those minerals entering the lake; and the processes or conditions that affect rates of removal and replenishment.

7. Economic and Sociological Trends

- Ecosystem services: Determine the economic value of GSL-related ecosystem services to migratory bird populations (including the value of the Gunnison Island rookery), over-wintering bald eagles, brine shrimp, invertebrates, green algae, etc.
- Lake effect snow: Determine the economic value of lake effect snow on the local economy. A study of direct and indirect effects of the economic relationship between GSL and the snow produced on the Wasatch Range could increase our economic understanding of our reliance on this natural phenomenon.

Appendix F. SWCA Environmental Consultants List of Preparers

Table F.1. *SWCA Environmental Consultants List of Preparers*

Name	Title	Resource
Laura Burch Vernon*	Senior Planner/GSL CMP Project Manager	Minerals and hydrocarbons, land use, visual resource management, economic and social trends, public involvement
John Christensen	Geologist	Minerals and hydrocarbons
Patrick Crowley	Water Resource Specialist	Climate, water, law enforcement and search and rescue
Jarod Dunn	Economist	Economic and social trends
Erica Gaddis	Senior Water Resource Scientist	Air quality, water
Hope Hornbeck	Biologist	Biology: aquatic biology, reptiles, amphibians, mammals
Rachel Johnson	GIS Specialist	Mapping
Eric McCulley	Ecologist	Biology: birds
Brian Nicholson	Wetlands Specialist	Ecosystem, wetlands
John Pecorelli	Graphics Designer/Editor	—
Dave Reinhart	GIS and Database Specialist	Mapping and public involvement
Krislyn Taite	Archeologist	Cultural and paleontological resources
Linda Tucker Burfitt	Technical Editor and Formatter	—
Christina White	Planner	Economic and social trends
Sue Wilmot	Environmental Specialist	Recreation, public involvement

In June 2012, Laura Burch Vernon was hired by the Division of Forestry, Fire and State Lands as a land use planner and was responsible for coordinating and finalizing the plan with SWCA through March 2013.

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