Nevada Bureau of Mines and Geology Special Publication 38

The Nevada Bureau of Mines and Geology: Current and Future Benefits to the University, the State, and the Region

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Nevada Bureau of Mines and Geology

University of Nevada, Reno

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Subhash B. Bhagwat has studied in India, Germany, and the United States. After a bachelor's degree in physics in India, he obtained a graduate degree in Mining Engineering and a PhD. in Resource Economics at the Technical University in Berlin, Germany. He also earned an M.B.A. degree from the University of Illinois. After several years of employment in industry and academia in Germany, he joined the Illinois State Geological Survey in 1979 and headed the economics unit. In his 27 years of service in Illinois he conducted research on economic aspects of coal, oil, industrial minerals, water, minerals processing, and engineering applications. He also taught economics of raw materials at the University of Illinois and published about one hundred reports, articles, and research papers. Among his most widely recognized contributions is the development and application of a methodology to estimate the economic benefits of geological research to society. Aside from Illinois, the approach has been applied in Kentucky, Ohio, Spain, and now Nevada. Subhash is internationally recognized for his contributions and has been awarded Fulbright fellowships to lecture in Germany and Kazakhstan as well as to conduct water resources management research in India. He received special recognition for his scientific contributions and for the development of a staff performance evaluation method at the Illinois State Geological Survey. Subhash retired in 2005 and is now active as a consultant.

Contents

Executive summary 3

1. Introduction 5

2. Objectives 7

3. Previous studies on benefits of geologic information 7

4. Methodology for the present study 8

5. The NBMG program and its impacts 9

5.1 Minerals 9

5.2 Energy 12

5.3 Water 16

5.4 Natural hazards 16

5.4.1 Earthquakes 16

5.4.2 Floods 18

5.4.3 Radon 18

5.4.4 Environmental concerns 19

5.5 Science education 20

5.6 Geologic research 21

6. Results of the Nevada user survey on geologic information 26

7. Assessing the benefits 42

8. A look to the future of NBMG at UNR 44

9. Conclusions 48

Appendix A. User survey and assessment 50

Appendix B. Cost of power plants by source of energy 54

Appendix C-1. Sage-Grouse habitat categorization map 55

Appendix C-2. Sage-Grouse habitats and active mines and mineral deposits 56

Appendix C-3. Sage-Grouse habitats and recent exploration projects and mining claims 57

Appendix D. Public vs. private goods 58

Appendix E. Statistics on visitors to GBSSRL 61

Executive summary

This study was commissioned by the College of Science, University of Nevada Reno (UNR), to assess the benefits of geological research and service by the Nevada Bureau of Mines and Geology (NBMG) and to consider future synergies between NBMG and the other geoscience units at UNR, while maintaining the core mission of NBMG.

The study involves two steps: 1) review and assess the benefits derived from NBMG's past geologic research and services, and 2) assess how best to focus available resources in the future. After studying NBMG's past publications, a questionnaire was sent to over 1,800 users of geologic information in Nevada. The purpose of the campaign was to assess how users perceive the usefulness of geologic research and services of NBMG, both in terms of its quality as well as in monetary terms. Eighty-four users (4.6%) responded.

Several observations can be noted from the review:

