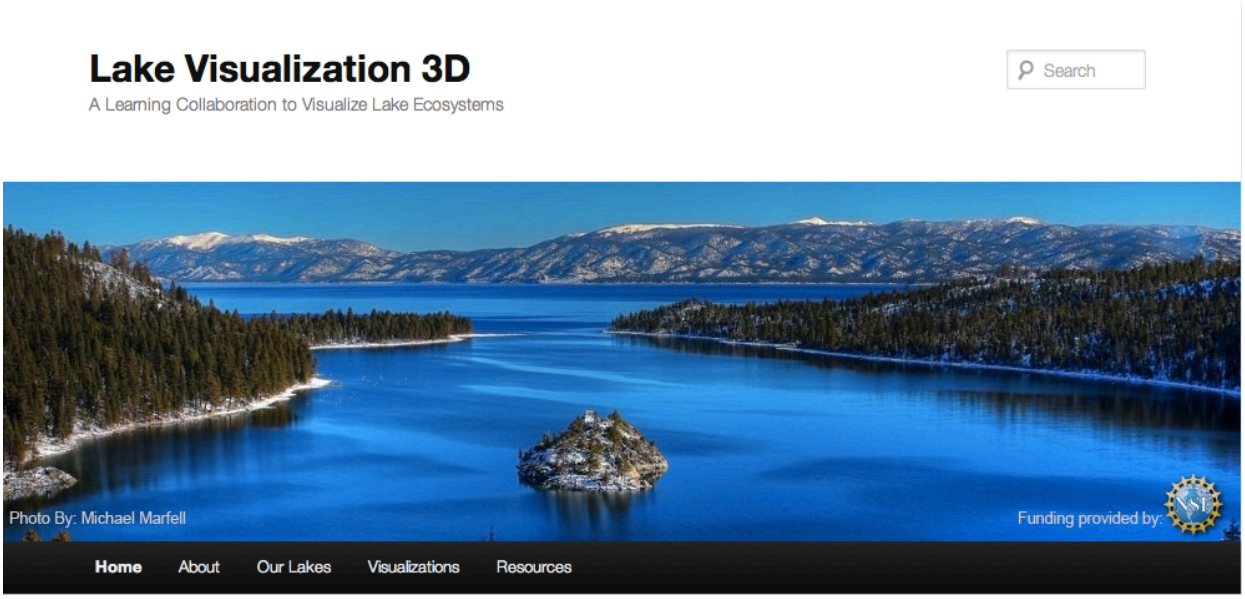
3D Visualization Tools for Enhancing Awareness, Understanding and Stewardship of Freshwater Ecosystems

Front-End Evaluation Report



Prepared by:

Steve Yalowitz, Ph.D.
Jane Morgan Alexander, Ed.M.
Kara Hershorin, M.A.

Audience Viewpoints Consulting
Herndon, VA

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EXECUTIVE SUMMARY

Background

The National Science Foundation (NSF) awarded an Informal Science Education (ISE) grant, since renamed Advancing Informal STEM[1] Learning (AISL) to a group of institutions led by two of the University of California, Davis's centers: the Tahoe Environmental Research Center (TERC) and the W.M. Keck Center for Active Visualization in Earth Sciences (KeckCAVES). Additional partner institutions were the ECHO Lake Aquarium and Science Center (ECHO), Lawrence Hall of Science (LHS) at the University of California, Berkeley, and Audience Viewpoints Consulting (AVC). The study was designed to examine how 3-D visualizations could most effectively be used to improve the general public's understanding of freshwater lake ecosystems and Earth science processes through the use of immersive three-dimensional (3-D) visualizations of lake and watershed processes, supplemented by tabletop science activity stations. Two iconic lakes were the focus of the study: Lake Tahoe in California and Nevada, and Lake Champlain in Vermont and New York, with products readily transferable to other freshwater systems and education venues. The project planned to implement, evaluate, and disseminate knowledge of how 3-D visualizations and technologies could be designed and configured to effectively support visitor engagement and learning about physical, biological and geochemical processes and systems. An additional part of the project was to evaluate how these technologies could be transferred more broadly to other informal science venues and schools for future career and workforce development in these critical STEM areas. For more information about the project see: http://www.nsf.gov/awardsearch/showAward?AWD_ID=1114663&HistoricalAwards=false and www.lakeviz.org .

Purpose of the Study and Evaluation Questions

The purpose of the evaluation was to gather feedback from museum professionals and the general public about the proposed 3D visualization project and its related components. Additionally, the study aimed to assess the current understanding of visitors around related terms and concepts and examine visitor preferences for certain types of activities and experiences.

[1] STEM stands for Science, Technology, Engineering and Math, four subjects that the National Science Foundation focuses on for the AISL and other related programs.

The main evaluation questions driving the project were the following:

1. What are current technological best practices for ISE institutions communicating STEM content about freshwater ecosystems? Which aspects of the project are ISE professionals most interested in?
2. What are current and potential visitors' attitudes and knowledge about freshwater ecosystems and habitats?
3. What are the entry points (i.e., activities and content) for engaging audiences in the content?
4. How can the project promote and encourage environmental awareness and stewardship among those who engage in the various components?

Methods and Characteristics of the Samples

All data were collected between April 11, and August 26, 2012. The evaluators developed instruments and procedures for this study in consultation with the project team. Data were collected by AVC and in some cases project staff through a variety of qualitative and quantitative methods. Online surveys were used to access the ISE professional community, while focus groups and on-site interviews were used to get feedback from the general public at the three partner sites: the Tahoe Environmental Research Center (TERC), the Lawrence Hall of Science (LHS) and the ECHO Lake Aquarium and Science Center (ECHO). One of the focus groups at TERC was conducted in Spanish, and the on-site interview materials were available in Spanish at the Lawrence Hall of Science, which typically has a larger population of Spanish-speaking visitors than the other two sites.

The data were coded and/or entered into statistical analysis software and open-ended items and data were analyzed using qualitative and quantitative methods appropriate to the data and sample sizes. Where appropriate, tests of statistical significance were applied.

Method	**Sample size (n= # of individuals)**
1. ISE Professionals Online Survey	n=42
2. Focus Groups	n=70
3. On-site Interviews	n=268

1. ***ISE PROFESSIONALS ONLINE SURVEY –*** (n=42) In order to understand which parts of the project the professional community would be most interested in and to understand their current technological capacity for employing 3D technology, a select group of ISE professionals who work at institutions that interpret freshwater ecosystems were sent an invitation to an online survey about the project. An invitation was also posted to the Association of Science-Technology Centers (ASTC) listserve.

2. ***Focus Groups –*** (n=70) A total of six focus groups, three at each of the project partners (TERC, LHS and ECHO) were conducted. Each site included an adult focus group and an upper elementary school/middle school focus group; the adult focus group at TERC was conducted with Spanish-speakers. These provided a more qualitative and in-depth understanding.

3. ***On-site Interviews –*** (n=268) To gather a more representative sample of the general public, on-site interviews were conducted at the three partner sites (TERC, LHS, and ECHO) with adult visitors. The interview focused on understanding the public's current knowledge about freshwater ecosystems and related concepts, as well as their interest in specific topics and approaches that could be covered in the project.

Main Findings

The main findings section is centered around the evaluation questions listed above.

1. What are current technological best practices for ISE institutions communicating STEM content about freshwater ecosystems? Which aspects of the project are ISE professionals most interested in?

Current Practices: Of the select institutions represented in the ISE Online Surveys, three quarters were already presenting information about freshwater ecosystems, and four out of five were already encouraging stewardship behaviors around freshwater ecosystems. The most common stewardship behaviors were general conservation behaviors, specifically conserving and managing water, controlling invasive species, restoring land through cleanup initiatives and planting native plants. The high degree of encouraging behaviors was not surprising, given that the evaluation focused on getting feedback about the project from institutions that would be most inclined to embrace 3D visualizations of freshwater ecosystems.

Interest in Types of Exhibits: In terms of potential approaches they could employ around freshwater ecosystems, institutions were most interested in the 3D visualization, computer models, and simulations, most likely because these approaches were high technology and not as commonly used by the group. When asked to comment on the three big ideas (see "Big Ideas" section below) being proposed for the project, ISE professionals responded positively to the ideas, and also had specific suggestions about how to make them more relevant to their visitors. These suggestions include providing personally relevant as well as more local examples, as well as the relationship between humans and freshwater ecosystems: how humans positively impact freshwater ecosystems and how freshwater ecosystems impact humans.

3D Visualization and Tabletop Exhibits: In terms of the types of tabletop exhibits, respondents were most interested in those that allowed visitors to examine or experiment as well as play or interact, suggesting that the interactive and hands-on aspects were perceived as some of the more attractive elements to visitors. There also seemed to be solid

interest in the 3D visualization, with almost two thirds saying they would either probably or definitely be interested in having a 3D visualization at their institutions. The most interesting aspects of the 3D visualization to ISE professionals were the ability to place content in a local geographic context, have user controlled/hands-on experiences, and being able to engage visitors to a higher degree than with more traditional exhibit types. By far the most common perceived barrier to not including this type of visualization was cost, mentioned by almost four-fifths of respondents; the second most common perceived barrier was having enough space to set up the visualization, noted by two-fifths of respondents.

2. What are current and potential visitors' attitudes and knowledge about freshwater ecosystems and habitats?

Knowledge of Freshwater Ecosystems and Watersheds: In trying to get a sense of peoples' understanding of what makes up freshwater ecosystems, focus group and on-site interview participants were asked what comes to mind when they hear the term "freshwater ecosystem." The top four terms mentioned were "fish," "rivers," "water" and "lakes." While not as top of mind as the types of freshwater ecosystems, some visitors did mention terms specifically related to the environment like "clean" and "pollution." Nearly one third of respondents incorrectly identified a freshwater ecosystem, while almost a quarter needed to be prompted before they could name a freshwater ecosystem, indicating a significant gap in the visiting public's ability to recall specific freshwater ecosystems. However, when given an example and prompted to name other types of freshwater ecosystems, people again were most likely to mention rivers, lakes, streams, ponds and wetlands. Additionally, during the focus groups people also talked about the plants and animals that live in the freshwater ecosystems, while some brought up the relationship and impact humans have on these ecosystems. Spanish-speaking groups seemed to have less of an understanding of freshwater ecosystems, or were at least more hesitant in talking about them, and students tended to focus more on the plants and animals than the adult groups. Given that two of the focus group sites (TERC and ECHO) were conducted next to very large lakes, it is not surprising that with some prompting people could talk about freshwater ecosystems, though they did not make an immediate connection between the term "freshwater ecosystem" and the knowledge that was already there. This may or may not translate to other sites around the country, although people in the San Francisco Bay Area (at LHS) seemed to be relatively familiar with freshwater ecosystems in general, specifically Lake Tahoe.

The project team was also curious about the extent to which it would need to explain the term "watershed" to participants, so visitors were asked to define the term. In the on-site surveys visitors struggled to define a watershed, with only a little more than one out of three being able to give either a partially correct or correct answer. In fact, only just over one in ten gave a correct definition of the term watershed. When asked about the specific watershed they lived in, slightly less than half were able to describe any aspect about their local watershed; of those who were able to describe something, about a quarter could describe how the watershed functioned, and a little more than one out of ten described their watershed by name. This indicated that the team would need to define and describe

watersheds to the general public when engaging them around this topic, and most likely need to provide a link to local watersheds if they wanted to have visitors make those connections.

Big Ideas: Three Big Ideas for the project developed by the team were presented to the adult focus groups: 1) water connects to water, land, air and life, 2) freshwater ecosystems are dynamic, complex and are constantly changing, and 3) humans study, manage and impact freshwater ecosystems on a local as well as a global scale. The adults generally liked the Big Ideas, although they mentioned some ways that the Big Ideas could be modified or further considered. There was some confusion with Big Idea 1 about how water can connect to water, and what the water-air connection was. There was limited conversation about Big Idea 2 and a lot of discussion about Big Idea 3 about the human relationship with freshwater ecosystems. Focus group participants emphasized that the relationship is dynamic and two-directional: not only do humans impact freshwater ecosystems, but these ecosystems also affect humans. The Spanish-speaking focus group was much more interested in Big Idea 3, compared to the other two Big Ideas.

3. What are the entry points (i.e., activities and content) for engaging audiences, in the content?

Personal Connections: The top four reasons adult visitors felt connected to freshwater ecosystems were because of being close to or familiar with particular places, recreational activities or vacations, being attracted to the wildlife or beauty there, or because they grew up going to certain freshwater ecosystems. Given their locations, it was not surprising that focus groups and on-site interviews with adults at TERC and ECHO showed the strongest connections to Lake Tahoe and Lake Champlain, respectively. At LHS, these ecosystems being places of recreation or vacationing was the most important factor, followed by the proximity of freshwater ecosystems, and being attracted to the wildlife and beauty of these areas. Being close to or familiar with freshwater ecosystems was also an important factor for those at LHS, second only to these freshwater ecosystems being places of recreation or vacation. Having jobs or family members related to freshwater ecosystems was not very common, but was more common at TERC and ECHO based on these institutions being located close to very large lakes.

The Spanish-speaking focus group at TERC had a more challenging time coming up with specific connections they had to freshwater ecosystems, even though many participants lived close to Lake Tahoe. It may have been the result of this particular group of Spanish-speaking adults having less of a professional association with the institutions and lakes, compared to the English-speaking groups. It is also possible that were other cultural or economic factors relating to this difference, including reduced leisure time or access to recreational activities around these freshwater ecosystems. Each of the student focus groups had little trouble coming up with multiple examples of how they had connections to freshwater ecosystems; the main connection was often through recreational activities, and students also mentioned living near and having relatives who had jobs associated with freshwater ecosystems.

3D Visualization: It was important in this evaluation to understand how the 3D visualization could be applied to other lakes and freshwater areas. While the 3D version could be shown to the focus groups at TERC, a portion of a 2D version (without the 3D glasses) was projected onto a screen for focus group participants at ECHO and LHS. This version included a narration and a pre-determined "flight" around Lake Tahoe that was a less dynamic version than the live docent-led 3D visualization shown at TERC.

Focus group participants were generally pleased with the 2D version, but some said that the visualization was not as exciting as it could have been. This was especially true for the student groups, who suggested changing the music, the narration, and adding animals (the adult groups also mentioned the animals). However, participants also clearly saw the potential for this type of visualization, that it could show changes over time and provide unique experiences and perspectives not possible with more traditional approaches. Students in particular believed that a good 3D visualization would help keep their attention and would ultimately result in more learning than a non-3D version. Given that there was not a Spanish version of the visualization, the Spanish-speaking group suggested providing a version in Spanish, and a couple of Spanish-speaking adults suggested talking more about the human impact on the lake.

Tabletop Exhibits: Focus group participants were shown pictures and given descriptions of eight different tabletop activities being considered for the project, and asked to say which ones they were most interested in and why. For English-speaking adults, the four most popular tabletop activities were *Working Model, Play and Interact, Multimedia/iPad,* and *Small Experiment.* When asked why they chose the specific activities, answers included using real time data, enjoying hands-on experiences and being interested in technology. For the Spanish-speaking group, the four most popular tabletop activities were *Observe Closely, Tactile Display/Sculpture, Play and Interact* and *Small Experiment.* For middle school students, the favorite tabletop activity, by far, was *Play and Interact*, mostly because students thought it would help them visualize and understand exhibit concepts. The next most popular were *Multimedia/*iPad, because students said they enjoy technology showing scientific processes, and *Make and Take,* because students enjoy creating or making things. This was important to note, given that there is often the implicit assumption that students will almost always prefer technology-related activities, but two of the top three chosen were not technological in nature. Most of the focus groups mentioned whether having high technology activities that used smartphones or iPads would reduce the accessibility for some individuals, especially those of lower income levels. Given the differences in opinions across groups, it would likely be best to offer a variety of tabletop activities when a variety of audiences are being served, keeping in mind the preferences mentioned above.

Content: Included in the interview protocol were five questions related to scientists who study lakes that could be addressed by the project, meant to inform the team about areas that visitors would be most interested in. Evaluators showed interview respondents five questions representing potential 3D visualization project topics and asked visitors to select the two questions they found most interesting. Topics included how specific scientists got interested in studying lakes, the questions they ask in their research, how they collect the data, the kinds of data they collect, and the specific tools and technologies they use to

collect data. The most popular question, by far, was what questions scientists are trying to answer, followed by the tools and technologies they use, and the kinds of data they are collecting. Respondents were only somewhat interested in how the scientists collect data, and generally not interested in how specific scientists got interested in studying lakes.

4. How can the project encourage environmental awareness and stewardship among those who engage in the various components?

Perceptions of Human Impact: Various focus group discussions led to mention of how humans impact freshwater ecosystems, which is not surprising given that many of the focus group participants either had a connection to or were frequent visitors of the partner institutions that happened to be near lakes. One of the project's Big Ideas focused on conservation, stewardship and how humans and these systems interact; quite a few focus group participants felt that the human impact portion of the Big Idea should be emphasized even more. In an attempt to understand how visitors perceived the impacts humans have on freshwater ecosystems, a series of questions in the on-site interviews examined respondents' perceptions of both positive and negative human impacts. Interestingly, even when visitors were asked about the positive impacts humans have on freshwater ecosystems, they still focused mostly on the negative impacts. In fact, visitors at ECHO and LHS gave very low ratings for how positively humans were impacting freshwater ecosystems; TERC visitors rated the positive impact as higher than the other two, but still gave humans middling marks on the scale. When asked to explain their somewhat negative ratings about positive impacts, visitors focused on the pollution humans were causing, talked about the fact that humans on balance were hurting more than helping freshwater ecosystems, and that humans don't know much or care about freshwater ecosystems. Only two out of five, in answering the question about positive impacts, actually talked about positive impacts: they mentioned those actively taking care of freshwater ecosystems, that there is increased knowledge on this topic, and how humans are repairing previous damage done by humans. In contrast, when asked about the negative impacts humans had visitors could easily come up with examples of the negative impacts, many of which were the same impacts they mentioned in responding to the question about positive impacts of humans. These included comments about pollution, lack of awareness and caring, harming of wildlife, and the negative impacts of development, agriculture and industry on freshwater ecosystems. Overwhelmingly, the perception among this group was that did far more harm than good.

Personal Behaviors: In terms of their own actions, quite a few of the visitors in the focus groups brought up examples of how they were acting to help freshwater ecosystems. Meanwhile, four out of five visitors in the on-site interviews said they were already taking actions to reduce their impact on freshwater ecosystems; this was consistent across the three partner sites of TERC, ECHO and LHS. When asked which actions they were already taking, the most common already occurring behaviors were recycling, conserving water, eco-friendly landscaping or gardening, and actively cleaning up the environment. An important part of this study was to understand which behaviors visitors were not already doing but might be receptive to engaging in. In this manner, the project could focus on

encouraging behaviors with the highest possible return. The actions visitors were most open to beginning to do were installing a rain barrel, volunteering, composting food waste, and using phosphorous-free fertilizers. In fact, installing a rain barrel was by far the most popular response, with nearly twice as many respondents saying they would consider doing this above the next most popular behavior. The most common reason for why they would consider adopting a new behavior was convenience; this has implications for not only which behaviors the project team could suggest, but that they should focus on helping people see the behaviors as convenient.

ISE PROFESSIONALS SURVEY SUMMARY

OVERVIEW

In order to ensure that the project was relevant for the Informal Science Education (ISE) field, an online survey was used to gather feedback from science-based institutions about their interest in the *3D Visualization Tools for Enhancing Awareness, Understanding, and Stewardship of Freshwater Ecosystems* project and its components. The survey covered topics including interest in 3D technology, reactions to tabletop activities and content, and institutional capacity and feasibility for immersive 3D visualizations at these institutions. The project team will incorporate the findings into the planning of the project, taking into account both the abilities of institutions to support the technology and their specific interests in communicating about freshwater ecosystems using 3D technology. Rather than determining if the project would be useful, the main goal was to fine-tune the approaches and thinking around the deliverables so it would be maximally useful to the field.