- Geologic information is used in every area of human activity, including industry, government agencies at all levels, public safety agencies, tourism and education.
- NBMG's geologic research and services are valued for their independent, accurate, and unbiased nature and the scientific reputation of its scientists.
- Geologic research conducted by NBMG has economically benefited industries in Nevada, especially gold, various other minerals, and geothermal energy. NBMG's detailed geologic mapping contributed in a major way to the development of these industries, making Nevada a leading producer of gold and geothermal power. These industries have produced high-paying jobs and generated millions of dollars in revenues for the State.
- As an earthquake-prone state, Nevada has benefited from NBMG's research, which has identified geologic faults, studied histories of past earthquakes, compiled guidelines to mitigate damage, and educated the public about possible damage and injury from earthquakes. Geologic research has also helped to identify environmental concerns, such as indoor radon gas concentrations, and provided geologically oriented guidebooks for tourism, the second largest economic sector in Nevada.
- User survey indicated that NBMG's geologic research and services are especially beneficial to financially weaker, small companies and individuals.
- Quantitatively, user responses indicated that detailed geologic maps, publications, and geologic databases are highly valued NBMG products. For detailed geologic maps, users indicated that they would willingly pay an average of $6,414 per 7.5' quadrangle, and an average of $11,574 for all geologic information in a typical project. The cumulative value of geologic maps sold in the past 40 months alone would be $13 million, and the value of benefits of geologic maps would be at least 147 times higher than the costs of geologic maps completed under the STATEMAP component of the national geologic mapping initiative since 1994. Additional value accrues from geologic publications, databases, guidelines, and curation and storage of samples.
- In spite of its productive past, NBMG needs to redouble its geologic efforts, because only about 20% of the state has been adequately mapped for assessment of natural hazards and mineral and energy resources.
- Basic and detailed geologic mapping is time and labor intensive, as well as expensive. NBMG has produced 121 new geologic maps and digitized 136 already existing maps since 1994. Most of these efforts have been funded through grants from the USGS STATEMAP program, which NBMG has successfully obtained on an annual basis. However, significant cuts in state funding have severely reduced NBMG's ability to continue these efforts, because the STATEMAP program requires a 100% match from state funds for each grant.
- Users have provided highly useful input on both the topics of future research, and geographic areas of focus. New detailed geologic mapping, digitizing older high-quality maps, systematic assessments of mineral and energy resources, and increased involvement in professional and public education are the great needs of the future.

- User responses to the question of a possible name change for NBMG are inconclusive, with opinions evenly split on the issue. However, the national trend appears to justify a change to Nevada Geological Survey as more in tune with the broad mission and dynamic nature of NBMG.

The overall observation from the study is that spending on geologic research pays many times over, both qualitatively and monetarily. While greater integration of NBMG with other geoscience units within the College of Science is essential and desirable, restoring NBMG's funding is critical to the success of geoscience research and education in Nevada, and ultimately to the economy of Nevada.

The Nevada Bureau of Mines and Geology: Current and Future Benefits to the University, the State, and the Region

Subhash B. Bhagwat, Consulting Resource Economist[1]

1. Introduction

The Nevada Bureau of Mines and Geology (NBMG) is a department within the College of Science (College) at the University of Nevada, Reno (UNR) **(fig. 1).** Five out of the nine departments in the College are related to earth sciences and reside within the Mackay School of Earth Sciences and Engineering. The College thus displays a major commitment to geology, geography, and mining engineering.

The NBMG, created by the Nevada Legislature, is mandated to study the geology of Nevada and use the knowledge to provide services to Nevada industries, public institutions, government agencies and the general public to promote the economy, public safety and environmental interests of the state. As a department within UNR's College of Science, NBMG is also expected to participate in the educational mandate of the College.

The College's primary mission includes research and education. Although the primary targets of education are the UNR students, the College embraces educating the general public through outreach programs and collaboration with various industries through its research and services.

Both the College and NBMG are involved in some of the same mission goals, albeit with differing target audiences and different emphases. In the aftermath of recently imposed severe

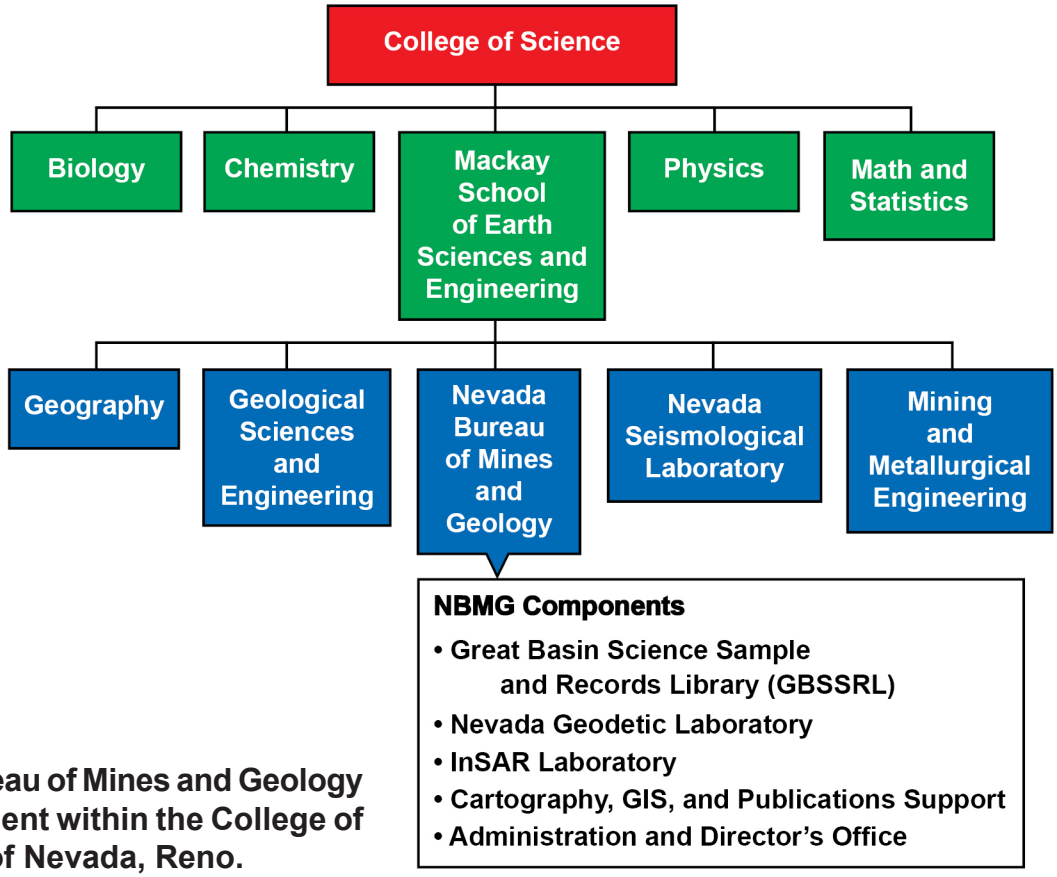


Figure 1: Nevada Bureau of Mines and Geology (NBMG) as a department within the College of Science, University of Nevada, Reno.

[1] Retired Principal Resource Economist, Illinois State Geological Survey

budget cuts experienced by UNR, the need for greater collaboration amongst the geoscience units within the College has been recognized. A brief description of NBMG's structure and organization is helpful at this point. **(fig. 2)**

Including the director, approximately thirty individuals make up the staff of NBMG. About one-third of the personnel are state funded, the rest are funded from grants and contracts. About two-thirds of the staff are directly involved in geologic research, with the others contributing in various capacities to make research possible. The latter include cartographic and GIS specialists, publications support, publication sales, administrative assistants. Three other units – the Great Basin Science Sample and Records Library (GBSSRL), the Nevada Geodetic Laboratory, and the InSAR Laboratory – conduct research and/or provide services to researchers, industry, and the public.

NBMG's programs address many aspects of geologic research and services, albeit with limited and diminishing available resources. Programs such as geologic mapping and framework studies are fundamental to most geologic research, including 1) mineral and energy resources evaluations, 2) natural hazard assessments and mitigation for earthquakes, floods, landslides, radon emissions etc., and 3) engineering geology involving soil stability and construction safety. Nearly all programs draw on interdisciplinary research. For example, geothermal energy involves structural, geochemical, hydrogeological, and geodetic research. NBMG's internationally renowned geodetic laboratory analyzes movements of the earth's crust induced by broad-scale tectonic motions, which can trigger major earthquakes, to finer scale motions resulting from withdrawal of groundwater associated with