Method and sample

Two recruiting approaches were used to gather feedback from the field. In the first, the team pre-identified 40 institutions that currently present information on freshwater ecosystems and sent and invitation directly to them to participate in the survey. In some cases, project team members were also able to provide individual names and contact information at these institutions; in other cases, an institution was identified and the evaluators located and identified the appropriate person to contact. A second approach was employed to gather a broader sampling from ISE institutions, with an invitation to participate in the survey posted by a project team member on the Association of Science-Technology Center (ASTC) listserv. Those who clicked on the link in the email invitation filled out a web survey (see Appendix A for the survey instrument).

Overview of the survey instrument

The ISE Professionals Survey included a number of closed- and open-ended questions. The survey covered the following topics:

- Name, affiliation and title of the individual completing the survey
- Primary audiences served by the institution
- Whether the institution presents any information about freshwater ecosystems
- Whether their institution encouraged visitors to engage in stewardship behaviors; and if so, which behaviors
- Initial interest in content related to the 3D visualization project
- Likelihood of using proposed tabletop interactive exhibits about lake ecosystems at their institution

- Likelihood of using an immersive 3D visualization at their institution, as well as the identification of any barriers preventing them from installing this exhibit
- What they found most interesting about the 3D visualization project
- Whether they would like to be engaged in the project.

The ISE Professional Surveys addressed the following evaluation questions:

1) What are the current technological best practices for ISE institutions communicating STEM content about freshwater ecosystems?

Sample demographics

A total of 42 ISE professionals completed the online survey, from April 11, 2012 to May 7, 2012 while it was "live" and available to collect responses. Since the survey allowed for multiple responses per link and participants were encouraged to forward the invitation to other members of their institution, a response rate could not be calculated. Since the invitation was sent to the ASTC list serve, it is estimated that more than 1,200 informal science professionals had the opportunity to view the invitation during the survey period. As such, this sample should be treated as self-selected and not as representative and generalizable across the ISE field. Of the 42 respondents, a total of 19 were identified by the project team and invited directly via email, while 23 of the 42 respondents came from the ASTC listserv invitation.

Table 1 shows the different institutions that were included in the sample, including some of the institutional characteristics. More than one staff person filled out the survey at two of the institutions. In looking at respondents' titles, staff came from a wide variety of roles and departments, including Education, Exhibits, Researchers, Directors, as well as Professors, Scientists, and other positions. In terms of the audiences the institutions focused on, staff reported that almost three quarters (71%) focused on families with young children, while a majority also focused specifically on school groups (60%) or adults (57%). Over three quarters (76%) of the survey respondents worked for institutions that were currently presenting information about freshwater ecosystems.

Table 1: Institution sample description (n=42), ISE survey

Institution name	Count (n=)	Percent
Bell Museum of Natural History	3	7%
Shedd Aquarium	2	5%
Arizona Science Center	1	2%
Arizona-Sonora Desert Museum	1	2%
CAISE	1	2%
Colorado State University	1	2%
Columbia Gorge Discovery Center	1	2%
ExplorationWorks Science Center - Helena	1	2%
Finger Lakes Institute at Hobart and William Smith	1	2%

Colleges		
Great Lakes Science Center	1	2%
Idaho Museum of Natural History	1	2%
John F. Kennedy University	1	2%
Lake Erie Nature & Science Center	1	2%
Milwaukee Public Museum	1	2%
Museum of Science	1	2%
Museum of the Earth	1	2%
National Park Service - Crater Lake National Park	1	2%
Nauticus	1	2%
New England Aquarium	1	2%
New York Hall of Science	1	2%
NOAA	1	2%
NOAA Chesapeake Bay Office	1	2%
Ogden Nature Center	1	2%
Oregon State University/Hatfield Marine Science Center	1	2%
Paleontological Research Institution and its Museum of the Earth and Cayuga Nature Center	1	2%
Rochester Museum & Science Center	1	2%
Royal Botanical Gardens	1	2%
Rutgers University	1	2%
Science Museum of Virginia	1	2%
Science Spectrum	1	2%
Sciencenter	1	2%
ScienceWorks Hands-On Museum	1	2%
Terry Lee Wells Nevada Discovery Museum	1	2%
The Exploratorium	1	2%
U.S. Geological Survey	1	2%
UIC / NySci	1	2%
UPCLOSE	1	2%
Unidentified	2	5%
Primary audiences		
Families with young children (0 to 9 years old)	30	71%
School groups (Elementary, Middle, High School)	29	60%
Adults (18 years and older)	24	57%
Tweens (10 to 12 years old)	18	43%
Scientists/STEM professionals	17	41%
Teens (13 to 17 years old)	8	19%
Other	9	21%

Institution presents information on freshwater ecosystems		
Yes	32	76%
No	10	24%

RESULTS & DISCUSSION

Interest in 3D visualization content

Institutions presenting information on freshwater ecosystems were asked whether they were interested in covering a topic, but also able to indicate that they were already covering it (see Table 2). Topics already being covered by a number of institutions included the following: biology/ecology, watersheds, lakes/rivers/streams, and water cycle. There was higher interest in 3D visualizations and computer models and simulations, followed by LIDAR/sonar and physical processes/forces on the lakes.

Table 2. Level of interest in freshwater ecosystem topics (n=32), ISE survey

Topics	Count (n=)	Interest Level		
		Currently Cover	Not interested	Interested
3D visualization	25	5	-	20
Computer models and simulations	25	5	2	18
LIDAR and sonar	20	3	5	12
Physical processes/forces on lakes	22	5	6	11
Geological processes	23	12	2	9
Watersheds	26	19	-	7
Lakes, rivers, streams	23	17	-	6
Water cycle	23	17	2	4
Properties of water	21	13	4	4
Biology/ecology	25	23	-	2
Other	6	5	-	1
Total	32			

Respondents were asked if their institution currently encouraged visitors to engage in stewardship behaviors related to freshwater ecosystems. The large majority of institutions in the sample (79%) were already encouraging visitors to engage in stewardship behaviors.

Table 3. Encouraging stewardship behaviors (n=28), ISE survey

Stewardship Behaviors	Count (n=)	Percent
Encourages stewardship behaviors	22	79%
Does not encourage stewardship behaviors	6	21%
Total	28	100%

When asked which stewardship behaviors they were already encouraging, respondents mostly focused on minimizing human impact, conserving and managing water, controlling invasive species, restoring land through cleanup initiatives and planting native plants.

> *We also encourage sustainability, awareness of water processing, awareness of invasive species/algal blooms/dead zones/etc. Some of this is done through exhibits, and some solely through education programming.*
>
> *Invasive species control, monitoring, and management; tree plantings; roadside cleanups; stream monitoring; green infrastructure home applications; beach cleanups; etc.*

The complete list of examples of stewardship behaviors is included in Appendix B.

Interest in 3D visualization big ideas

Members of the project team were looking for feedback about the three proposed "big ideas" that would drive the design and development of the project's deliverables. The big ideas are the overarching concepts that the project team hopes to encourage participants to notice and/or learn while engaging the project's deliverables.

1) Water connects all Earth systems.
2) Freshwater ecosystems are dynamic, complex and diverse.
3) Humans impact freshwater ecosystems both locally and globally.

Respondents were asked to provide comments on the appropriateness of the project's "big ideas" related to freshwater ecosystems. Table 4 details all of the responses from participants, broken down by which question they were commenting upon.

Comments for Big Idea 1 about "water connects all Earth systems" suggested the need for more information about the specifics of this idea, and that it could too broad, taking the focus away from freshwater.

Comments about Big Idea 2 for "freshwater ecosystems are dynamic, complex and diverse" focused on unpacking what is meant by "dynamic, complex, and diverse" and also that specific, local examples could be employed.

Big Idea 3 that "humans impact freshwater ecosystems both locally and globally," had the largest number of responses; respondents suggested that human impact can be positive and it would be good to incorporate the message that not only do freshwater ecosystems affect humans, but humans are impacted by these freshwater ecosystems as well.

Other responses reaffirmed the appropriateness and importance of all three big ideas. In the general comments, multiple respondents mentioned the importance of making the big ideas more relevant to people, either through personal examples or presenting things on a smaller, more manageable scale.

Table 4. Respondent comments about proposed big ideas (n=20), ISE survey

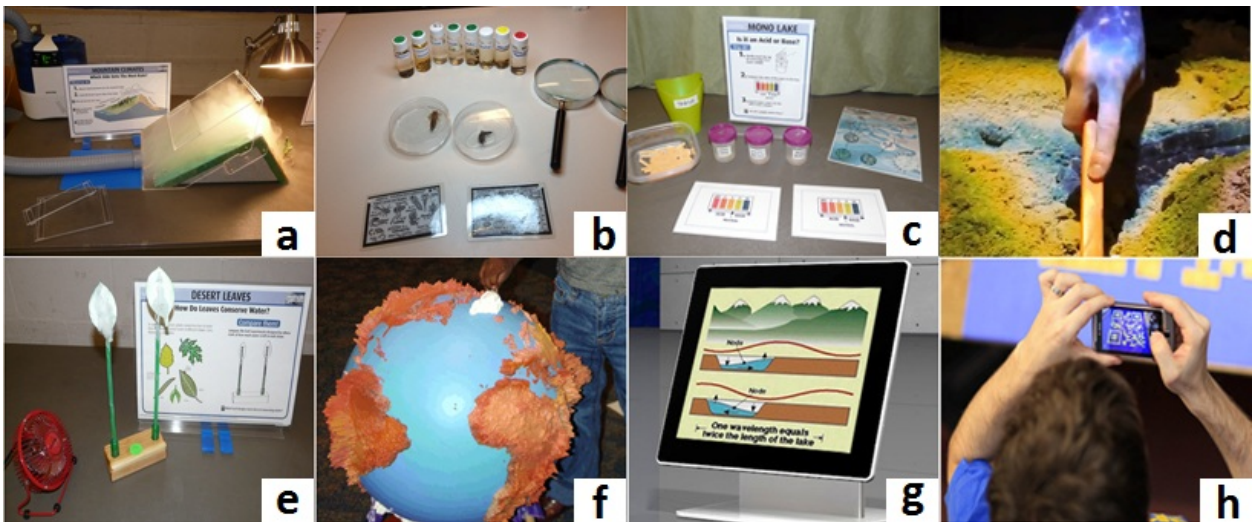
Big Idea 1: Water connects all Earth systems
Water connects all Earth systems' Do you mean via the water cycle or directly after precipitation as liquid water? The former is certainly true. I'd need to hear you say more to buy the latter, though I might.
Water connects all Earth systems seems to take the focus away from freshwater systems, seeing as freshwater is such a small proportion of water in the planet. Or maybe I misunderstood what it meant (which is a different problem).
Big Idea 2: Freshwater ecosystems are dynamic, complex and diverse.
Freshwater ecosystems, "dynamic complex and diverse." VERY important. People in Minnesota know that fish spawn early in the spring after ice-out and that walleye are harder to catch in August when water is warm or that trout respond to aquatic insect hatches, but they don't, I think, think much about the interrelationships of the many aquatic organisms and physical and chemical variables. Nor do they think about the fact that while those organisms may be interdependent, they may also be responding to different environmental cues or have different environmental requirements. In such cases the system can be fairly fragile. I think it's important to explore these relationships in some detail (specific organisms) rather than just in general (that's not a criticism of your good topic statement).
Seem generally appropriate as big ideas. Might simplify the second to explain what is meant by "dynamic, complex, and diverse."
Big Idea 3: Humans impact freshwater ecosystems both locally and globally.
"Humans impact..." This is very important, but how to make the point interesting is challenging. Examples, perhaps, of specific pollutants or temperature changes with specific organisms and systems are important here. Or the effect on rainfall in the Sahel of de-vegetation by overgrazing or the effect of Saharan dust on N. American weather. But I think these only go so far. For many people, it's hard to think of such huge systems acting over such long times (years to tens of years). Start with the more immediately understandable scale. We need to be careful of dulling receptivity by too much 'Humans are ruining everything' even if it's true. If we build understanding as in #2 above, this message (#3) will be better understood.
Especially those last two, as they relate to the great lakes - it is important for these communities (those around the GLs) to recognize the important global role the lakes play in freshwater supplies. Stewardship of these supplies rest with these communities, and the engagement, or lack there-of, will have a globally felt impact on freshwater supplies in the future.
I think with number three it is important to focus on positive changes people can make. From experience we have seen that many groups will become disengaged if they are overwhelmed with the negative impacts of humans. This has to be introduced in a time and sensitive matter so as not to alienate the group we are hoping to educate and eventually change.
"Could specify that human impact can be a positive (restoration and stewardship)."
The others are fine; although I'd rephrase the last to be "Humans impact freshwater ecosystems both locally and globally, and humans are impacted by freshwater ecosystems both locally and globally."
I think these are good, but that it would also be important and interesting to recognize that freshwater ecosystems impact humans, for example, the development of civilizations and agriculture

around water, and the impacts of the lack of clean water on many communities today.
General comments about all three big ideas
These are great ideas.
Great
Very appropriate and important
I think they are wonderful. We work with some inner-city students who have never been to the water and we surrounded by it. They don't get the opportunity to leave their neighborhood so giving them the big picture of what throwing a candy wrapper on the ground in their school parking lot can lead to is amazing.
The big ideas could potentially be engaging. They seem very similar to the ocean, Great Lakes and climate literacy principles. http://greatlakesliteracy.net/
Great ideas; all very important. We're finishing a new traveling exhibition that connects everyone to the ocean via watersheds emphasizing that everyone plays a role [in] the health of watersheds and the ocean
These are great. I think lots of people take clean water for granted, and believe that all microorganisms are bad. These big ideas are an opportunity to challenge some of these ideas.
They all sound good
Overall suggestions
These are great, but they miss a big idea - the biota - living organisms are a major force in determining the character and health of aquatic systems as seen in the impact of exotic species.
Needs to be specific to local watershed to help make an impact on learning
Make sure the "big idea" resonates with the visitors and that the idea is not so big it's irrelevant
I don't find the meta level of ideas mentioned a very engaging or inspirational way to think about and design for the topic. Embedding it on a social, ethical or personal context or action-oriented would seem more compelling.
Developed the next level down of topics from these high level learning goals has always helped our process.
Start with basics and frame the big ideas relative to: 1. all life is interconnected; then follow with life being dependent upon hydrosphere, lithosphere, atmosphere, etc.
You probably know about this: -- Supporting concepts of Big Idea 5 of the Earth System Literacy Principles (http://www.earthscienceliteracy.org/) Not Big Ideas-related directly, but as long as I'm listing URLs, here are a couple other things you probably already know about: -- National Center for Earth-Surface Dynamics education tools (some of which are 3D): http://www.nced.umn.edu/content/teachers -- "SAHRA" (rec'd an 'NSF geosciences education grant to develop a 3D watershed visualization DVD that demonstrates the hydrologic processes of a natural watershed, from mountaintop to basin floor')

Interest in tabletop interactive exhibits

One of the main deliverables of the project, the tabletop exhibits, were being developed by the project team to help further illustrate, reinforce, and integrate key concepts covered on the topic of freshwater ecosystems. The project team was interested in learning which types of tabletop activities would be most appealing to informal science institutions that cover freshwater ecosystems. Survey participants were provided with following images (see Figure 1) and descriptions of a variety of tabletop exhibits being considered.

Figure 1: Photographs of tabletop types, ISE survey



The following descriptions were included with the images above.

a) Working Model
A physical working model that demonstrates a real scientific phenomena in which visitors can experience first hand.

b) Observe Closely
Visitors examine closely an authentic object or specimen (dead or alive) from the local environment with or without the aid of magnification.

c) Small Experiment
A small science experiment that enable visitors to make their own discoveries when given all the materials, ingredients, and tools that can be carried out with simple instructions.

d) Play and Interact
A lightweight exhibit that has no particular right or wrong answer, but allows the visitor to manipulate and play with a material such as creating a new landscape or landform with sand.

e) Make & Take
A visitor follows simple instructions to make or design an artifact using a set of ready-to-use materials. Visitors then take this object home as a souvenir or for use for further investigations.

f) Tactile Display or Sculpture
A sculpted or artistically created model that visitors can explore using the primary sense of touch to understand shapes, forms, and features of an environment.

g) Multimedia / iPad
Interactive digital media content that allows the user to explore online models, simulations, videos, and/or game-like activities delivered from a tablet computer. The tablet computer can be mounted in desktop kiosk stand or passed around in a classroom.

h) Mixed Reality
A mobile device is used as a periscope to view a map that enables digital real-time data to be retrieved from a live source and displayed onto a physical background display.

After viewing the photographs and reading the descriptions, respondents were asked to report the likelihood of their institution using each specific tabletop type. As shown in Table 5, respondents were most likely to indicate that their institution would definitely use *Observe Closely, Small Experiment*, and *Play & Interact*. These were followed closely by *Make & Take* and *Working Model*. While there were very few of the tabletop activities they would not likely use, *Make & Take* seemed to be more divided than the others, with the highest number of "Not likely" responses but the second highest "Would definitely use" responses.

Table 5. Likelihood of using tabletop activities, number of responses (n=25), ISE survey

Tabletop types	Not likely (n=)	Possibly (n=)	Probably (n=)	Would definitely use (n=)
Observe Closely	2	6	7	10
Small Experiment	4	4	7	10
Play & Interact	2	5	8	10
Make & Take	6	7	3	9
Working Model	3	3	11	8
Tactile Display or Sculpture	4	5	9	7
Multimedia/iPad	2	9	7	7
Mixed Reality	2	8	8	7

Interest in immersive 3D visualizations
Immersive 3D visualizations (and non-immersive 3D and 2D visualization versions) were being developed for Lake Tahoe and Lake Champlain using the latest technologies. An important consideration for this project was to understand how easily these technologies could be transferred to additional informal science venues. The online survey asked a series of questions in order to gauge informal science institutions' interest, capacity and familiarity using immersive computer-based (digital) visualizations or simulations with visitors.

After viewing a short movie online about the 3D visualization, respondents were asked how interested their institution would be in potentially including a 3D visualization exhibit

(e.g., wall-mounted or theater) related to their local freshwater ecosystem (see Appendix A for the survey question). All respondents thought it was at least a possibility that their institution would consider including a 3D visualization (see Table 6). One quarter (25%) of respondents felt their institution would definitely be interested, and almost two thirds (63%) would either probably or definitely be interested.

Table 6. Interest in 3D Visualization, number of responses (n=24), ISE survey

Interest	Count (n=)	Percent
Definitely	6	25%
Probably	9	38%
Possibly	9	38%
Not likely	0	-
Total	24	100%

An understanding of respondents' hesitations about incorporating 3D visualizations at their institutions also provided additional context to their answers. Respondents were asked to identify the two biggest barriers their institutions would face in including immersive 3D visualizations. The most frequently mentioned barrier was cost (n=18, 78%), followed by space (n=9, 39%) as shown in Table 7.

Table 7. Biggest barriers to incorporating 3D visualization (n=23), ISE survey

Barriers	Count (n=)	Percent
Cost	18	78%
Space	9	39%
Technical requirements	5	22%
Staff	4	17%
Other	5	22%
Total respondents	23	22%

*Multiple responses allowed.

"Other" barriers were the following:

- *Already considering through another vendor*
- *We're a federal office and don't do a lot of interpretive displays, but we partner with lots of folks who would likely find these visualizations worthwhile.*
- *Must stand up to 2.1 million visitors each year.*
- *Visual appeal, meaning making concerns*
- *Equipment management*

At the time, not many of the institutions represented in the online survey had existing large, immersive computer-based (digital) visualizations or simulations. Those that indicated already utilizing visualizations mentioned "science on a sphere," "planetarium," and recreating experiences such as a "nature walk" or "pilot the sub" (see Table 8).