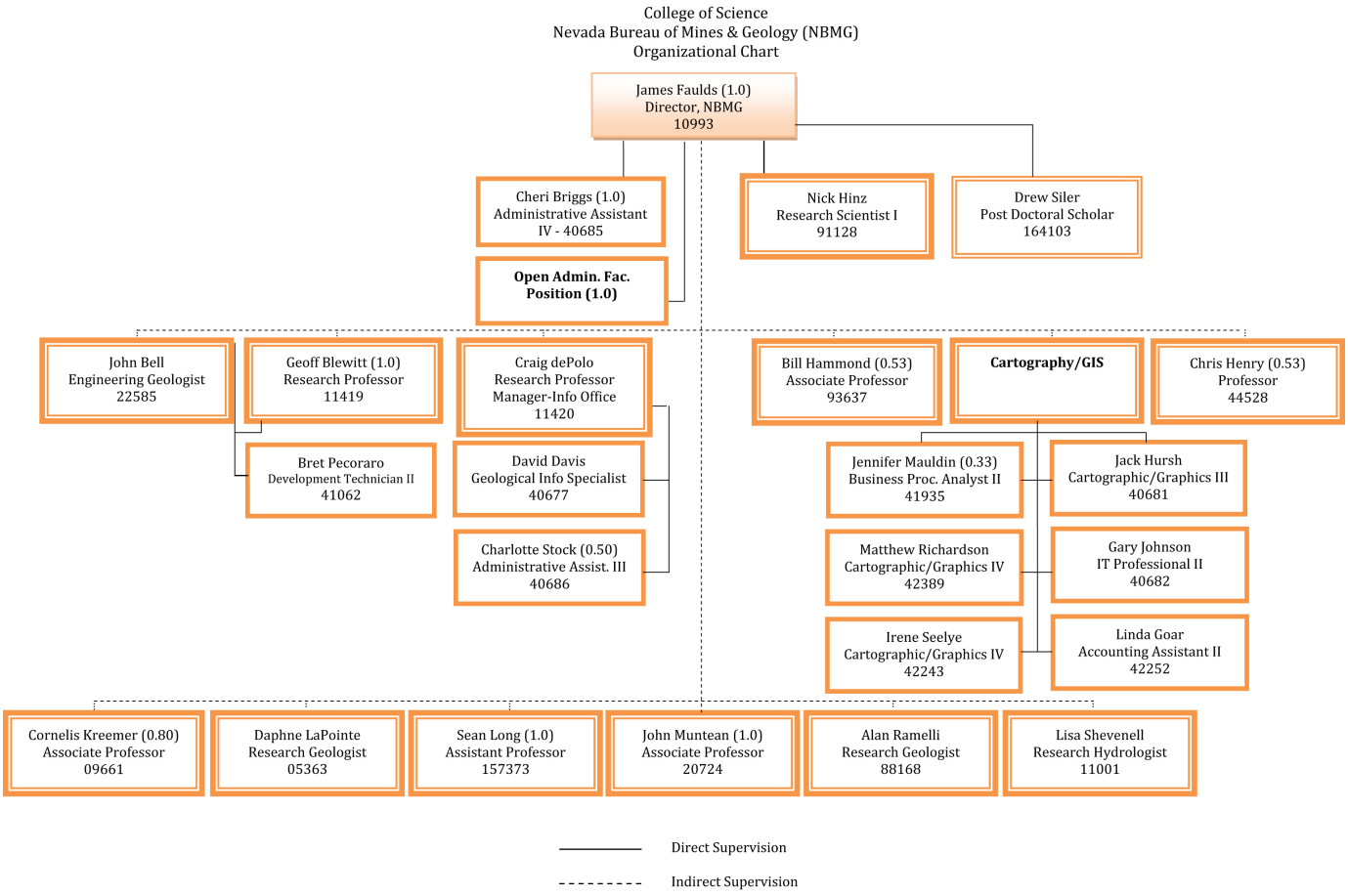


Figure 2: NBMG organization chart.

geothermal production or irrigation for agriculture. Similarly, the InSAR Laboratory (Interferometric Synthetic Aperture Radar) at NBMG uses satellite radar data to measure sub-centimeter-scale ground movement, most commonly in surface deformation studies related to earthquakes, volcanoes, and groundwater-related land subsidence. In addition, the GBSSRL, housed in a new off-campus building, is the repository of hand specimens, drill cores and cuttings, well logs, air photos, assays, historical maps of mining districts and all geologic and topographic maps of Nevada. It serves as the information and sales office for all NBMG products and services. Geologists and others from industry, academia, government agencies, and the general public commonly visit GBSSRL or access its data online.

NBMG thus serves as an enormous wealth of data for industry, science, education, and common citizens on all aspects of Nevada's geology for commercial, public safety, general research, or recreational purposes. It is thus an economic asset for Nevada.

This report has been commissioned to identify ways in which NBMG contributes to Nevada's economy, public safety and environmental quality and to quantify the contributions in monetary terms where possible. The report also looks into the future needs of the state in the area of geologic research, and ways in which NBMG can be better integrated with the other geoscience units while retaining its vital core mission.

2. Objectives

This study was commissioned to pursue three main objectives:

1. To identify the value of the NBMG programs to Nevada's well-being and to quantify them, through both analysis of available data and with a questionnaire campaign among users.

2. To discuss ways to increase the integration of NBMG and the UNR's College of Science, particularly with the Department of Geological Sciences and Engineering (DGSE) and Nevada Seismological Laboratory (NSL).

3. To cast a look forward into the future of NBMG, DGSE, and NSL under a broader geoscience institute yet maintaining the core missions of NBMG.

3. Previous studies on benefits of geologic information

Basic research, when carried out by private entities, remains in private possession. Any further use of it is limited to those who pay for creating it or using it. It is, therefore, described as "private good." The knowledge generated by public-funded research is accessible to everybody at little or no cost. It is described as "public good." Other examples of "public good" are national parks or national defense. As discussed in **appendix D,** public goods have no markets comparable to the markets that most are familiar with. The consumers of public goods can, and often do, receive the benefits without paying for them or paying much less than their actual cost. It is, therefore, impossible to directly assess the benefits of public goods by their price. The public good could be a geologic map or geologic information. Unlike a commercial enterprise that would price a geologic map based on its cost and the market demand, the pricing of geologic maps by entities like NBMG and other geological surveys usually covers only the expense of printing them and does not reflect their real costs, nor does the market typically send any signals whether the price is acceptable. Prices, therefore, do not represent the value of geologic information. Its value can only be determined indirectly by using some proxy parameters or by asking consumers directly. The latter approach was followed in Kentucky and Spain. For this report, as well, a questionnaire campaign was conducted, the results of which will be discussed in subsequent sections. At this point, an analysis is presented here based on studies in Illinois, Kentucky, Ohio, and Spain. The questionnaires used in those studies were very similar to the one used in the present study. The results of the four studies[2],[3],[4],[5]

[2] Benefits and Costs of Geologic Mapping Programs in Illinois: Case Study of Boone and Winnebago Counties and Its Statewide Applicability. Subhash B. Bhagwat and Richard C. Berg; Illinois State Geological Survey, Circular 549 (1991), 40p.

[3] Economic Benefits of Detailed Geologic Mapping of Kentucky. Subhash B. Bhagwat and Viju C. Ipe; Illinois State Geological Survey, Special Report 3 (2000), 39p.

[4] Economic and Social Value of the MAGNA Plan. Edited by: Institito Geologoco Y Minero De Espana (2005),57p.

[5] An Economic Impact Analysis of the Ohio Geological Survey's Products and Services, Kleinhenz & Associates, (2011), 25p.

indicate a consistency of outcomes that can serve as a reliable indicator of the order of magnitude of benefits that the state of Nevada may be reaping from NBMG. They can also be compared with the results of our own questionnaire campaign.

The first three studies focused on geologic mapping, whereas the fourth study, in Ohio, included other products and services of the geological survey, as well as funds attracted to Ohio as a result of the work of the Ohio Geological Survey. However, it does not attempt to estimate benefits to costs ratios.

The studies from Illinois, Kentucky, and Spain also differ from each other in their scope. In Illinois the study covered two counties out of the state's total of 100 counties. Here, a conservative estimate, based on the assumption that about 25% of estimated benefits will actually be realized, indicated a benefit to cost ratio of 11 at the minimum to 27 at the maximum. A real possibility existed in Illinois that the savings, and therefore the ratios, may have been higher. The Kentucky study covered the entire state mapped at 1:24,000 scale and indicated a benefits-to-costs ratio of 25 (min.) to 39 (max). In Spain, the study was done at the national level but the mapping scale was generally 1:50,000, and the ratios of benefits to costs were estimated to be about 18.

The Ohio study, in part, concludes that when benefits of geologic work were estimated in ways similar to the other studies referred to here, the results were comparable even though no ratios were calculated. An important aspect of the geologic information generated today in comparison with the past is dealt with by Bernknopf et al[6]. The report points to the improved quality of geologic information, which enables map users to achieve more focused and accurate exploration results than in the past and results in higher cost savings to the industry. The implication of the findings is that geologic mapping programs ought to be repeated periodically in order to make them relevant and their impact greater. The NBMG faculty and staff have recognized and emphasized the need to remap previously mapped areas in more detail and at finer scales while also expanding the program to unmapped areas.