Table 8. Currently using visualizations with visitors (n=23), ISE survey

Using visualizations	Count	Percent
Yes	8	35%
No	15	65%
Total	23	100%

Reactions to overall project

In order to understand their overall reactions, respondents were asked what they found most interesting about the current project (see Table 9). Some found the ability to place the information into a local context most interesting. Others mentioned liking the hands-on nature of experiences and the potential the project has to engage visitors. Two respondents specifically referred to the strong impact of combining two very different types of experiences (visualizations and tabletops) to communicate messages.

Table 9. Most interesting aspects of 3D viz (n=22), ISE survey

Interesting aspect	Count (n=)	Percent	Quotes
Place in geographic context or local appeal	7	32%	*The idea of locally relevant content expressed through a variety of hands-on and immersive activities.*
User-controlled / Hands-on experience	5	23%	*I would want the 3D visualization to be interactive--i.e. visitors and/or staff can change the outcome--rather than a canned video.*
Engage visitors	5	23%	*Engagement is the first step in educating people. Anything that is hands-on or uses cool technology engages people faster and keeps them engaged longer allowing then to absorb the information more fully.*
Combining visualizations with tabletops	2	9%	*The continuum of experiences afforded by the different interactive/communication modes.*
Other	2	9%	*Our organization utilizes tabletop exhibits with school groups, we are not currently investing in new hands on exhibits and we are in conversation with a vendor about 3d*

technology.

A Word Cloud[2] was created in order to visualize the survey responses regarding the most interesting aspect of the 3D visualization project. The largest words represent the most frequent responses, and for the most part included general words like "visitors," "experiences," "interested" and "exhibits." The next most common set of words provided some insight into what most interested survey respondents about the project, such as "local," "hands on," "engaging," and "learning." In considering the third tier of words, respondents talked about the nature of the project and how it would be "relevant," "immersive," and "virtual."

Figure 2. Word Cloud of most interesting aspects of exhibit, ISE survey

Follow up

To encourage future engagement with and to assess interest in the 3D visualization project, the online survey allowed respondents to indicate how they would like to remain involved or in contact with the project as it progresses; there were a number of options respondents could choose from (see Table 10). The majority wanted at a minimum to be kept informed of the project's progress, while a majority also wanted to learn more about specific exhibits. About half expressed an interest in hosting these types of exhibits, and would have been willing to talk with an evaluator about their survey responses. Although it should be noted

[2] All Word Clouds were created using the website www.wordle.net. Word clouds are a visual representation of a group of words or text; in this report word clouds are used to show visitors' responses to an individual question. The larger the word, the more times a word was mentioned by respondents.

that this was a self-selected sample where most of the staff worked at places already interpreting freshwater ecosystems, it indicates a solid level of interest in the project.

Table 10. Future engagement with the project (n=23), ISE survey

Engagement	Count (n=)	Percent
I would like to be informed about the progress of this project	14	61%
I would like to learn more about these specific exhibits	12	52%
I am interested in hosting the types of exhibits described above	11	48%
I would be willing to talk more about my responses in the survey	11	48%
I am interested in talking about becoming involved with this project in some way	9	39%
No thanks, I'm good	4	17%
Total Respondents	23	

*Multiple responses allowed.

FOCUS GROUP SUMMARY

OVERVIEW

Purpose the focus groups

From February 20, 2012 to March 1, 2012 a total of six focus groups were held, with two each at the Echo Lake Aquarium and Science Center (ECHO), the Tahoe Environmental Research Center (TERC), and the Lawrence Hall of Science (LHS). At each site one group was held with middle school students and one with adult audiences; at TERC the adult group was held and Spanish-speakers.

The primary purpose of the focus groups was to learn about individuals'

- connections to freshwater ecosystems
- knowledge of freshwater ecosystems
- reactions to the project's big ideas
- interest in activities related to the project, including the 3D visualization of freshwater ecosystems and related tabletop activities

The focus groups addressed the following evaluation questions:

2) What are current and potential visitors' attitudes and knowledge about freshwater ecosystems and habitats?
3) What are the entry points (i.e., content and activities) for engaging audiences, including rural and Spanish-speaking groups, in the content?

Method and sample

Staff members at ECHO, LHS and TERC identified and recruited focus group participants using their organizations' mailing lists, contacts with schools and local school parent-organizations. Three of the six focus groups were conducted with middle school children in order to include feedback about the proposed activities from children in the target age range. Two of the six focus groups focused on English-speaking adults with children in order to get feedback from adults representing the general public, with children in the target age group. Additionally, one focus group held at TERC was conducted with Spanish-speaking adults in order to include groups typically underrepresented in informal science endeavors, and to examine any cultural or language differences in the potential topics, activities and deliverables.

A total of 31 adults, 18 English-speaking and 13 Spanish-speaking, participated in a project-related focus group, as well as 39 upper elementary/middle school students (see Table 11). Of the 18 English-speaking adult participants, 12 were female and 6 male. Ages of English-speaking adult participants ranged from 35 to 55 years of age. Of the 13 Spanish-speaking adult participants, 6 were female and 7 were male. For the three student focus groups, the

institutions recruited each group based on criteria provided by the evaluators. Two were conducted at ECHO and TERC, while one was conducted with an after-school program connected with LHS. A group of Grade 6 students met on February 21, 2012 at ECHO and included 19 students, 10 boys and 9 girls. A group of Grade 5 students from North Tahoe Middle School participated in a focus group on February 28, 2012 at TERC. This focus group included 13 students (7 boys and 6 girls). Evaluators visited Oxford Elementary School in Berkeley, California on February 29, 2012 for the LHS focus group, talking with 10 Grade 5 students (6 boys, 4 girls) in the after-school care program.

Each focus group was digitally recorded so that the audio could be listened to and analyzed after the group was conducted. Two evaluators were present during each focus group, one moderating the focus group and one taking notes. There were 2D versions of the Lake Tahoe visualization shown at LHS and ECHO; a 3D version was shown at TERC since they were already set up with a 3D projection system.

Table 11. Summary of focus groups and samples, focus group

Institution	Type of visitor	Sample size	Date held
Echo Lake Aquarium and Science Center (ECHO)			
	English-Speaking Adults	8	February 20, 2012
	Middle School Students	16	February 21, 2012
Tahoe Environmental Research Center (TERC)			
	Spanish Speaking-Adults	13	February 27, 2012
	Middle School Students	13	February 28, 2012
Lawrence Hall of Science (LHS)			
	English-Speaking Adults	10	February 29, 2012
	Upper Elementary/ Middle School Students	10	February 29, 2012
TOTAL		**70**	

Overview of the focus group instrument

The focus groups were conducted using a structured focus group guide (see Appendices C, D & E). The guide addressed a number of topics regarding freshwater ecosystems including individuals' knowledge of, connection to, and interest in freshwater ecosystems. The guide also presented three big ideas for the project and asked participants to identify the big idea that most interested and engaged them. Furthermore, during the focus groups, participants viewed either a 2D version (at ECHO and LHS) or a 3D visualization (at TERC) of Lake Tahoe (see Figure 3 below). After viewing the video, participants were asked for feedback about the video, including what parts they liked best, which content was familiar, and which content was new to them. Participants were then shown eight different tabletop activities that would further reinforce and integrate key concepts about freshwater

ecosystems. Participants were asked to identify which tabletops activities were their favorites and to explain why they were their favorites.

See Appendix C for the focus group guide in English, Appendix D for the focus group guide in Spanish, and Appendix E for supporting materials shown to focus group participants about tabletop activities.

In order to account for and note the differences in the focus groups based on audience differences, the results of the focus groups are reported in three sections: 1) English-speaking adults, 2) Spanish-speaking adults, and 3) middle school students. In this manner, a comparison can be made more easily across the various groups.

FOCUS GROUP RESULTS & DISCUSSION

English-Speaking Adult Focus Groups

Summary of findings for English-speaking adult focus groups (at ECHO, LHS)

Connections to freshwater ecosystems
Given that many of the participants were recruited through connections to the partner institutions, many people in both of the two adult English-speaking focus groups were very familiar with their local freshwater ecosystems. Since ECHO sits on Lake Champlain many had visited or lived near the lake; many of the participants at LHS were familiar with Lake Tahoe, given that it is about a 3 hour drive from the San Francisco Bay Area. The connections focus group participants had to freshwater ecosystems tended to be the result of currently living near freshwater ecosystems or having visited specific freshwater ecosystems during their childhood. As a result of these connections, participants also associated freshwater ecosystems with recreational activities like boating and/or fishing.

Knowledge of freshwater ecosystems
When asked "What comes to mind when you hear the term 'freshwater ecosystems?'" many participants tended to bring up specific types of freshwater ecosystems including lakes, rivers, springs, and wetlands; it was interesting that more than one participate mentioned vernal ponds. The term "ecosystem" indicated life cycles to some participants who also referenced plant and animal life found in freshwater ecosystems:

> *I think food chains, what is an ecosystem and how it happens. Which animals eat each other and the effect on the landscape.*
>
> *Invasive species – Pike and the American bullfrog. I know they ravaged other species.*

The fish and animals who live there are very different from the ones in the ocean and their needs are really different.

About one third of participants in the two focus groups mentioned that they see freshwater ecosystems are in peril as a result of humans' negative impact:

I see an ecosystem in peril.

Depletion of freshwater sources.

I worry about pollutants in the water, both prescriptive pollutants and litter.

Reactions to the project's Big Ideas

Participants in the two adult English-speaking focus groups provided feedback on the project's potential big ideas related to freshwater ecosystems.

Big Idea 1: *Water connects to water, land, air and life.*

Focus group participants summarized this Big Idea as water being the basis for life. Individuals in both of the focus groups emphasized the term "connects" as important to this main message:

[Water] connects to all these physical entities, but it is the lifeblood of life.

I think the 'connects' part is important because that seems to be an important part of an ecosystem, how things connect to each other.

One participant particularly liked this big idea because of its simplicity:

I wanted to be a cheerleader for this one. It is very simple. The others [big ideas] get wordy.

Participants identified several challenges related to this Big Idea. Some adults at LHS found the concept of "water connecting to water" confusing since it was about something connecting to itself. When asked what they thought this meant, two participants responded, *"Rivers connecting to things," and "Water cycle, vapor, and the idea that water permeates everything."* In the focus group conducted at ECHO, participants discussed how *"water connects to air."* For some focus group participants, the link between air and water was not immediately apparent. Participants hypothesized examples of air and water connecting such as acid rain, weather, and the air quality near water.

Big Idea 2: *Freshwater ecosystems are dynamic, complex and are constantly changing.*

Most participants in the two English-speaking adult focus groups agreed that freshwater ecosystems are constantly changing. Example participant responses are:

> *How [a] stream changes from both human intervention and natural intervention.*
>
> *For me it is constantly changing. It is completely different from when I was a kid.*
>
> *Changing is what makes freshwater ecosystems freshwater ecosystems. If they are not changing they are stagnant and they are not really freshwater anymore.*

Two adults in the focus groups found the wording of this Big Idea to be somewhat redundant. Participants felt that the words "dynamic" and "constantly changing" have the same meaning.

Big Idea 3: *Humans study, manage and impact freshwater ecosystems on a local as well as global scale.*

Participants in both of the English-speaking focus groups had an issue with the placing of the word "study" in this Big Idea. Participants felt that more emphasis could be placed on how humans impact freshwater ecosystems; they suggested that "impact" should be placed before "study" or that "study" should be removed from the sentence. Focus group participants felt that both "manage" and "impact" were important words to include in the big idea:

> *I think impact should come before study. 'Humans impact, study and manage freshwater ecosystems…'*
>
> *I agree. I would drop study. I think manage is essential, you either manage it well, or mismanage it. I would simplify these.*

A few participants in both focus groups suggested incorporating all three of the previously mentioned big ideas into one. One participant, as an example, combined the three ideas as follows:

> *Basis of life. Always changing. If it's not changing it's not really freshwater anymore and we are a large part of that change. We are impacting and we have to manage it. If everyone understood that, we would have much better water systems.*

Adults participating in the focus group at LHS were asked if they felt there was anything missing from the Big Ideas as a group. One participant felt that the big ideas should mention animals. Several other participants felt the big ideas should include how freshwater ecosystems are "the basis of life," that we all depend on freshwater, and that we are an integral part of freshwater ecosystems. Another idea raised was that humans not only impact freshwater ecosystems, but freshwater ecosystems also impact humans; that

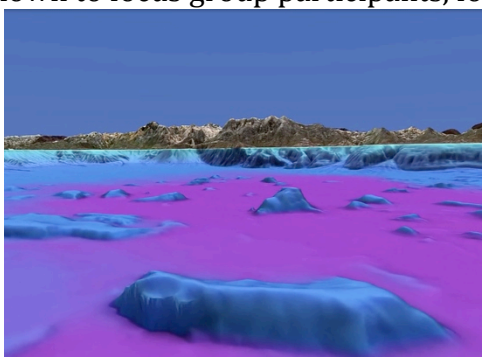
is, we should think of it as a system that works in both directions. However, respondents felt that we particularly need to manage our own impact on freshwater ecosystems:

> *The mention of animals…kids think of animals.*
>
> *I am an integral part of the freshwater ecosystem. I am an integral part of the freshwater cycle. I not only impact it, but it impacts me, and I am part of it.*

Interest in activities related to the project

3D visualization

Figure 3. Screen shots of 2D visualization shown to focus group participants, focus group



Since it was not possible for viewers at LHS and ECHO to see the 3D version of the visualization, which requires special software and equipment, they saw a 2D version of the visualization with a pre-recorded "flythrough" around the lake with an audio recording describing what they were seeing. While it was explained to participants that the lack of a 3D visualization system at the location prevented the 3D version from being shown, many participants noted that this approach seemed "canned" and not as dynamic as they imagined the 3D version would have been. As such, some participants in the two adult English-speaking focus groups were not impressed with the 2D video of the 3D visualization. Participants first noted room for improvement in the video itself, with two participants feeling that it was "static" and tried to cover too much content. Another participant felt the speaker talked too fast, while one individual felt the content of the video was not as organized as it could have been. Others stated that the big ideas were not apparent:

> *I thought it was really static, probably would be pretty in 3D, could have done it in 2D.*
>
> *Speaker was way too fast. It was interesting, just too much too fast. Trying to cover way too much.*
>
> *Found it to be really disorganized, too much.*

Series of vignettes without good transitions. I don't see your Big Ideas being woven through it. If you had it laid out as trails of Big Ideas that you could go through.

While there were criticisms of the visualization as it was presented, some participants identified its strengths, including the ability to show change over time, to provide an experience that was not accessible any other way, and the ability to "dive underwater." A few participants thought the visualization was "cool" and informative.

Participants suggested that the video's content should be better organized and the scope narrowed to clearly incorporate the big ideas. One participant suggested developing a type of "modeling game:"

Sid Meier's civilization games. Kids have their own ecosystem and bring humans into it. Social puzzle that simplifies human impact around the lake. "You are Samuel Champlain."

Another participant recommended creating more focused individual video "tours" about geology, biology, and stewardship:

Go around lake for a geological tour; go around lake for a biological tour; urbanization; etc. tour.

During the focus group at ECHO, participants were asked to think about specific things they would like to see included in a similar kind of video about Lake Champlain. Participants gave a range of responses including water treatment plants, algae, invasive species, and the role of politics around the lake.

Tabletop activities

During the focus groups, participants were presented with images and read descriptions of eight different tabletop activities that reinforced and integrated key ideas related to freshwater ecosystems (see Appendix C for images and descriptions given to participants). Adults were asked to vote for their top two activities.

As shown in Table 12, adults expressed a high degree of interest in particular for three tabletop activity types: *Mixed Reality*, *Working Model,* and *Play and Interact.* Participants in the LHS focus group tended to favor *Working Model* and *Play and Interact*. At ECHO, *Mixed Reality* appeared to be most interesting to participants.

Table 12. Number of adult votes for tabletop activity types, focus group

Activity type	ECHO (n=8)	LHS (n=10)	Total (n=18)
Mixed Reality	5	4	9
Working Model	2	6	8
Play and Interact	2	5	7

Multimedia / iPad	2	2	4
Small Experiment	3	1	4
Make & Take	1	1	2
Tactile Display , Sculpture	1	1	2
Observe Closely	0	0	0

Mixed Reality: In both focus groups, most participants found *Mixed Reality* appealing because it uses real time data:

> *Fourth through sixth grade kids are interested in real stuff….It's really cool to see stuff that is really happening.*
>
> *You are seeing data coming in, in real time.*

Building on this idea of real data, a few participants felt the platform of *Mixed Reality* allowed visitors *"to be their own scientist."* One participant like *Mixed Reality* because she felt it is a new form of technology and different from typical tabletop activities. However, participants in the ECHO focus group expressed concern regarding the economic disparity of visitors and their access to and familiarity with technology. A few individuals thought smart phones should be provided to visitors so they could participate in this tabletop activity:

> *There is a huge economic disparity with Burlington [VT].*
>
> *I'd expect to have a device available at the site.*

Working Model*: Working Model* was a top choice for focus group participants at LHS. Participants expressed their interest in the following ways:

> *I like the visual, identify with it, easier to grasp.*
>
> *I think of the Exploratorium, really see how things work.*
>
> *Complex processes that are actually very simple, working model is very tangible, helps grasp concepts.*
>
> *The problem is that they are the first thing to stop working.*

Play and Interact: The tabletop type categorized as *Play and Interact* was also interesting to adults. Many liked that you could manipulate it and play with it: "*You are doing it and getting to see the results*." A few participants felt that through this type of tabletop, visitors can learn while playing and having fun:

Play is more important. People learn through play. Provides a place where bigger kids can play. Not every kid has seen an iPad, but all can play.

So much fun, get to do something with hands.

Fun plus educational.

For participants in both the ECHO and LHS focus group, the least popular tabletop activities were *Observe Closely, Make & Take,* and *Tactile Display*.

Spanish-Speaking Adult Focus Groups

Summary of findings for Spanish-speaking adult focus group (at TERC)

Connections to freshwater ecosystems

Few of the adults in the Spanish-speaking focus group conducted at TERC reported strong personal connections to freshwater ecosystems. When asked what activities they did on lakes, streams, or rivers, participants hesitated to respond. One participant offered that he went fishing on Placer Lake and another individual described aquatic activities that others did like kayaking and rafting. This was quite different from the English-speaking adult focus groups, although it should be noted that individuals in the English-speaking groups often had strong professional connections to LHS or ECHO. Additionally, no Spanish-speaking focus group participants had a job related to freshwater ecosystems, so this may also have made a difference. No socioeconomic or income data were collected, so it is difficult to say whether this was a factor in the difference.

Knowledge of freshwater ecosystems

Focus group participants' understanding of the definition of a freshwater ecosystem appeared to be limited. When asked to define the term, participants hesitated to respond. One individual finally replied, *"It's where the water is located and it's not saltwater, it's freshwater. [Es donde se ubica el agua y es agua no de sal, es agua dulce.]"* A few participants were able to offer examples of freshwater ecosystems and mentioned rivers, lakes, and lagoons. After describing a number of other freshwater ecosystems, the moderator then asked participants if they had a favorite ecosystem. Prompted by the probe, several focus group participants identified streams, lakes, and springs as places that were pretty and where families could go to enjoy outdoor activities like swimming. So it does turn out that there are personal connections, they may just not be perceived as such.

Focus group participants appeared to have limited knowledge regarding how the freshwater ecosystem, in this case Lake Tahoe, was formed. After some probing about their understanding of the formation of the lake, four participants offered various explanations, which included that the lake was formed by snow, a volcano, glaciers, and an earthquake:

Earthquake. I live in Salinas and therefore, I'm not used to earthquakes. [Earthquake, el terremoto. Yo vivo en Salinas entonces no estoy acostumbrado a terremotos.]

One supposes it was formed with snow. [Supone que forma con la nieve.]

From a volcano. It was something…an eruption that made a hole where [the lake is]. There is a crater that the snow fills up with water. [De un volcán. Fue algo…un erupción que hizo en el hoyo donde este. allí es un cráter que la nieve se va colectando el agua.]

Glaciers [Los glaciales]

It was evident from the discussion that some focus group participants understood that various natural forces worked to create Lake Tahoe; however, there was limited in-depth knowledge of how the lake was actually formed. One participant felt that in educating the public about Lake Tahoe, it would be important to address the legend of Tessie, an underwater dinosaur that is said to live in the lake. Several focus group participants joined in a discussion of Tessie and explained that many people did not know if Tessie was fact or legend:

And people don't know if it's real or no. It (the legend) hasn't been tested whether it's true or a lie. [Y la gente no sabe si es verdad o no. No esta comprobado si es verdad o mentira.]

They also say that (Tessie) hides in a tomb and comes out from the South Shore. It's her home. It's interesting. [También dicen que se esconde en el tomb esta saliendo para South Shore. Es su casa. Es interesante.]

And down there is a cave where she lives. [Y hay abajo hay una cueva donde vive.]

Reactions to the project's big ideas

The moderator presented the project's three big ideas to focus group participants and asked them for reactions and feedback related to the ideas. Focus group participants voted for their favorite idea.

Big Idea 1: *Water connects to water, land, air and life.*

Only 2 of 13 individuals indicated that they favored this Big Idea 1. They did not offer a specific explanation as to why they selected this big idea.

Big idea 2: *Freshwater ecosystems are dynamic, complex and are constantly changing.*

Two individuals also voted for big idea 2. When asked why they were interested in this big idea, one participant explained he did not understand how freshwater ecosystems were dynamic. To gather additional feedback about the wording of big idea 2, the moderator asked what participants thought the phrase "freshwater ecosystems are constantly changing" meant. One individual interpreted this statement to mean that humans are contaminating the environment and destroying the planet. However, the participant acknowledged that even if humans were not present, the environment would still continue to change:

> *Because of the cycle of the seasons. For example, if there isn't much snow. In years past there was a lot. Therefore, the cycle of life makes it that things keep on changing. [Por el ciclo de estación. Por ejemplo si no hay mucha nieve. Y en años atrás había bastante entonces el ciclo de la misma vida va haciendo que las cosas vayan alterando.]*

Big Idea 3: *Humans study, manage and impact freshwater ecosystems on a local as well as global scale.*

While the large majority of participants felt that the three Big Ideas made sense, most individuals (8 of 13) favored Big Idea 3. One individual explained why she preferred this Big Idea:

> *Because we're destroying everything natural that we have on the earth because of inventing technological things, and we're destroying nature. [Porque estamos destruyendo toda la natural que tenemos en la tierra por inventar cosas tecnológicas y destruimos la naturaleza.]*

Another individual felt that Big Idea 3 was logical. As in the English-speaking adult focus groups, this individual felt that all three Big Ideas related well to each other:

> *The first idea is a combination of elements and functions. And the second, there are complexities that not everyone understands. And the third one, we're transforming the planet. Therefore, in reality, the three (ideas) make sense. [La primera idea es una combinación de elementos y funciona entre si. Y la segunda son complejos y no todas las personas los entendemos. Y la tercera estamos transformando el planeta. Entonces en realidad los tres tienen sentido.]*

Interest in Activities Related to the Project

3D visualization

As part of the focus group, participants watched a short video of a 3D visualization of Lake Tahoe, although it should be noted that the video was in English. The viewing of the visualization differed from the English-speaking groups at ECHO and LHS in that the version they watched was actually in 3D, since TERC had a 3D system set up there.

After viewing the video, the moderator asked participants for their reactions and feedback. Participants found the video interesting, with one individual explaining that she had never seen a 3D visualization of the lake. Another participant said she liked the video because she enjoys nature and she is interested in everything having to do with the topic. When asked what suggestions they had for improving the video, participants not surprisingly felt it would be important to translate the video into Spanish. A Spanish translation, one individual explained, would be likely have a greater interest for Spanish-speaking visitors. Also, Spanish-speaking visitors would be better able to understand the video.

A few participants felt that the video should include more information about the human impact on Lake Tahoe so that visitors understand the need to take care of the lake. One participant emphasized that it was important to show the video to parents with children so the parents would learn how to take care of the lake. This individual described how she has watched parents take their children and dogs to Lake Tahoe and not pick up their trash. It is interesting to note that in response to the statement that it was important to show the video to parents, one participant suggested that parents might not be interested in the video. She explained that coming from Mexico may have an impact:

> *Honestly, one doesn't know the culture here and it doesn't interest them. [La verdad, la cultural de aquí no la conoce o no les interesa.]*

Tabletop activities

The moderator described to focus group participants, in Spanish, the eight different types of tabletop activities that reinforce key concepts regarding freshwater ecosystems (see Appendix D for materials, which were translated into Spanish). After reviewing brief definitions of the activities, participants were asked to vote for their two favorite tabletop activities. As shown in Table 13, votes were spread pretty evenly among the top five choices, favoring *Observe Closely, Tactile Display, Play and Interact, Small Experiment* and *Working Model.* It is interesting to note that *Observe Closely* and *Tactile Display* were the least favorite tabletop activities with the English-speaking adult and middle school student focus groups, yet were highest among Spanish-speaking participants.

Table 13. Number of adult Spanish-speaking votes for tabletop activity types (n=13), focus group

Activity type	TERC
Observe Closely	8
Tactile Display, Sculpture	7
Play and Interact	6
Small Experiment	5
Working Model	4
Multimedia / iPad	2
Make & Take	2
Mixed Reality	1

When asked, few of the Spanish-speaking focus group participants specifically explained why they favored a particular tabletop activity. One individual commented that seven of the activities seemed fine to her. However, she felt that *Mixed Reality* was an activity that might not be accessible to everyone because of the technology involved in this activity:

> *I think that the seven (activities) are fine, only (Mixed Reality). I don't believe that it's possible for everyone to interact with modern things because there are many people, for example…we still don't know technology well. Therefore, it would be difficult for us in the long term. I think that all the other (activities) are fine…they're more practical. [Yo pienso los siete son bien, solo la realidad. No creo que no toda las personas tenemos o tienen la posibilidad de interactuar con cosas mas modernas. Porque hay muchos por ejemplo…no sabemos todavía muy bien la tecnología, entonces nos costaría mas en la ultima. Entonces yo pienso que todas las demás están bien porque son mas para...son mas practicas.]*

Agreeing with this statement, another individual felt that people without cell phones would not be able to participate in *Mixed Reality.* Another focus group participant commented that she did not have a cell phone.

Middle School Student Focus Groups (at ECHO, TERC, LHS)

Summary of findings for middle school student focus groups

Connections to freshwater ecosystems

Students expressed strong connections to freshwater ecosystems. During the focus groups, students described how they use freshwater bodies of water for recreational purposes including boating, swimming and fishing. A few children have friends or relatives with jobs relating to freshwater ecosystems. Although students from Berkeley lived near the San Francisco Bay, they were also familiar with local and national lakes, and had connections as well. The students in all three locations were easily able to come up with personal connections they had to freshwater ecosystems.

Knowledge of freshwater ecosystems

When asked what came to mind when they heard the term "freshwater ecosystem," students most frequently mentioned habitats for animals, plants and fish. A few students associated freshwater ecosystems with water quality. Participant comments' included *"clear," "clean"* or *"drinking water."* Some students at Oxford Elementary School in Berkeley, California viewed an ecosystem as a cycle, while two students mentioned human involvement with freshwater ecosystems. Types of freshwater ecosystems that students mentioned frequently included lakes, ponds, rivers, and streams. Very few students referred to springs or wetlands; however, it was apparent that some students were familiar with these types of freshwater ecosystems. When asked how lakes were formed, students in both focus groups were able to offer explanations such as natural erosion, volcanoes,

glaciers, and tectonic forces. Some of them referred to the fact that they either were currently or had recently covered these topics in school.

In two of the three focus groups conducted with middle school students, participants were asked to vote for the freshwater ecosystem type that they found most interesting. Students indicated that lakes, rivers and springs were most interesting to them (see Table 14). There were some differences in the two groups, with students at TERC most interested in rivers and students at LHS most interested in springs.

Table 14. Number of student votes for types of freshwater ecosystem, focus group

Freshwater ecosystem type	TERC (n=13)	LHS (n=10)	Total (n=23)
Lakes	3	3	6
Ponds	0	1	1
Rivers	6	0	6
Streams	1	0	1
Springs	1	6	7
Wetlands	1	0	1

Interest in activities related to the project

3D visualization

As in the adult focus groups, middle school students at ECHO and LHS were shown a brief video of a 2D visualization of Lake Tahoe, simulated from a 3D version (see Figure 3 above); middle school students at TERC were shown the 3D version. After watching the video, students offered suggestions for improvement. Several students recommended incorporating animals into the visualization, while other participants also wanted to view underwater features of the lake. To make the video more fun and exciting, students recommended changing the background music and the voice of the narrator. A few individuals found the content to be above their grade-level and would have liked to see more definitions and explanations to *"make it so other people understand it, that way all ages get the movie."* A few students wanted to make the video more realistic. They proposed adding plants, flowers and animals as well as improved graphics from Google Earth:

> *Frame-rate issues. Needs to be more refined. Define the terms. Use Google Earth more, better graphics, more up to date graphics.*
>
> *The guy's voice – other people may think it's boring, maybe have the voice be more lively. Show what the lake really looks like.*

Students at ECHO were asked why the visualization should be in 3D. Students responded that three-dimensional movies are *"unique," "exciting,"* and *"leave a bigger impression."* There was a perception among the students that the 3D nature would attract their

attention and get them to learn better than 2D versions. Some of the students emphasized the realistic qualities of 3D movies and that this helps them remember more:

> *You will remember for longer because it feels like you are actually there.*

When asked if the team were to develop a similar video for Lake Champlain, what would they like to see included, several students at ECHO (located on Lake Champlain) indicated that they would like more information about aquatic life living in the lake. A couple of students also wanted to include local legends about to the lake like the legend of Champy and Native American stories related to Lake Champlain:

> *Zebra mussels.*
>
> *The legend of Champy.*
>
> *Include more scientific parts and tell the story of how the God turns into stone [combine native American legends with scientific information].*
>
> *All animals that are in the lake. Talk about how we have the sturgeon, about how all fish in the lake are there.*

Tabletop activities

As with the adult focus groups, students were shown visuals and given descriptions of eight tabletop activities to consider (see Appendix C).

By a wide margin, the favorite tabletop activity among students who participated in a focus group was *Play and Interact,* (see Table 15). Most of the students (n=33) voted for this activity because they felt that playing is fun and they enjoy hands-on activities. A few students mentioned that this tabletop activity would help them visualize concepts. Representative responses include:

> *I like playing. Makes things really fun.*
>
> *I really like hands on stuff and to do stuff.*
>
> *Because it makes what you're learning about a lot easier to visualize. If [you] hold it in your hand it is easier to visualize.*

Table 15. Number of school group votes for tabletop activity types, focus group

Activity type	ECHO (n=16)	TERC (n=13)	LHS (n=10)	Total (n=39)
Play and Interact	15	12	6	33
Multimedia / iPad	7	4	3	14
Make & Take	3	6	3	12

Mixed Reality	5	3	1	9
Small Experiment	2	1	3	6
Tactile Display, Sculpture	2	0	3	5
Working Model	2	0	1	3
Observe Closely	1	0	0	1

Fourteen students also liked the concept of *Multimedia/iPad*, with students selecting this activity because was is a new piece of technology and because they felt the multimedia display could show something small on a larger scale or demonstrate how a scientific process actually works. Students in the ECHO focus group also suggested content to include with the iPad. A number of students were particularly interested in including a game (once this was raised, quite a few students voiced their support for the idea):

> *Games – about turtles or glaciers.*
>
> *Types of landforms and how lake was formed, facts about the Lake.*
>
> *Like a big board game, facts get more intense [as you progress], when you land on a square there could be a video pop-up.*
>
> *Answer right, then go ahead 5 spaces. If wrong, move back five spaces.*
>
> *Mini games [unlock mini-games].*
>
> *Champ game, special point fish [fish worth points].*

However, students expressed concerns regarding this tabletop activity type. Some students felt the iPad was expensive and would need to be supplied by the museum. One participant did not pick the iPad because she favors "real things" as opposed to technology.

After the iPad, *Make and Take* was the next most popular tabletop activity, with 12 students expressing interest in this activity. Students indicated that they liked creating or making things and the option to take something home would reinforce concepts later:

> *I really like making things. You do it and see how it works. Take it home and you are more likely to remember it.*
>
> *It can be really fun to build something of your own. If you take it home, it reminds you later.*

Some students were also interested in *Mixed Reality* because it shows real data and would help visitors visualize things that are not initially apparent, such as the depth of a lake. However, one student noted that not all children would have smart phones so this activity might not be universally accessible.

ON-SITE INTERVIEW SUMMARY

OVERVIEW

Purpose and design of the interviews

While the focus groups provided valuable feedback about the project, they were qualitative in nature and thus not meant to provide a more representative understanding of the target audiences. The main purpose of the on-site interviews conducted at the three institutions (TERC, LHS and ECHO) was to conduct a quantitative study with a larger and broader sample of visitors at the participating institutions. This would allow the project team to build off of the focus group findings while also giving them more confidence that the findings could be more readily generalized. By means of the interviews, evaluators examined visitors' existing knowledge, attitudes, interests, and reactions to the proposed content areas of the 3D visualization project.

The on-site interviews addressed the following evaluation questions:

2) What are current and potential visitors' attitudes and knowledge about freshwater ecosystems and habitats?
3) What are the entry points (i.e., content and activities) for engaging audiences, including rural and Spanish-speaking groups, in the content?
4) How can the project promote and encourage environmental awareness and stewardship among those who engage in the various components?

Methods

Interviews were conducted at the three participating institutions form August 10 to 26, 2012 with a total of 268 adult visitors. Table 16 below shows the number of visitors that were interviewed at each institution. Due to varying degrees of visitation, the number of interviews completed at each institution, and methods for recruiting interviewees also varied. At LHS (n=150) and ECHO (n=88), which have larger visitation, interviewees were recruited on the floor for general visitors. At TERC (n=30), which receives many fewer walk-in visitors, visitors were recruited during a one-day family science festival so that a larger number of interviews could be conducted.

Table 16: Number of visitors interviewed at each institution (n=268), interview

Institution	Count	Percent
LHS	150	56%
TERC	30	11%
ECHO	88	33%
Total	268	100%

Overview of the interview instrument

Front-end interviews lasted about 10 to 15 minutes and were conducted by evaluators using a structured interview protocol (see Appendix F). To understand participants' general knowledge of freshwater ecosystems, the interview began by gathering general information about visitors' familiarity with different types of freshwater ecosystems. Visitors were then asked about any personal connections they had to freshwater ecosystems, in order to better identify entry points for engaging audiences on this topic. To gather information about individuals' perception of human impact, visitors were then asked to rate the impacts humans have on freshwater ecosystems and to describe what they were doing to reduce their own impact on freshwater ecosystems.

Later in the interview, visitors were asked to define the term "watershed" and to describe their local watershed. The purpose of this section of the interview was to better understand visitors' knowledge of specific topics that could be addressed in the 3D visualization project, as a means for knowing where to start the conversation around the topic. Also related to identifying project content that would most engage visitors, interviewers presented individuals with a number of questions related to scientists who study lakes and asked them to select the questions that most interested them.

Finally, visitors were asked during the interview to identify from a provided list the actions they were currently undertaking to help freshwater ecosystems. Evaluators concluded the interview by requesting visitors to fill out a brief demographic questionnaire. See Appendix E for the full interview protocol.

Sample characteristics

The demographic characteristics of the visitors interviewed across the institutions were fairly homogenous, so the groups were very similar to each other. Most individuals in the sample were Caucasian and between the ages of 25 and 64 (see Tables 17 and 18).

Table 17: Ethnicity of interview participants, interview

	TERC (n=30)	ECHO (n=87)	LHS (n=154)	Total (n=271)
Caucasian/White	77%	97%	73%	81%
Asian	20%	2%	18%	13%
Hispanic	3%	0	8%	8%
Black	0	2%	3%	2%
Other	3%	2%	1%	1%

* Some individuals selected more than one response, so columns may add to more than 100%.

Most individuals who participated in an interview were between the ages of 25 and 64 (see Table 18). Due to the variance in the age of visitors in the overall interview sample, answers to a number of interview questions were tested to see if there were statistically significant differences in participants' responses by age group. However, no significant

differences in responses were found between age groups, suggesting that the difference in age across the three samples would not adversely affect the results.

Table 18: Age of interview participants, interview

	TERC (n=29)	ECHO (n=83)	LHS (n=141)	Total (n=253)
0-17	0%	5%	0%	2%
18-24	3%	7%	3%	4%
25-44	45%	27%	53%	44%
45-64	35%	37%	31%	34%
65-100	17%	24%	13%	17%
Total	100%	100%	100%	100%

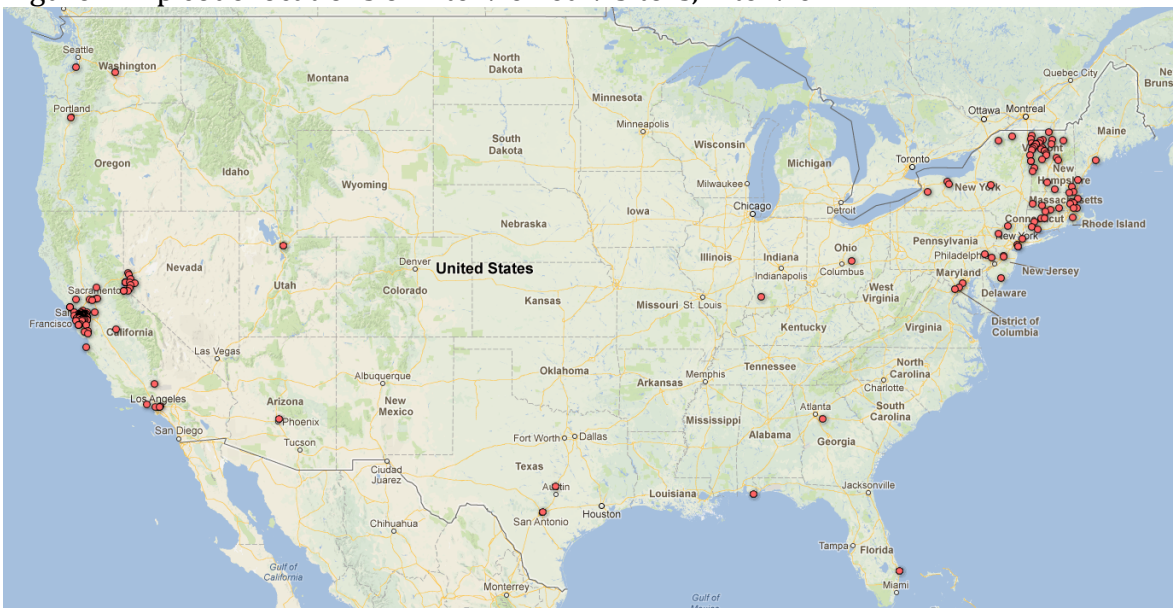
Of visitors who participated in an interview, nearly one quarter (24%; 63 of 268) spoke a language other than English at home. As shown in Table 19, Spanish and French were the most common languages identified by visitors. Counts rather than percentages are presented in the table below due to the small number of individuals within each institution who spoke another language at home.