4. Methodology for the present study

The Nevada Bureau of Mines and Geology (NBMG) is a statewide public agency charged with the study of Nevada geology, natural hazards, and resources and serving the entire state. The geologic knowledge it generates provides the underpinning of many applications that benefit everybody. Therefore, the contributions of NBMG can only be valuated indirectly. Instead of measuring the price paid by its users as the indicator of value, geologic research must be judged by the costs saved by its use, the "avoided costs" and by the "value" users assign to it subjectively.

We use a qualitative and a quantitative approach to assessing the value. The extensive array of NBMG publications as well as large numbers of samples and items (e.g., air photos, mining district files, various databases) it collects and curates provide a wealth of information on how it is used and how the users benefit from it in real terms. The benefits, not expressed in monetary terms, are readily discernible to rational observers. In depth readings or field use of NBMG publications and special reports provide rich documentation to make these values visible. Additional evidence is provided by the user survey. Some quantitative indicators of value exist within the available published sources. One such indicator is the sales of geologic maps, educational materials, and practical guides. Their use provides the foundations for minerals and energy exploration, natural hazard mitigation, and many other benefits. The subsequent economic activity can be causally linked with the geologic information.

In addition to existing sources, a questionnaire campaign was conducted to solicit user input. In order to estimate the costs that users avoided because NBMG products were available to them at little or no cost, they were asked how much they would have willingly paid for geologic maps

[6] Analysis of Improved Government Geological Map Information for Mineral Exploration: Improving Efficiency, Productivity, Effectiveness, and Risk Consideration. Bernknopf, R.L.; Wein, A.M.; St-Onge, M.R.; Lucas, S.B. Geological Survey of Canada Bulletin 593/ U.S. Geological Survey Professional Paper 1721, 2007.

and other geologic information and services, if the maps were not available from NBMG. Finally, they were asked to provide qualitative ratings for various products and services provided by the NBMG and to submit descriptive comments about how they use NBMG products and services, how their work benefits from NBMG's work, and what priorities the NBMG should set for the future. (**appendix A** shows the full survey). In addition to the compilation of replies to the survey questions, data from similar previous studies from other states and countries were used for comparison.

In the latter part of the study, the organizational issues arising out of the partially overlapping yet different missions of NBMG and other geoscience units at UNR are discussed. The NBMG is also intricately associated with the U.S. Geological Survey (USGS), which has a strong research presence in Nevada. The goal of the discussion is to seek a mutually beneficial integration of NBMG with the other geoscience units at UNR while preserving NBMG's core mission.

5. The NBMG program and its impacts

The NBMG program activities can be broadly viewed in four categories:

- Minerals, energy, and water resources
- Natural hazards and urban growth
- Environmental concerns
- Geologic science underpinning the above

5.1 Minerals

Mining of minerals is a major industry in Nevada. Currently, there are 115 operations in all parts of the state **(fig. 3).** The largest economic contribution is from gold and silver mining. However, geothermal energy, discussed later, plays a significant role. Other minerals listed in figure 3 are potentially important for their future applications, such as lithium for battery technology and rare earths for other energy and high-tech uses.

The gold deposits of the Carlin trend in NE Nevada, for example, started production in the 1960s and have produced over 76 million troy