Table 19. Languages other than English spoken at home, interview

	TERC (n=5)	ECHO (n=12)	LHS (n=46)	Total (n=63)
Spanish	1	5	14	20
French	0	4	8	12
Chinese	2	1	8	11
German	1	1	4	6
Arabic	0	0	3	3
Other	1	4	18	23

For most interviewed individuals, it was not their first visit to the institution; 58% (155 of 268) of visitors in the sample had visited previously. During the interview, visitors were asked to provide their home zip code, and this was used to generate a map that showed where visitors included in the sample resided (see Figure 4). Not surprisingly, most visitors to TERC and LHS lived in the Lake Tahoe region and San Francisco Bay areas, respectively. Visitors to ECHO were spread throughout New England and the Mid-Atlantic states, with the greatest density of zip codes centering in Vermont. Included in Appendix G are enlarged sections of California and the Atlantic coastal states that provide a more detailed view of the visitors' location. Not surprisingly, only a small number of visitors in the interview sample were visiting from outside the United States. Of these individuals, five were from Canada, two from France, two from the United Kingdom, one from Singapore and one from Ireland.

Figure 4. Zip code locations of interviewed visitors, interview



Most individuals in the interview sample indicated that they had visited the institution with other visitors that day, with the majority of other visitors being 17 years old or younger (see Table 20. Ages of other people in group with interviewed individuals). In total, 662 visitors were in attendance with the 268 individuals who were interviewed at the three institutions participating in this study; the interviews represent a total of 930 visitors across the three institutions. Over two thirds of those who accompanied interview participants were 17 years old or younger, which is not surprising given that the interviews were conducted during the summer when family visitation was very high and many of the groups consisted of one or two adults with children.

Table 20. Ages of other people in group with interviewed individuals, interview

	TERC (n=95)	ECHO (n=195)	LHS (n=280)	Total (n=662)
0-17	63%	41%	75%	63%
18-24	2%	7%	2%	3%
25-44	20%	12%	12%	13%
45-64	8%	27%	7%	13%
65 & older	6%	14%	5%	8%
Total	100%	100%	100%	100%

In order to identify if many visitors had extensive knowledge of freshwater ecosystems, during the interview individuals were asked if they currently had a job related to freshwater ecosystems. Just 7% (19 of 262) indicated that their work was related to freshwater ecosystems.

RESULTS & DISCUSSION

The interview findings are organized by the evaluation questions.

1) What are current and potential visitors' attitudes and knowledge about freshwater ecosystems and habitats?

Visitors' general knowledge about freshwater ecosystems and habitats

A primary focus of the interview was to capture visitors' general knowledge, attitudes, and connections regarding themes that could be addressed by the 3D visualization project. To elicit visitors' top of mind understanding of freshwater ecosystems, interviewees were asked to give the words or phrases that came to mind when they heard the term "freshwater ecosystem." A Word Cloud of responses illustrated that for many visitors' the first thing that came to mind were types of freshwater ecosystems like rivers, streams, marshes, and ponds, as well as wildlife associated with freshwater ecosystems like fish, birds, frogs, and plants (see Figure 5 below). It was interesting to note that some visitors made comments about the conditions of freshwater ecosystems. For example, a number of visitors mentioned "clean" in connection with freshwater ecosystems along with "green," "healthy," as well as "damaged" and "polluted." Word Clouds of top of mind responses for visitors at each of the three participating institutions can be found in Appendix H.

Figure 5. Word Cloud of top of mind responses, interview

Similar to the top of mind responses regarding the term "freshwater ecosystem," when asked to identify as many types of freshwater ecosystems as they could, most visitors named common ecosystems like rivers, lakes, and streams, the three of which were named by over 50% of respondents across the locations (see Table 21). However, there was some variation in which ecosystems they named based on the location of the interviews. While ponds was a freshwater ecosystem that many individuals identified at ECHO and LHS, only

a quarter of individuals at TERC mentioned this ecosystem. In contrast, visitors at TERC more frequently named streams compared to individuals who were interviewed at ECHO and LHS. Wetlands, reservoirs, and springs were freshwater ecosystems that were less commonly identified by visitors, especially at TERC and LHS. In addition, 14% of respondents across institutions identified a number of less common ecosystems like glaciers, waterfalls, and icebergs; these responses were grouped into the miscellaneous category.

Table 21. Types of freshwater ecosystems that visitors identified, interview

Freshwater Ecosystem	TERC (n=29)	ECHO (n=84)	LHS (n=142)	Total (n=255)
Rivers	79%	76%	79%	**78%**
Lakes	66%	62%	70%	**67%**
Streams	72%	55%	55%	**57%**
Ponds	24%	68%	44%	**49%**
Wetlands	10%	46%	24%	**30%**
Reservoir	10%	6%	13%	**10%**
Springs	0%	7%	2%	**4%**
Miscellaneous	10%	17%	13%	**14%**

* Some individuals selected more than one response, so columns may add to more than 100%.

While the categories for correctly identifying freshwater ecosystem are included in Table 21, of those who responded to this interview question more than one quarter (28%) also incorrectly identified at least one freshwater ecosystem. A common error visitors made was naming saltwater ecosystems like deltas, estuaries, and the ocean. Further, 23% of respondents to this question (58 of 255) were initially unable to identify a freshwater ecosystem at all, which necessitated the evaluator providing an example of a freshwater ecosystem in order to prompt the visitors' response (e.g., "One example of a freshwater ecosystem is a lake…").

Upon gathering visitors' general knowledge of freshwater ecosystems, evaluators then sought to capture visitors' specific knowledge about watersheds, a less well-known topic that will need to be addressed by the project. When asked to complete the sentence "A watershed is…" many visitors' struggled to provide a definition with many ultimately guessing. As illustrated in Table 22, 64% of individuals who were interviewed either did not know what a watershed was, guessed the definition incorrectly, or gave an unrelated response. Compared to ECHO and LHS, more visitors at TERC (45%) were able to give a definition that was completely or partially correct.

The observed variance in visitors' definitions of the term "watershed" was tested using analysis of variance (ANOVA)[3] wherein the means of the responses across institutions were compared to determine whether there was a statistically significant difference in the

[3] An ANOVA is a statistical test of whether or not the means of several groups are equal.

correctness of the definitions visitors gave at the three institutions. No statistically significant differences were found when testing responses across institutions. Further, in applying ANOVA to test differences in responses across age groups[4] within the total sample no significant difference in the correctness of responses by age group was revealed. This means that being able to define the term "watershed" correctly was not impacted by someone's age.

Table 22. Percent of individuals that incorrectly or correctly define the term "watershed," interview

	TERC (n=29)	ECHO (n=87)	LHS (n=150)	Total (n=266)
Incorrect / Don't know	55%	62%	66%	**64%**
Partially correct	24%	24%	19%	**21%**
Correct	21%	14%	15%	**15%**
Total	100%	100%	100%	**100%**

Once visitors had given their definition of a watershed, the evaluator provided a standard definition of the term and then asked visitors to describe something about the watershed they live in. As with the definition of watershed, visitors struggled to identify aspects of their local watershed; this sometimes occurred even if someone could correctly define the term. Just over one third of visitors across institutions indicated that they were essentially unfamiliar with the watershed in which they lived (see Table 23). TERC visitors were better able to identify aspects of their watershed compared to visitors at LHS. Additionally, 13% of visitors in the interview sample gave a response unrelated to the question or did not correctly identify characteristics of their watershed. Finally, 7% of respondents identified characteristics of the local environment that were unrelated to their local watershed. In total, slightly less than half (44%) of the interview sample was able to describe any aspect about their local watershed.

Of the visitors who did offer a description of the watershed where they lived, nearly one quarter of individuals across institutions described the flow or drainage of a body of water. Just 15% of individuals were able to identify their local watershed by name and/or description. In describing the watershed where they live, 22% of visitors attributed positive or negative human impacts on that watershed, see Table 23.

Table 23. Aspects of local watershed that visitors described, interview

	TERC (n=28)	ECHO (n=88)	LHS (n=146)	Total (n=262)
Unable to describe watershed				
Unfamiliar with local watershed	21%	33%	41%	**36%**
Does not correctly identify any aspect of a watershed or the response is unrelated	18%	17%	10%	**13%**

[4] In order to ensure that the cell sizes were sufficiently robust to apply ANOVA to analyze interview questions, the ages of visitors in the sample were regrouped into 3 categories: 0-35, 36-50, 51-100.

Identifies characteristics of the general local environment, not watershed	7%	7%	7%	**7%**
Offers description of watershed				
Describes a body of water or the flow and drainage of a body of water	29%	18%	26%	**24%**
Identifies a local watershed by name and/or description	21%	21%	11%	**15%**
Attributes positive characteristics to watershed and/or efforts to preserve it	25%	10%	10%	12%
Describes local water or watershed as damaged, polluted, or scarce	7%	7%	12%	10%

* Some individuals gave more than one response, so columns may add to more than 100%.

Visitors' attitudes regarding freshwater ecosystems and habitats

In order to help inform decisions about the design and development of the project, the interview sought to not only capture visitors' knowledge of freshwater ecosystems, but also visitors' attitudes toward freshwater ecosystems and habitats. One way of exploring visitors' attitudes was through examining their connections to freshwater ecosystems. During the interview, visitors were asked if there were a single freshwater ecosystem to which they felt particularly connected. Across institutions, 86% of interviewed visitors indicated that they shared a connection with a specific freshwater ecosystem, whether local or distant, see Table 24. While the percent of individuals who felt a connection to a particular ecosystem varied across institutions, a chi square test for independence[5] found no significant difference in responses across institutions or across age groups.

Table 24. Whether visitors' felt a connection to a freshwater ecosystem, interview

	TERC (n=30)	ECHO (n=88)	LHS (n=149)	Total (n=267)
Yes	93%	90%	83%	**86%**
No	7%	10%	17%	**14%**
Total	100%	100%	100%	**100%**

In addition, visitors identified the freshwater ecosystems to which they felt connected (see Appendix I for full responses) and described the reasons for this connection. As shown in Table 25, over half of individuals at TERC and ECHO felt connected to a freshwater ecosystem because they lived nearby the ecosystem or visited the location frequently. This is not surprising given the close proximity of TERC to Lake Tahoe and the fact that ECHO is located on Lake Champlain. Across institutions, 35% of visitors felt connected because the freshwater ecosystem is a place where they vacation or do recreational activities. Just over 10% of individuals at TERC felt connected due to family associations, meaning they have family who live in the area or it is a place they go to often with their family. A lower percent of individuals at ECHO and LHS associated family connections with a particular freshwater

[5] A chi-square test for independence evaluates whether or not there is a relationship between two variables.

ecosystem. In total, 10% of individuals who were interviewed gave answers categorized as miscellaneous, meaning that the responses were either irrelevant to the question, too general to categorize, or represented a range of responses that were unrelated to the main categories.

Table 25. Reasons why visitors feel connected to a particular ecosystem, interview

	TERC (n=27)	ECHO (n=80)	LHS (n=123)	Total (n=230)
Physical proximity or a place that respondent visits frequently	59%	55%	31%	**43%**
A place of recreation or vacation	33%	30%	38%	**35%**
Attracted to the wildlife or the natural beauty of the area	19%	6%	29%	**20%**
Nostalgia; respondent would go there in the past	15%	9%	15%	**13%**
Respondent has family connections to the area	11%	6%	1%	**4%**
Dependent upon resources of the area	0%	5%	3%	**3%**
Relevant to respondent's job	4%	1%	2%	**2%**
Miscellaneous	11%	8%	11%	**10%**

* Some individuals gave more than one response, so columns may add to more than 100%.

As another means to assess visitors' attitudes toward freshwater ecosystems, during the interview individuals were asked to rate on a 10-point scale where 1 is "none" and 10 is "a lot," how much of a positive impact they feel humans currently have on the health of freshwater ecosystems. Table 26 below describes visitors' mean rating both within and across institutions. While the overall mean rating was 4.0, indicating that visitors' felt humans had a somewhat positive impact on freshwater ecosystems, it is surprising to note that the mean rating of visitors' at TERC was somewhat higher than the mean of the other two institutions. Applying an Analysis of Variance (ANOVA) statistical test revealed a statistically significant difference (at the .05 level of significance) in mean ratings across institutions, and that TERC visitors rated the positive impact of humans significantly higher than did visitors at the other two institutions.[6]

Table 26. Mean ratings of positive human impact on freshwater ecosystems, interview

	TERC (n=28)	ECHO (n=87)	LHS (n=147)	Total (n=262)
Mean	4.6	3.6	3.7	**4.0***
Std. Dev.	2.3	2.2	2.2	**2.3**

* $p<.05$

[6] [F(2, 259) = 4.515, p = .012]

In addition to rating the positive impact of humans on freshwater ecosystems, visitors were asked to explain the reason for the rating they gave. As illustrated in Table 27, even though visitors were asked to focus on the positive impact, visitors commonly mentioned the negative impacts of humans in explaining their ratings of how positive an impact humans had on these systems. A quarter of individuals across institutions felt that humans were polluting freshwater ecosystems and another 22% said that humans generally hurt more than help ecosystems. In contrast, 22% of visitors in the interview sample identified that there were some people who were concerned about freshwater ecosystems and took care of them. Surprisingly, only roughly a quarter of individuals at TERC and LHS indicated that some people were caring for ecosystems[7] while just 11% of visitors at ECHO identified this positive human impact. Overall, respondents pointed out many negative human impacts although they had been prompt by the evaluator to consider the degree to which humans positively impact freshwater ecosystems.

Table 27. Human impacts on freshwater ecosystems as identified by visitors considering the positive effects of humans, interview

	TERC (n=29)	ECHO (n=88)	LHS (n=150)	Total (n=267)
Negative human impacts				
Humans are polluting ecosystems	21%	26%	25%	**25%**
Humans generally hurt more than help ecosystems	24%	17%	24%	**22%**
Humans lack awareness, care, and/or effort in regards to the health of ecosystems	14%	19%	15%	**16%**
Humans harm wildlife and/or wildlife habitats	10%	6%	9%	**8%**
Development, agriculture, and/or industry have a negative impact on ecosystems	0%	6%	5%	**5%**
Positive human impacts				
Some people are taking care of ecosystems	31%	11%	26%	**22%**
There is more education and knowledge about the environment than in the past	14%	14%	7%	**10%**
Humans are repairing previous ecological damage	17%	9%	7%	**9%**
Other				
Humans are both helping and hurting ecosystems	3%	10%	1%	**4%**
Miscellaneous	7%	11%	15%	**13%**

* Some individuals gave more than one response, so columns may add to more than 100%.

Visitors were also asked to consider the negative impact humans have on freshwater ecosystems. Using the same 10-point scale, visitors across institutions gave humans' negative impact a mean rating of 7.6, see Table 28. Although mean ratings across

[7] In their responses, visitors did not always specially address freshwater ecosystems, but rather referred to humans' impact on the environment in general.

institutions varied somewhat, a test of statistical significance in mean ratings between institutions revealed no statistically significant differences.

Table 28. Mean ratings of negative human impact on freshwater ecosystems, interview

	TERC (n=28)	ECHO (n=87)	LHS (n=148)	Total (n=263)
Mean	8.1	7.4	7.6	**7.6**
Std. Dev.	1.6	1.9	1.7	**1.7**

Visitors were also asked to explain the reason for the negative rating they gave, as illustrated in Table 29. Humans polluting ecosystems was a negative impact that over 41% of individuals identified. In contrast, when asked to rate humans' positive impact, just 25% of individuals identified that humans are polluting ecosystems, see Table 28 above. While 16% of visitors across institutions felt that humans lacked awareness, care, and effort in regards to the health of ecosystems when considering the positive impacts of humans, 25% of visitors identified this as an issue when considering the negative impacts of humans. Also when considering the negative impact of humans, fewer individuals focused on how humans positively affect freshwater ecosystems. Further, nearly 20% of visitors who responded to this question gave a response that was unspecific, could not be grouped with any of the primary categories, or was unrelated to the interview question.

Table 29. Human impacts on freshwater ecosystems as identified by visitors considering the negative effects of humans, interview

	TERC (n=28)	ECHO (n=88)	LHS (n=149)	Total (n=265)
Negative human impacts				
Humans are polluting ecosystems	46%	27%	48%	**41%**
Humans lack awareness, care, and/or effort in regards to the health of ecosystems	18%	26%	26%	**25%**
Humans harm wildlife and/or wildlife habitats	21%	16%	17%	**17%**
Development, agriculture, and/or industry have a negative impact on ecosystems	4%	11%	18%	**14%**
Humans generally hurt more than help ecosystems	21%	8%	13%	**12%**
Positive human impacts				
Some people are taking care of ecosystems	0%	5%	10%	**7%**
There is more education and knowledge about the environment than in the past	0%	7%	1%	**3%**
Humans are repairing previous ecological damage	7%	3%	0%	**2%**
Other				
Both helping and hurting ecosystems	**4%**	7%	1%	**3%**
Unspecific/other	**21%**	15%	17%	**17%**

* Some individuals gave more than one response, so columns may add to more than 100%.

Looking across visitors' ratings of the positive and negative impact of humans on freshwater ecosystems, it is apparent that across and within institutions, visitors' perceive that humans have a more pronounced negative effect on their environment and freshwater ecosystems than positive. Most individuals identified the negative effects of humans, even when asked to consider humans' positive impact. Individuals who were interviewed identified that humans pollute ecosystems, do not care for or respect the environment, and allow agriculture and industry to develop at the expense of freshwater ecosystems. However, a few individuals noted that there are some people who are concerned about the environment and that there is growing knowledge and awareness about the need to take care of the environment and greater effort to repair ecological damage.

2) What are the entry points (i.e., content and activities) for engaging audiences, including rural and Spanish-speaking groups, in the content?

The interview with visitors at TERC, LHS, and ECHO not only captured individuals' knowledge and attitudes toward freshwater ecosystems, but also identified several entry points for engaging visitors around this topic. During the interview, visitors were asked to give examples their own actions in reducing the negative impact humans have on freshwater ecosystems. As shown in Table 30 four out of five respondents felt that they took actions to reduce their impact on freshwater ecosystems. When tested statistically, visitors' responses did not vary significantly across institutions or by age group.

Table 30. Whether visitors were reducing their impact on freshwater ecosystems, interview

	TERC (n=28)	ECHO (n=88)	LHS (n=149)	Total (n=265)
Yes	82%	82%	79%	**80%**
No	18%	18%	21%	**20%**
Total	100%	100%	100%	**100%**

Actions individuals are taking to reduce their impact on freshwater ecosystems

When asked to describe what they were doing to reduce their impact on freshwater ecosystems, the single most common response was recycling (29%) followed by actively conserving water (21%) (see Table 31). Maintaining ecofriendly landscaping and/or gardening was an action untaken by 16%. A number of individuals were also using ecofriendly household products and properly disposing of these products, as well as actively cleaning up the environment and educating others (usually the visitors' children) about how to take care of the environment.

Table 31. Actions respondents are taking to reduce impact on freshwater ecosystems, interview

	TERC (n=24)	ECHO (n=76)	LHS (n=124)	Total (n=224)
Recycling	21%	37%	25%	**29%**

Conserving water	21%	16%	23%	**21%**
Maintaining ecofriendly landscaping and/or garden	29%	20%	11%	**16%**
Cleaning up environment	21%	17%	11%	**14%**
Properly disposing of products	4%	9%	18%	**13%**
Not littering	4%	17%	12%	**13%**
Educating others	0%	11%	16%	**13%**
Using ecofriendly food and household products	13%	7%	12%	**10%**
Not disturbing wildlife and/or wildlife habitats	17%	11%	7%	**9%**
Giving financial donations or other support to environmental groups	4%	4%	11%	**8%**
Reducing waste	0%	3%	13%	**8%**
Taking civic action	8%	7%	7%	**7%**
Generally not polluting	4%	4%	7%	**5%**
Using ecofriendly transportation or reducing use of a motorized vehicle	13%	5%	3%	**5%**
Composting food waste	0%	5%	4%	**4%**
Having consciousness awareness or respect for environment	0%	1%	5%	**3%**
Miscellaneous	0%	8%	10%	**8%**

* Some individuals gave more than one response, so columns may add to more than 100%.

Understanding which actions visitors were already taking to conserve the environment would enable 3D visualization project members to design activities, content, and components that directly connect to visitors' lives. It would also enable project developers identify areas that could build on visitors' knowledge about how they can better protect and converse freshwater ecosystems. While the open-ended question above would allow for visitors to report a variety of behaviors, there were specific behaviors the project team was interested in encouraging around freshwater ecosystems; this list is included in Table 32 below. Knowing the extent to which the visitors were already engaging in these specific behaviors would help the team to understand where there was capacity to increase these behaviors among visitors.

Of the list of behaviors provided by the project team, visitors were most likely to be using less toxic products (85%), composting (60%), using phosphorous-free fertilizers (42%) and installing a rain garden (40%). They were least likely to volunteer (10%) or to clean boats to reduce invasive species (18%).

Table 32. Environmentally friendly actions visitors do regularly, interview

	TERC (n=28)	**ECHO (n=83)**	**LHS (n=144)**	**Total (n=255)**
Using less toxic home/personal cleaning products	82%	77%	90%	**85%**

Composting food waste	36%	49%	72%	**60%**
Using only phosphorus-free fertilizers on plants	29%	42%	44%	**42%**
Picking up after your dog	39%	43%	38%	**40%**
Installing a rain garden, rain barrel or porous walkway/ driveway	39%	27%	15%	**22%**
Cleaning, draining or drying boats stop invasive species	25%	27%	12%	**18%**
Volunteering for a local watershed, wetland, environmental group	18%	8%	10%	**10%**

* Some individuals selected more than one response, so columns may add to more than 100%.

Actions visitors would most likely take to reduce their impact on freshwater ecosystems

After finding out which behaviors visitors were already doing, the evaluator then asked visitors which of the behaviors they *were not* currently doing they would be most likely to engage in. In this manner, the team could identify the behaviors with the greatest potential to increase freshwater ecosystem-friendly behaviors (i.e. the "low hanging fruit" behaviors). As illustrated in Table 33, the actions selected by the highest percentage of visitors across institutions were installing a rain barrel to catch water run-off (40%), volunteering (22%), composting food waste (21%) and using only phosphorous-free fertilizers (20%). Far fewer individuals selected stopping invasive species through maintaining their boat (5%) and picking up after their dog (4%). When asked this question during the interview, many visitors offered that they did not have a boat or dog, and many of those individuals who said they had a dog were already picking up after it.

Table 33. Actions visitors' would be most likely to undertake to protect freshwater ecosystems, interview

	TERC (n=26)	**ECHO (n=71)**	**LHS (n=124)**	**Total (n=221)**
Installing a rain garden, rain barrel or porous walkway/ driveway	23%	38%	45%	**40%**
Volunteering for a local watershed, wetland, environmental group	31%	21%	21%	**22%**
Composting food waste	31%	24%	17%	**21%**
Using only phosphorus-free fertilizers on plants	19%	17%	22%	**20%**
Using less toxic home/personal cleaning products	8%	7%	8%	**8%**
Cleaning, draining or drying boats stop invasive species	12%	4%	5%	**5%**
Picking up after your dog	0%	7%	2%	**4%**

* Some individuals selected more than one behavior, so columns may add to more than 100%.

When asked why they would undertake a particular action to protect a freshwater ecosystem, convenience was the primary reason visitors gave. Across institutions, 34% of

respondents said they selected a specific action because it was possible to do, they were already doing it, or they had done it before (see Table 34). It is interesting to note that fewer visitors were motivated to undertake a particular action because they felt it was good for the environment or beneficial for their health. Of all respondents, 43% gave a response that was unspecific or otherwise unrelated to the interview question. Many individuals responded to the question of why they selected a particular action by describing why they did not select the other actions.

Table 34. Reasons why visitors selected a particular action to preserve freshwater ecosystems, interview

	TERC (n=22)	ECHO (n=59)	LHS (n=104)	Total (n=185)
It is possible to do	23%	14%	23%	**20%**
Already doing it or did it before	14%	15%	13%	**14%**
Conserve or reuse water	0%	10%	13%	**10%**
Good and/or interesting idea	5%	10%	11%	**10%**
Better for the environment	0%	17%	5%	**8%**
Fun or enjoyable	0%	3%	5%	**4%**
Good way to get involved with the community	0%	0%	6%	**3%**
Better for health	5%	0%	3%	**2%**
Respondent cares about environment	9%	0%	1%	**2%**
Reduce waste in landfills	9%	0%	1%	**2%**
Unrelated or unspecific responses	59%	46%	39%	**43%**

* Some individuals gave more than one response, so columns may add to more than 100%.

3D visualization topics that most interest visitors

Included in the interview protocol were five questions related to scientists who study lakes that could be addressed by the project, meant to inform the team about areas that visitors were most interested in. Evaluators showed interview respondents the five questions that represented potential 3D visualization project topics and asked visitors to select the two questions they found most interesting. As illustrated in Table 35, Question C (what questions scientists are asking) was most popular, by a wide margin. Question E (tools and technologies) and Question B (kinds of data collected) were also interesting to about half of visitors in the total sample. These were followed by Question A (how scientists collect data) and Question D (how scientists get interested in studying lakes), selected by just 9% of visitors

Table 35. Visitor interest in potential 3D viz topics, interview

	TERC (n=28)	ECHO (n=88)	LHS (n=146)	Total (n=262)
Question C: What questions are scientists trying to answer about lakes?	75%	73%	76%	**75%**
Question E: What are tools and	46%	61%	45%	**51%**

technologies scientists use to collect data?				
Question B: What kinds of data do scientists collect about lakes?	54%	39%	49%	**46%**
Question A: How do scientists collect data about lakes?	14%	25%	20%	**21%**
Question D: How did specific scientists get interested in studying lakes?	4%	11%	8%	**9%**

* Visitors could select two questions, so columns add to more than 100%.

Upon selecting their two favorite questions about scientists who study lakes, visitors were asked to explain the reasons for their selection (see Table 36 to Table 40). Data collectors purposefully varied which question they asked visitors to explain, so that responses were more equally distributed across the five questions. As such, the number of individuals at each institution who selected a particular question was relatively small. Therefore, counts of individuals (n=) are presented in the tables below rather than percentages.

Question A - How do scientists collect data about lakes?

When asked why they were interested in Question A, the majority of respondents (26 of 53) were most interested in the data collection methods and tools that scientists use. A few visitors (6 of 53) identified a connection between Question A and Question E ("What are the tools and technologies scientist use to collect data?") and suggested that Question E would provide the answer to Question A. Additionally, a few individuals (6 of 53) felt that the question would be fun for kids to answer and that it was a fundamental question to understanding scientists' conclusions.

Table 36. Reasons for selecting Question A, interview

	TERC (n=4)	ECHO (n=19)	LHS (n=30)	Total (n=53)
Interested in the data collection methods and tools scientists employ	2	12	12	26
Question A is related to Question E	0	3	3	6
Exploring the question would be fun for kids	1	2	3	6
It is important to understand how scientists make conclusions	1	2	2	5
The question is open-ended, broad, or all encompassing	0	0	4	4
Miscellaneous	0	3	10	13

Question B - What kinds of data do scientists collect about lakes?

Question B was chosen by 46% of individuals in the total interview sample. When asked what most interested them about the question, 30 of 116 visitors more or less just restated the question, expressing an interest in the data scientists are collecting. Some visitors (23 of 116) were most intrigued to know what scientists find out from the data they collect. The remaining reasons visitors gave for selecting this question represent a range of categories as detailed in Table 37 below.

Table 37. Reasons for selecting Question B, interview

	TERC (n=13)	ECHO (n=32)	LHS (n=71)	Total (n=116)
Interested in the data scientists are collecting	4	10	16	**30**
Interested in what scientists find out	1	8	14	**23**
Interested in both the methods scientists are using and the kinds of data they are collecting	2	2	9	**13**
Interested in the reason why scientists are collecting data	1	4	7	**12**
Interested in the methods scientists are using to collect data	1	1	9	**11**
Personal connection to the topic due to related knowledge or employment	3	1	4	**8**
Questions B is related to Question C and/or A	1	1	4	**6**
Interested in finding out more information about the lake	0	2	3	**5**
The question is generally interesting	0	5	0	**5**
Reduces lack of knowledge about what data are collected	1	0	3	**4**
Miscellaneous	0	3	7	**13**

Question C - What questions are scientists trying to answer about lakes?

Question C was by far the most popular question with visitors, as 75% of individuals who were interviewed selected this question. Visitors described a range of reasons for their interest in this question. As displayed in Table 38, 18 of 97 visitors felt this was a fundamental question, while 17 of 97 simply restated the question by indicating an interest in the questions scientists have. The remaining visitor responses represent a range of reasons, including that it sounded interesting, or wanted to know scientists' objectives; some were included in the miscellaneous category.

Table 38. Reasons for selecting Question C, interview

	TERC (n=10)	ECHO (n=40)	LHS (n=47)	Total (n=97)
Question C is a broad and/or fundamental question	6	5	7	**18**
Interested in knowing what questions scientists have	1	7	9	**17**
Question C is generally interesting	1	7	6	**14**
Interested to know scientists' objectives	0	5	6	**11**
Interested in learning what scientists are doing/studying	0	6	3	**9**
Interested in learning what scientists are finding out	0	2	5	**7**
Interested in learning how to improve the	0	1	5	**6**

environment				
Question C is related to B and/or E	1	1	3	**5**
Miscellaneous	1	9	7	**17**

Question D - How did specific scientists get interested in studying lakes?
Question D was the least popular with visitors, as just 9% of the total sample selected this question. Of the 20 individuals who explained their reasons for selecting this question, 7 visitors paraphrased the question saying they were interested to learn why scientists chose their career (see Table 39). A small number of individuals indicated interest in the human aspect of pursing science, while a few individuals found the question of general interest or important for educating youth about science careers.

Table 39. Reasons for selecting Question D, interview

	TERC (n=1)	**ECHO (n=7)**	**LHS (n=12)**	**Total (n=20)**
Interested to learn why scientists chose their career	1	2	4	**7**
Interested in the human aspect of pursuing science	0	1	4	**5**
Question D is generally interesting	0	1	3	**4**
Question D would educate young adults about careers in science	0	2	0	**2**
Miscellaneous	0	1	1	**2**

Question E - What are tools and technologies scientists use to collect data?
Question E was the second most popular question with visitors as just over half of the interview sample selected this question as one they would like to learn more about. Table 40 displays the reasons visitors gave for their selection. When asked why they chose Question E, a total of 49 of 95 (52%) respondents more or less rephrased the question, stating they were interested in the methods scientists use and their tools for collecting data.

Table 40. Reasons for selection Question E, interview

	TERC (n=9)	**ECHO (n=38)**	**LHS (n=48)**	**Total (n=95)**
Interested in learning about scientists' methods	2	12	11	**25**
Interested to learn about tools scientists use to gather data	2	9	13	**24**
Personal interest in technology	0	5	18	**23**
General interest in the topic	1	5	1	**7**
The question would be interesting to kids	0	2	4	**6**
Question E would increase personal knowledge about the topic	0	3	2	**5**
There would be a hands on way of going about	1	0	3	**4**

answering the question				
Question E relates to Question A and/or B	1	2	1	**4**
Interested in what data scientists collect	1	0	0	**1**
Miscellaneous	3	6	8	**17**

APPENDIX A: ISE Professional Survey

[FRONT PAGE]
Thank you for agreeing to answer our questions. The information you provide will be extremely valuable in the design and development of this NSF-funded project. Your responses will be kept anonymous, and will be grouped with other responses.
To get started click "Next page"

[NEW PAGE]
About Your Institution
First we'd like to learn a little bit about your institution.

1. What is the name of your institution? [open-ended]

2. What is your title? [open-ended]

3. Who do you consider to be the primary audiences for your institution? Check all that apply.
   - School groups (Elementary, Middle, High School)
   - Families with young children (0 to 9)
   - Tweens (10 to 12)
   - Teens
   - Adults
   - Scientists/STEM professionals
   - Other: [open-ended response]

4. Does your institution currently present any information about freshwater ecosystems (lakes, rivers, streams, watershed)?
   - Yes
   - No

4a. If yes, Which of the following freshwater ecosystem topics does your institution currently cover in the content it presents? **Please drag the following topics into the boxes that are most appropriate.**

- Water and the processes of water
- Lakes & rivers, streams
- Watersheds
- Environmental stewardship
- Geological processes

- Physical processes/forces on lakes
- Biology/ecology
- Other:

5. Does your institution currently encourage visitors to engage in stewardship behaviors related to freshwater ecosystems?
   - Yes
   - No

5a. If yes, which behavior(s)

[NEW PAGE]

Content

We are also interested in your feedback about the content related to this project.

6. The project is working on coming up with a number of "big ideas" that drive the planning and development of all aspects of the project. What comments, if any, do you have about how appropriate these "big ideas" are for presenting visitors with information about freshwater ecosystems? (Such as relevancy, broadness/narrowness, missing concepts, etc.) [open-ended]

   Big Ideas:
   Water connects all Earth systems.
   Freshwater ecosystems are dynamic, complex and diverse.
   Humans impact freshwater ecosystems both locally and globally.

[NEW PAGE]

Tabletop Interactive Exhibits

Six tabletop activities will be developed by the UC Berkeley Lawrence Hall of Science to include a mix of hands-on interpretive materials, lightweight exhibits, and tablet PCs (iPads) for multimedia interactives and stories. These will help further illustrate, reinforce, and integrate key concepts covered on the topic of freshwater ecosystems.

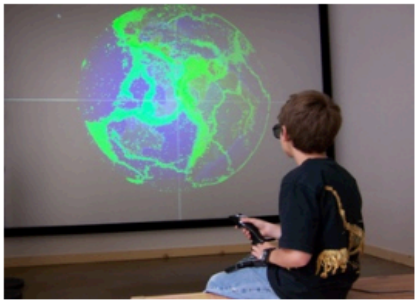
7. Given the description of the tabletop interactives above, how likely do you think your museum or science center would be to use the following tabletop interactive exhibits about lake ecosystems?

	Not Likely	Possibly	Probably	Definitely use
• Working model				
• Observe closely				
• Small experiment				
• Play and interact				
• Make & take				
• Tactile Display/Sculpture				
• Multimedia/iPad				

Immersive 3D Visualizations

Immersive 3D visualizations (and non-immersive 3D and 2-D visualization versions) are currently being developed for Lake Tahoe and Lake Champlain using the latest technologies. These exhibits illustrate the physical, biological and geochemical processes that constitute watersheds and freshwater ecosystems. They utilize real data sets and numerical simulations to show past and current conditions, and future scenarios under different natural and human impact conditions. Click on the top picture below to see a short movie about the 3D visualization.

Lake Tahoe In Depth teaser #1 in 2D from Steven McQuinn on Vimeo



Audience V *id*

8. Given the description above, how interested would your institution be in potentially including a 3D Visualization exhibit (e.g. wall-mounted or theater) related to your local freshwater ecosystem?
   - Definitely
   - Probably
   - Possibly
   - Not likely

9. Which of the following would be the two biggest barriers that might prevent your institution from including immersive 3D visualizations? [please check <u>two</u> <u>only</u>]
   - Cost
   - Space
   - Technical requirements
   - Staff
   - Other [please describe]

10. Is your institution currently using any large, immersive computer-based (digital) visualizations or simulations with visitors?
    - yes
    - no

11. If YES, please describe:

12. What, if anything, do you find most interesting about the idea of this project? [open – ended]

[NEW PAGE]

Follow up

13. There are multiple ways to engage with this 3D visualization project over the next few years. Which of the following interests you? Please select all that apply.
    - I would like to learn more about these specific exhibits
    - I would like to be informed about the progress of this project
    - I am interested in talking about becoming involved with this project in some way
    - I am interested in hosting the types of exhibits described above
    - I would be willing to talk more about my responses in the survey
    - No thanks, I'm good

14. If you checked “Yes” to any of the above please provide us with your name and email address and we will contact you shortly. We will only use your contact information for the purpose described above. [open-ended]

Thank you for your feedback!

APPENDIX B: ISE Professionals Survey, open-ended responses

Q5. Does your institution currently encourage visitors to engage in stewardship behaviors related to freshwater ecosystems? If Yes, Which behavior(s)?

- adopt a beach, rain barrels, rain gardens, general responsibility and stewardship of watershed
- bayscaping, stormwater runoff mitigation, cleanups, tree planting, gardening
- Beach cleanups, stream restoration, sustainable consumer practices, general water and energy conservation
- conserving paper
- using low flush toilets
- recycling
- Control of exotic species, protection of endangered species, maintenance of healthy and diverse ecosystems
- In our programs related to energy and water usage we encourage our visitors to think about their actions when it comes to faucet use, detergent use, periodicity of washing and drying clothes, using more energy efficient water heating systems, light bulbs composting, upcycling etc. This is still an area where we are growing.
- Invasive species control, monitoring, and management; tree plantings; roadside cleanups; stream monitoring; green infrastructure home applications; beach cleanups; etc.
- invasive species prevention and removal, reduction of water use, proper disposal of hazardous materials, including solid waste and pharmaceuticals, refraining from feeding shorebirds, native planting and xeriscaping, reduction of energy use, change in foo habits and purchasing
- Meaningful watershed educational experiences that lead to a willingness to act through such behaviors as stream clean-ups, community involvement, recycling, etc.
- Native plant restoration projects, awareness and respect for ecosystems, personal responsibility for actions and decisions that may impact stewardship of the land and water
- not polluting or unnecessarily disturbing freshwater habitats, systems thinking
- Reduce, reuse, recycle
- Minimizing primary watershed pollutants (animal waste, fertilizers, oil/gasoline, etc....
- composting
- personal energy conservation/production
- rain barrel use

- runoff management; managing use of fertilizers and pesticides, minimizing erosion, restoring wetlands;
- Science Club
- Clean the Bay Day
- The USGS participates in a wide-range of activities that support stewardship behavior. Visit usgs.gov for details.
- Water conservation
- Water conservation, land conservation, riparian conservation
- Water conservation, minimize all types of pollution, flora and fauna diversity and conservation
- We deal broadly with aquatic (fresh water) ecosystems. We have, in the recent past, had an outreach program that focused on fishes but that has been replaced with a new focus on bees. The audiences are mostly K-6 for these programs. We have many dioramas, several of which feature aquatic contexts but most of which do not provide a lot of detail in supporting labels. We have some material on display about "exotic aquatics, focusing on zebra mussels and milfoil and preventing the spread.
- We're the home of the Freshwater Innovation Alliance, a regional coalition of universities, non-profits, and businesses working together to encourage regional development around freshwater issues, making Northeast Ohio a great place to live, work, and play.
- We also encourage sustainability, awareness of water processing, awareness of invasive species/algal blooms/dead zones/etc. Some of this is done through exhibits, and some solely through education programming.

Q10. Is your institution currently using any large, immersive computer-based (digital) visualizations or simulations with visitors? If Yes, please describe:

- For the new Ocean Bound exhibition we created at 20' long immersive submersible with a captains station that lets you pilot the sub through watersheds and out into the ocean. We filmed underwater footage throughout North America and put it all in sequence into a Spin Browse device
- gigapixel image displays, gigapixel timelapse of NASA data sets.
- Interactive "nature walk" through Mendon Ponds park. Visitors manipulate through a large projection of Mendon Ponds that has been recreated using the Unreal game engine (similar to first-person shooting games). As they explore they find podiums throughout the virtual park where they can learn about the features left by glaciers.
- Portable explorer dome showing planetarium shows at off-site locations. The dome is too big to set up anywhere in our building. We are working to get funding to remodel a room to hold a theater for digital projection.

- Science on a Sphere
- Watt wall (20 ft x 8 ft video wall) on energy
- Science on a sphere
- 4 ft x 4 ft video walls with 1 minute content programs
- we have a touch-based simulation of crystallization, and are working on a multi-user simulation around sustainability.
- We have an astronomy program that takes place in a portable planetarium (exploradome).

Q12. What, if anything, do you find most interesting about the idea of this project?

- At the Museum of the Earth we're very interested in these sorts of experiences, which we think are very engaging and relevant to visitors. We have an NSF-funded project that features virtual field experiences (www.virtualfieldwork.org), which we use in teacher professional development, but we have not developed funding to bring virtual experiences into our Museum exhibits. Our local freshwater environments are the Finger Lakes, associated with numerous gorges and waterfalls; not far away are the Great Lake, Niagara Falls, and river systems such as the St. Lawrence and Susquehanna.
- can be related to local water resources
- Engagement is the first step in educating people. Anything that is hands-on or uses cool technology engages people faster and keeps them engaged longer allowing then to absorb the information more fully.
- Engaging people in a way that can comprehend and appreciate the way freshwater ecosystems function and the way humans interact with and depend upon these systems.
- engaging visitors in immersive experiences.
- Good engagement between the visitors and science
- Hard to say given the small snapshots we were given. If the connection between the 3D topography and the resultant processes found within the ecosystems is made clear, this would be very interesting. (And if learners could then manipulate the topography, s in the sand table picture, and see how that manipulation changes the ecosystem, all the better!)
- I would want the 3D visualization to be interactive--i.e. visitors and/or staff can change the outcome--rather than a canned video. I think it has the most promise for a facilitated experience.
- If we were to use such an exhibit and visualizations it would be most interesting to use them regionally. Our eleven Finger Lakes cover 14 counties and includes such a diverse landscape that an exhibit like that could share knowledge of similarities and

differences in a comparable format and allow for extensive information sharing and comprehensive learning. Also ground truthing and research data results could compliment the exhibit and make the experience of watching them applicable to specific interests ad trends.

- It draws people in. We are surrounded by water and we get visitors from all over the world who want to learn more about the ecosystems in this area.
- It's good to combine the different methods of learning. We prefer to use the open-ended interactive approach but some kids and adults learn better visually
- our organization utilizes tabletop exhibits with school groups, we are not currently investing in new hands on exhibits and we are in conversation with a vendor about 3d technology
- That it is tackling the importance of freshwater. Some of these things have been done for oceans before, or space, but not fresh water.
- The ability to place the specific biological phenomena we feature in a geographic and historic-geographic context for older kids and adults. It might allow visitors to understand phenomena on a larger scale. We in Minnesota are at the meeting point of3 North American watersheds which is interesting but not made much use of in our programming at the moment.
- The continuum of experiences afforded by the different interactive/communication modes.
- The idea of locally relevant content expressed through a variety of hands-on and immersive activities
- Very interested in the hands-on table-top exhibits that encourage inquiry type learning.
- We do not interpret any lakes, but we would be interested in visualizations or tabletop interactives about the Colorado River, streams, groundwater or the Gulf of California
- We have a fairly large exhibition on a local river system and would definitely be interested in adding additional content to the current exhibits.
- Working in the context of a museum, I constantly find parents and children are more interested with subject matter when they have manipulative to explore. It allows a starting point for the conversations that follow. When people are driving their own leaning they are more likely to remember it. I love the idea of creating pieces such as these that will focus on environmental science and supporting people in making informed decisions.

APPENDIX C: Focus group guide, in English

Focus Group Guide
3D Visualization and Tabletop exhibits

TAHOE ENVIRONMENTAL RESEARCH CENTER focus groups
February 27 and 28, 2012

Focus groups with General Audiences

1. **Warm up**
    - Introductions
    - Purpose of the focus group
    - Have you been to the Tahoe Environmental Research Center before today?
        - If Yes…
            - When did you come, and with whom?
            - During that visit what did you enjoy the most?
        - If No…
            - Any particular reason why you haven't visited before?

2. **Experiences with Connections to lakes/freshwater ecosystems**
    - What comes to mind when you hear the term "freshwater ecosystems"? Probe: can you tell me what kinds of ecosystems would be included in freshwater ecosystems?
    - Freshwater ecosystems are defined as any freshwater aquatic system, including *lakes*, *ponds, rivers, streams, springs, or wetlands.* What can you tell me about the freshwater ecosystems in this area; do you have a favorite type from the ones we just mentioned?
    - Let's talk a bit now about the connections you have to these freshwater ecosystems.
        - Do you regularly participate in any activities on or around lakes and ponds?
            - How about rivers or streams?
            - Springs or wetlands? ((does everyone know what a wetland is? an area that is seasonally or permanently saturated with water – like bogs, marshes or swamps))

- Does anyone here have a job ((or parents have a job)) relating to one or more of these freshwater ecosystems?

3. **Knowledge about Lake Tahoe**
   - How much would you say you know about Lake Tahoe, in terms of how it was formed? Can someone tell me something about how it was formed?
     - How about its ancient history? Anyone know about what was here 100's of thousands or years ago, or millions?
     - Does anyone know about the role glaciers played?
   - How much do you know about how people directly impact the lake?
     - Are you aware of any efforts by individuals or groups in the area to protect the lake and the life in and around it?

4. **Interest in freshwater ecosystems**

   The Tahoe Environmental Research Center is part of a project that is focusing on communicating with people about freshwater ecosystems. As part of this project the team is working on coming up with a number of overarching "big ideas" about freshwater ecosystems. All the project's educational products will focus on these main messages, so we want to know what you think of them.

   - Impressions of big ideas

     I'd like to show you three potential "big ideas" for this project, and for each one I'm going to ask you a couple of questions. [Show one at a time.]

     Idea 1: Water connects to water, land, air and life.
     Idea 2: Freshwater ecosystems are dynamic, complex and are constantly changing.
     Idea 3: Humans study, manage and impact freshwater ecosystems on a local as well global scale.
     - What do you think [idea 1, 2, 3] is about, what does it mean to you?
   - Which of these three topics is most interesting to you, and why?
   - Is there any one topic that you're significantly less interested in compared to the other two, and why?

5. **Interest in activities related to the project**

   The project will include new 3D technology, exhibits, and activities about freshwater ecosystems. There are a couple of different pieces that we'd like to you react to, to hear what you think about them.

   - **Reaction to the Lake Tahoe 3D Visualization**

First, I'd like to show you a short video, and after you've seen it, we'll talk about what you saw. Show http://vimeo.com/25686844 *until time mark of 9:45 where it reads… ("What do you think Lake Tahoe will look like in the future as a result of climate change?")*

So we just saw a flat screen 2D version of the video. Has everyone seen a 3D movie, and can picture what it might look like in 3D? You might imagine that the land and underwater features would "jump out" more in 3D, and give you the sense that you're actually flying around and under the lake.

- What is your overall reaction to the video – what caught your attention or stuck out?
- Which parts of the video did you like the most, and why?
- Were there some topics that you were already familiar with, either about Lake Tahoe or some of the processes or issues they talked about?
- Were there any parts that were new to you?
- If the team were developing a similar kind of video about Lake Champlain, what specific things would you like to see included?

- **Reactions to table-top activities, TYPES**
  In addition to 3D visualizations, tabletop activities will be developed to include a mix of hands-on interactives to help further illustrate, reinforce, and integrate key concepts about freshwater ecosystems. I'm going to show you some different types of tabletop activities, with examples, and ask which ones you would be most interested in doing. First, though, we'll take a look at an actual example of a tabletop so you know what they look like. [SHOW SLIDES WITH DIFFERENT TYPES OF TABLETOPS]

  - Now that we've looked at the 8 different types, I'd like you to vote for your two favorites, by show of hands. [do voting and record # for each]
  - Let's go around the table and talk about your absolute favorite type, and why you picked it.
  - Are there any of the types of activities that you think would be least desirable, or they could leave out?

- **Reactions to table-top activities, CONTENT**

We already talked about the types of tabletop activities and you saw a couple of examples of the types of exhibit we'd use. However, we haven't talked specifically about the content of those tabletops. There are five main content categories we're considering:

Water stations – these are about topics related to water movement, clarity, and density

Ecology stations – these have to do with the animals and other life forms that live in lakes, and the processes that affect them

Landform stations – these pertain to the different types of landforms in and around lakes, and how they affect lakes

Care and action stations – these show how people affect lakes and how they can make decisions to protect them

Scientists tools stations – these address the different tools and research that scientists use to study and understand lakes

- By a show of hands, based on the descriptions which station type would you be most interested in? [do voting and record # for each]
- Which was your favorite, and why?

6. Closing thoughts and comments

- Based on what you just saw, is there anything you think you'd consider learning more about after you leave here today? Something that piqued your curiosity?

We've reached the end of our time together and you've given us some wonderful ideas to think about. Thank you so much everyone for being so open and sharing so much. I know this will help the project team design valuable experiences about freshwater ecosystems.

APPENDIX D: Focus group guide in Spanish

Guía de discusión para grupo focal
Visualización tri-dimensional y exhibiciones de mesa

TAHOE ENVIRONMENTAL RESEARCH CENTER (TERC) grupos focales
27 y 28 de febrero de 2012

Grupos focales con personas del público en general

2. **Calentamiento**
    - Introducciones
    - Propósito del grupo focal
    - ¿Cómo Ud. se dio cuenta de este grupo focal?
    - ¿Alguien de Uds. ha venido antes al TERC, en este edificio?
        - Si sí….
            - ¿Cuándo vinieron y con quién?
            - ¿Qué es lo que más les gustó durante esa visita?
        - Si no…
            - ¿Hay alguna razón en particular por la que no han venido aquí antes?

7. **Experiencias con conexiones a ecosistemas de agua dulce/lagos**
    - ¿ Qué se les viene a la mente cuando escuchan la frase "ecosistemas de agua dulce"? Indagación: ¿Me pueden decir que tipos de ecosistemas estarían incluidos dentro de un ecosistema de agua dulce?
    - Los ecosistemas de agua dulce se definen como cualquier sistema acuático de agua dulce, como lo son *lagos, estanques, ríos, riachuelos, manantiales, o tierras pantanosas*. ¿Qué me pueden decir de los ecosistemas de agua dulce en esta zona? ¿Tienen algún favorito entre los que acabamos de mencionar?
    - Ahora hablemos un poco sobre las conexiones que tienen Uds.con estos ecosistemas de agua dulce.
        - ¿Participan Uds. con alguna frecuencia en algunas actividades en o alrededor de lagos y estanques? [lakes and ponds]
            - ¿En ríos o riachuelos? [rivers and streams]
            - ¿En manantiales o tierras pantanosas? [swamps and wetlands](¿Saben todos lo que es una tierra pantanosa? Es un lugar que siempre o durante ciertas estaciónes del año está saturado de agua, por ejemplo una ciénaga, marisma, o pantano).

- ¿Alguien de Uds. tiene un trabajo (o tiene padres que tienen un trabajo) relacionado con uno o varios de estos ecosistemas de agua dulce?

8. Conocimiento del Lago Tahoe

- ¿Cuánto dirían Uds. que saben del Lago Tahoe en cuanto a su formación? ¿Alguien de Uds. puede decirme algo de cómo fue formado?
  - ¿Qué me pueden decir de la historia antigua del Lago? ¿Alguien sabe que había aquí hace cientos de miles de años o hace mil millones de años?
  - ¿Alguien sabe que papel jugaron los glaciares?
- ¿Cuánto dirían Uds. que saben de la manera en que la gente tiene impacto directo en el Lago? ¿Dirían que saben [bastante, algo, un poco, o no mucho]?
  - ¿Están conscientes de algún esfuerzo que algúnos individuos o grupos de personas en esta zona esten haciendo para protejer el Lago y la vida adentro y alrededor de él?

9. Interés en ecosistemas de agua dulce

El TERC es parte de un proyecto cuyo objetivo es la comunicación con el público sobre ecosistemas de agua dulce. Como parte de este proyecto, el equipo está tratando de desarrollar varias "ideas grandes" que abarcan el tema de ecosistemas de agua dulce. Todo producto educativo creado por este proyecto se enfocará en estos mensajes principales y por eso quisiéramos saber lo que Uds. piensan acerca de ellos.

- Impresiones de ideas grandes
  Me gustaría enseñarles tres posibles "ideas grandes" para este proyecto y para cada una les voy a hacer un par de preguntas [Mostrar una idea a la vez].

  Idea 1: El agua conecta con el agua, la tierra, el aire y la vida.
  Idea 2: Los ecosistemas de agua dulce son dinámicos, complejos y estan cambiando constantemente.
  Idea 3: Los humanos estudian, manejan e impactan los ecosistemas de agua dulce a una escala local, así como a una escala global.
  - ¿De qué se trata la [idea 1, 2, 3], piensan Uds.? ¿Qué significa para Uds.?
- ¿Cuál de estos tres temas les parece más interesante y por qué?
- ¿Hay un tema que les parece mucho menos interesante comparado con los otros dos temas y por qué?

10. Interés en actividades relacionadas con el proyecto

El proyecto incluirá nueva tecnología 3D, exhibiciones y actividades sobre ecosistemas de agua dulce. Tenemos un par de cosas diferentes que mostrarles; quisieramos saber su reacción y escuchar lo que Uds. piensan de éstas.

- **Reacción a la visualización 3D del Lago Tahoe**

  Primero, quisiera enseñarles un video corto y después de que lo hayan visto, hablaremos de lo que vieron. Mostrar http://vimeo.com/25686844 *hasta la hora marcada 9:45 donde dice….("¿Cómo piensan que se verá el Lago Tahoe en el futuro como resultado de cambios climáticos?")*

  Bueno, acabamos de ver la versión 2D en pantalla plana del video. ¿Han visto todos alguna película 3D y pueden visualizar como sería el video en 3D? Como ya se imaginarán, la tierra y las características subacuáticas resaltarían más en 3D y les daría el sentido de que actualmente están volando alrededor y debajo del lago.

  - ¿Cuál es su reacción en general al video? ¿Qué es lo que más les llamó la atención?
  - ¿Qué partes del video les gusto más y por qué?
  - ¿Habían temas de los que ya tenían algún conocimiento, ya sea sobre el Lago Tahoe o algunos de los procesos u otras cosas que se mencionaron?
  - ¿Habían algunas partes que eran nuevas para Uds.?
  - ¿Si el equipo estuviera mejorando este video/experiencia sobre el Lago Tahoe, qué cosas específicas quisieran ver incluidas?

- **Reacciones a exhibiciones de mesa, TIPOS**

Además de las visualizaciones 3D, se desarrollarán exhibiciones de mesa que incluyen una variedad de actividades interactivas táctiles cuyo objetivo es demostrar, reforzar e integrar conceptos importantes sobre los ecosistemas de agua dulce. Les voy a mostrar diferentes tipos de actividades de mesa, con ejemplos, y luego les voy a preguntar cuáles les parecen más interesantes. Pero primero vamos a ver unos ejemplos de exhibiciones de mesa para que sepan cómo son. [PASAR DIAPOSITIVAS CON DIFERENTES TIPOS DE MESAS]

- *Modelo funcional – mostrar algo actual como una reacción, en una escala mas pequeña; puede mostrar como forma las nubles*
- *Observar de cerca – examinar animales diferentes y organismos, para identificar cual tipo de animal es*
- *Experimento sencillo – ver el nivel de [acidity] o alcalinidad de tres partes diferentes del lago*
- *Jugar e interactuar - mover la arena y el color cambia dependiendo en el [depth] de la arena*
- *Hacer & llevar – hacienda papel, construir modelos de hojas para comparar conservación de agua, mirando a las adaptaciones (por ejemplo en el desierto)*
- *Exposición, escultura táctil – tocar modelos de la planeta o una zona del lago (la tierra y el agua)*
- *Multimedia / iPad – ver como forma y funciona las olas, en algo como in ipad que puede ver el movimiento*
- *Realidad mixta – tiene realidad mixta o aumentada, que tiene los datos actuales de un sitio en el lago. utilizando información científica*

- Ahora que hemos visto los 8 tipos diferentes, quisiera saber cuales dos les gustan más; por favor levanten la mano para votar. [Hacer votación y anotar # para cada tipo].
- Quisiera que cada uno de ustedes me hable de su tipo favorito—el que le gustó más que todos—y porqué lo escogió.
- ¿Piensan Uds. que hay algunos tipos de actividades que serían menos deseables o que se podrían omitir?

- **Reacciones a exhibiciones de mesa, CONTENIDO**
  Ya hemos hablado de los diferentes tipos de actividades de mesa y Uds. han visto unos ejemplos de los tipos de exhibiciones que usaríamos. Pero aún no hemos hablado específicamente del contenido de estas exhibiciones. Hay cinco categorías principales que estamos considerando con respecto al contenido:

  Estaciones de agua—tratan temas relacionados con el movimiento, la claridad y la densidad del agua
  Estaciones de ecología –tienen que ver con los animales y otras formas de vida que se encuentran en los lagos y los procesos que los afectan
  Estaciones de formaciones terrestres –se refieren a las diferentes formaciones terrestres adentro y alrededor de los lagos y cómo afectan los lagos
  Estaciones de cuidado y acción–explican cómo las personas afectan los lagos y cómo pueden tomar decisiones para protegerlas
  Estaciones de instrumentos científicos –demuestran los instrumentos diferentes y métodos de investigación que usan los científicos para estudiar y entender los lagos

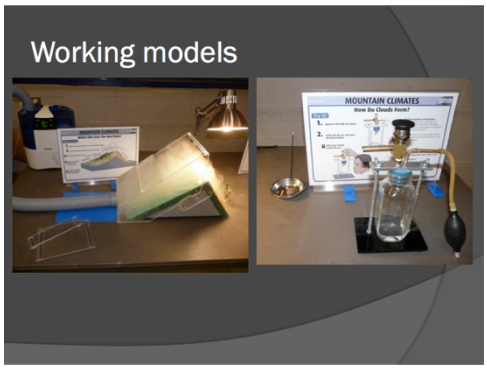
  - En base a estas descripciones, por favor levanten la mano para indicar qué tipo de estaciones les parece más interesante. [Hacer votación y anotar # para cada tipo].
  - ¿Cuál fue su estación favorita y por qué?

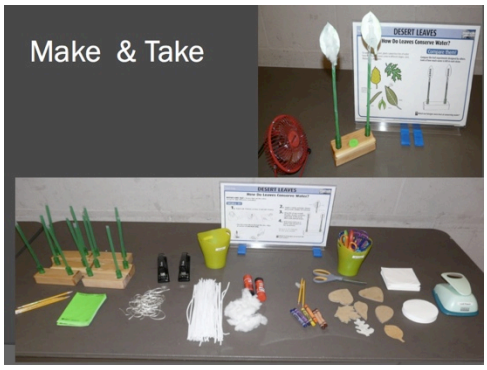
11. Observaciones finales y comentarios

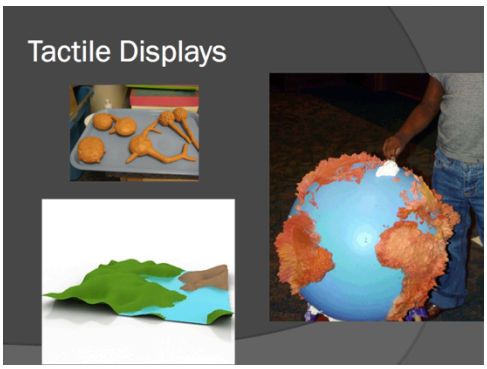
- En base a lo que acaban de ver, ¿hay algo de lo que quisieran aprender más después de que terminemos nuestra discusión aquí? ¿Hubo algo que les despertó la curiosidad?

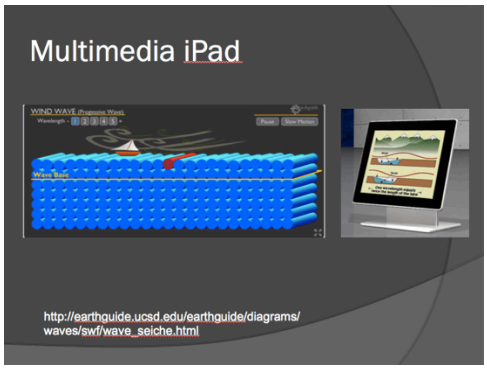
Hemos concluido nuestro tiempo juntos y queremos agradecerles por todas las buenas ideas que nos proporcionaron, nos han dado mucho en que pensar. Muchas gracias a todos por su franqueza y por compartir tanto con nosotros. Les aseguro que esto ayudará al equipo del proyecto a diseñar experiencias valiosas sobre ecosistemas de agua dulce.

APPENDIX E: Images and descriptions of tabletop activities, focus groups









DESCRIPTIONS INCLUDED WITH VISUALS FOR TABLETOPS (read out loud):

Working models – Using a humidifier to show the Rainshadow effect. Using a handpump and a jar to pressurize and show how clouds form.

Observe closely – Examine the different kinds of critters (macroinvertebrates and benthic organisms. Try to identify what kind they are.

Small experiment – Test the pH (acidity /alkalinity) of water from three places in the lake.

Play & interact – Sandy Sandbox Interactive. Visitors move sand around and colors change depending on depth. Exhibit showing waves formed by overhead fan to demonstrate mixing.

Make & take – Leaf adaptations to desert environments. Design an experiment using filter paper leaf models to compare the water conservation "adaptations" of each leaf design. Take your leaf home.

Tactile displays – Physical 3D models of landscapes, lake basins, vertical exaggerations, local fauna and fungi made from synthetic materials. Great for tactile oriented kids and low-vision/vision impaired.

Multimedia iPad – Users interactive with different simulations of standing waves, water mixing, and games of locating invasive species.

Mixed reality – Mixed or augmented reality is when you overlay some multimedia images onto a real place, but only see this through your iPhone.

APPENDIX F: 3D viz interview protocol

Date:_____ Time (hh:mm, AM/PM):_____ Data Collector:_____ ID #:_____

Institution: ___ TERC ___ ECHO ___ LHS

Front-end interviews
3D Visualization of Freshwater Ecosystems

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1. What words or phrases come to mind when you hear the term "freshwater ecosystems?" **[Probe: Anything else?]**

2. Please tell me as many of the types of freshwater ecosystems as you can think of right now? **[Probe ONLY IF NEEDED: For example, a lake is one type…]**

3. We're defining freshwater ecosystems as "any freshwater aquatic system, including lakes, ponds, rivers, streams, springs or wetlands." Is there a single freshwater ecosystem, either around here or farther away, you have a particular connection to?

   ☐ Yes ☐ No

   3a. If Yes, Which one?

   3b. And can you share with me why you feel a strong connection to this one?

4. On a scale from 1 to 10, where 1 is "none" & 10 is "a lot," how much of a positive impact do you think humans currently have on the health of freshwater ecosystems? ____

   4a. Why did you give the rating you did?

5. Using the same scale from 1 to 10, where 1 is "none" and 10 is "a lot," how much of a negative impact do you think humans currently have on the health of freshwater ecosystems? ____

   5a. Why did you give the rating you did?

6. Are you currently doing anything yourself to reduce the negative impact humans have on freshwater ecosystems? ☐ Yes ☐ No

   6a. If Yes, What are you doing?

7. Another term you sometimes hear when people talk about this topic is "watershed." How would you complete the following sentence: "A watershed is…"

8. A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. What can you tell me, if anything, about the watershed you live in?

9. I'm going to show you a few questions related to scientists who study lakes. Which two questions would you be most interested in hearing the answer to? You can just read me the letters. **[hand page, and check the TWO letters chosen]**

   ☐ A ☐ B ☐ C ☐ D ☐ E

   9a. Why did you pick _____?

Now we have just a few quick questions for you to fill out yourself. [hand clipboard]

11. Is this your first visit to the Tahoe Environmental Research Center?
    ☐ Yes ☐ No

12. Are you of Hispanic, Latino or Spanish origin?
☐ No
☐ Yes, Mexican, Mexican American, Chicano
☐ Yes, Puerto Rican
☐ Yes, Cuban
☐ Yes, Central American
☐ Yes, Spanish Caribbean
☐ Yes, South American
☐ Yes, Other Hispanic,Latino,Spanish

13. Which of the following best describes you?
    Mark as many as apply.
☐ White
☐ Black, African American
☐ American Indian or Alaska Native
☐ Native Hawaiian
☐ Guamanian or Chamorro
☐ Samoan
☐ Asian Indian
☐ Chinese
☐ Filipino
☐ Japanese
☐ Korean
☐ Vietnamese
☐ Other Asian
☐ Other Pacific Islander

14. What is your zip code (If from outside U.S., please indicate country): _____

15. What year were you born?
    _____

16. What are the ages of the <u>other</u> people in your group visiting the museum today?

    ___ ___ ___ ___ ___ ___ ___

17. Do you regularly speak any other languages at home besides English?
    ☐ Yes ☐ No

    17a. If yes, which one(s):

18. Do you currently have a job that is related to freshwater ecosystems such as lakes, rivers, streams, etc.?
    ☐ Yes ☐ No

    18a. If yes, please describe:

Thank you for your time

Q9. There are various topics we could cover about the scientists who study lakes. Which two questions would you be most interested in hearing the answers to?

A. How do the scientists collect data about lakes?

B. What kinds of data do scientists collect about lakes?

C. What questions are scientists trying to answer about lakes?

D. How did specific scientists get interested in studying lakes?

E. What are the tools and technologies scientists use to collect data?

Q10. Which of these actions are you already doing regularly?

1. Cleaning, draining or drying boats and related equipment to stop the spread of invasive species

2. Using only phosphorus-free fertilizers on plants

3. Using less toxic home/personal cleaning products – going natural

4. Installing a rain garden, rain barrel or porous walkway/ driveway to stop storm water runoff

5. Composting food waste

6. Volunteering for a local watershed, wetland, environmental group

7. Picking up after your dog – "scoop the poop"

APPENDIX G: Geographic subsections showing location of interviewed visitors

Figure 6. Geographic location of visitors within Northern California

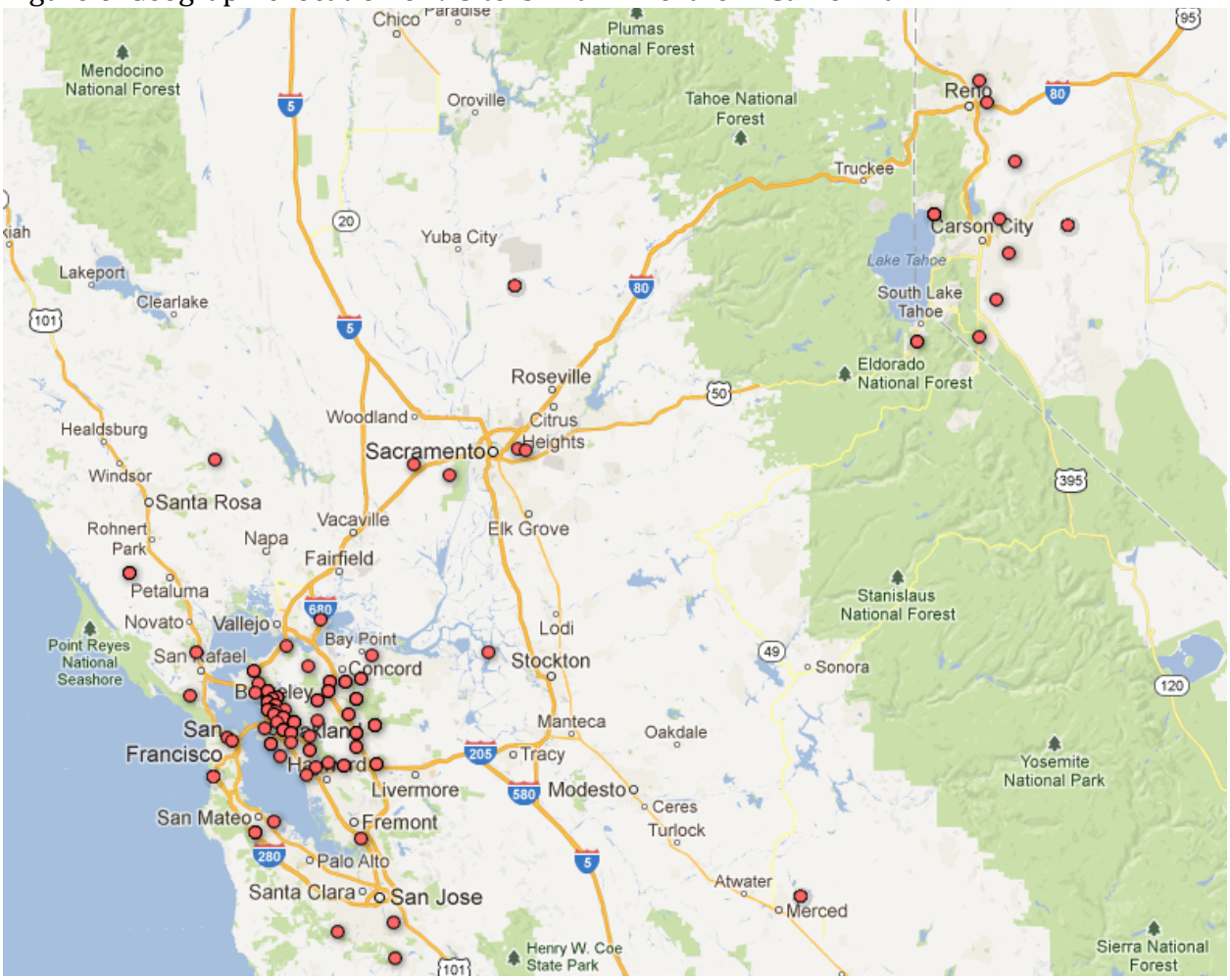
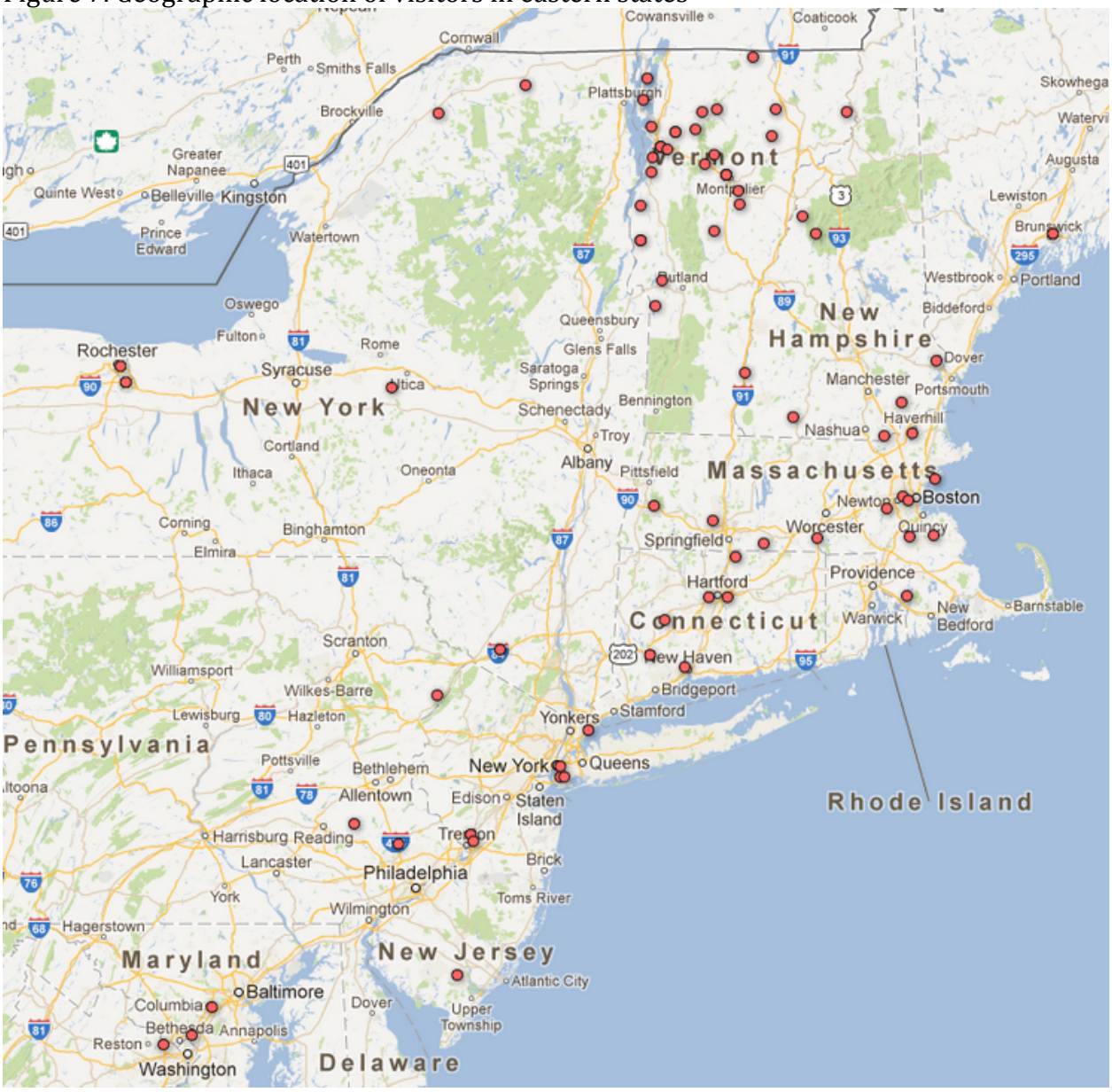


Figure 7. Geographic location of visitors in eastern states

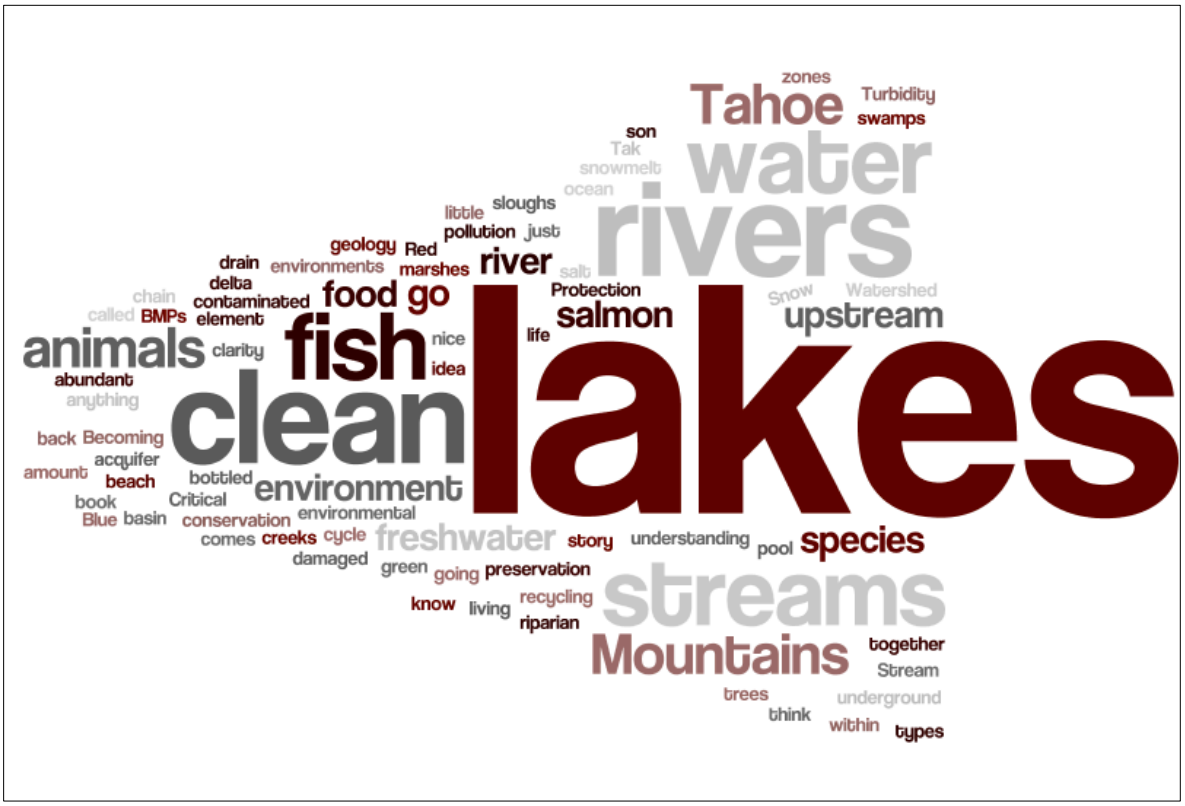


APPENDIX H: Word Clouds for top of mind responses to term "freshwater ecosystem" by institution

Figure 8. Word Cloud of ECHO visitors' top of mind responses

Figure 9. Word Cloud of LHS visitors' top of mind responses

Figure 10. Word Cloud of TERC visitors' top of mind response



APPENDIX I: Freshwater ecosystems to which visitors feel connected

Locations listed alphabetically by study site

TERC
Carmel River Valley
Carson River (n=2)
Crystal Springs
Donner Lake
East Bay
Lake Tahoe (n=22)
Missouri River
Steam Boat Creek
Taylor Creek
Trout Creek
Truckee River (n=2)
Yuba River

LHS
Alpine Lake
American River (n=2)
Arcata Wastewater Treatment Plant and Wildlife Sanctuary
Battle Creek
Chabot Lake
Clear Lake
Colorado River
Columbia River
Del Valle Lake
Donner Lake
Eel River
Fallen Leaf Lake
Folsom Lake
Georgetown Lake
Great Lakes
Inks Lake
Jewel Lake (n=4)
Kern River
Lafayette Reservoir (n=3)
Laguitas Creek
Lake Alpine
Lake Anza (n=8)

Lake Berryessa
Lake Biwa
Lake Cavassu
Lake Chabot (n=5)
Lake Don Pedro
Lake Geneva
Lake Kirkwood
Lake Lucerne
Lake Merritt (n=2)
Lake Michigan
Lake Namakagon
Lake Sonoma
Lake Tahoe (n=26)
Lake Temescal
Little Grass Valley Reservoir
Marin Wetlands
Merced River
Pine Crest Lake
Potomac River
Rainbow pools
Rock Creek
Rodeo Creek
Russian River (n=5)
Sacramento Delta
Sacramento River (n=2)
San Lorenzo Creek
Sausal Creek
Schollberge Wetlands
Shasta Lake
St. Lucia Wetland
Strawberry Creek
Trinity River
Tuolumne river (n=2)
Yakima River

ECHO
Bantam Lake
Black Pond
Cape Cod
Charles River
Chesapeake Bay (n=2)
Chickering Bog
Connecticut River (n=2)
Crystal Lake

Delaware River (n=1)
East Creek
East River
Edwards Acquifer
Fairfield Pond
Fingers Lakes
Gihon River
Grand River
Hudson River (n=2)
Lake Ashmere
Lake Bomoseen (n=2)
Lake Champlain (n=17)
Lake Dunmore
Lake Erie (n=2)
Lake Memphremagog
Lake Okeechobee
Lake Ontario
Lake Simcoe
Lake St. Catherine
Lake Tahoe
Lake Waramaug
Lake Winnepesaukee (n=3)
Laurel Lake
Maidstone Lake
Mousam Lake
Newfound Lake
Ottawa River
Otter Creek
Otter Lake
Panther Pond
Parker Lake
Quabbin Reservoir
River Boyne in Ireland
Salmon River
Saranac River
Sebago Lake
Silver Lake
The Herring Run
Warner River
Watuppa Pond
Weber River
White Pond
Winooski River (n=3)