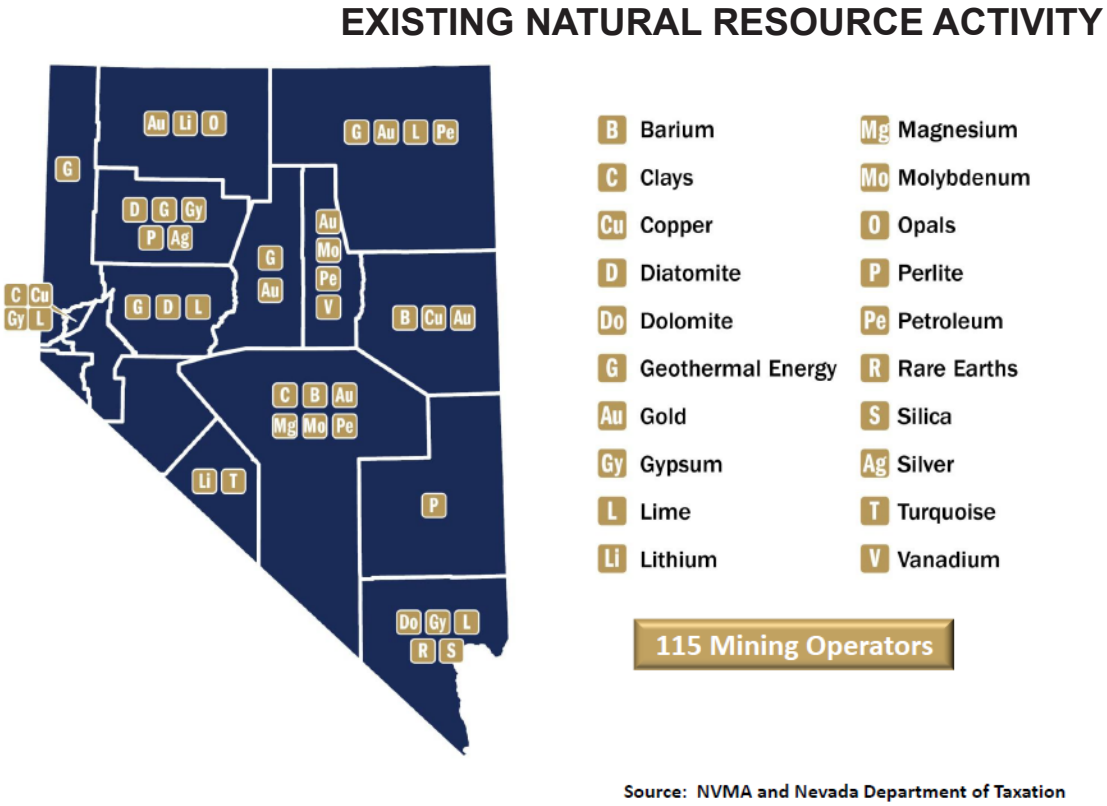


Figure 3: Existing natural resource activity in Nevada.

ounces of gold since.[7],[8] Today, Nevada is one of world's largest producers of gold. Nevada's potential for future gold production remains promising. For example, in 1988, the USBM published a report on production potential of gold and silver in the Tonopah quadrangle in Nye County, Nevada—halfway between Reno and Las Vegas[9]. As the metal prices rise, so does the potential for their production. **Figures 4 and 5** indicate that millions of ounces of gold and silver worth several billion dollars could be mined from this single quadrangle. Considering that gold and silver prices already far exceed the assumptions of the study, the economic value of the potential is even greater. As of September 2012, gold was priced at over $1,600 per tr.oz (60% above the highest price assumed in the graph), and silver was valued at $28 per tr.oz (40% above the highest in the graph).

The graphs also indicate, however, that the potential does not rise in step with the price. After a plateau is reached, the potential must eventually level off and decline, making it essential that geologic search for new deposits in new areas or even in the same areas continues. Although gold historically has been valued for ornamental purposes, it is now one of the central metals in high-technology applications and is likely to remain that way in the foreseeable future. Gold also has played an important role as a hedge against inflation, and in the investment community for offsetting the risk of exchange rate fluctuations, a feature that is becoming more important as world economic shifts become difficult to evaluate or predict. Even without significant increase in the quantities that can be potentially extracted, the continued increase in the prices of gold and silver well beyond the maximum prices in the graphs means greater revenues for the industry as well as the State in the future.

As research continues, other minerals and metals could partially replace gold in technological applications. Geologic research is essential to ensure that minerals-rich Nevada retains its position as a major supplier of such materials. Research such as this requires detailed geologic mapping and geologic framework studies, which facilitate exploration by industry. In addition, facilities and capabilities to do qualitative and quantitative mineralogical and chemical analyses are also needed. Since the publication of OFR 31-88, the ability of the USGS to conduct such studies has declined due to budget cuts and loss of qualified personnel. As federal and state funding for research declines, increased collaborative research between state and federal agencies has gained added significance. With the rich Nevada minerals endowment, the state is well positioned to lead in geologic research in the field of minerals exploration, assuming that it provides the appropriate funding and infrastructure for research units, such as NBMG, within the university system.

The NBMG has described the mineral resources of selected areas in the state of Nevada in its Reports series, which includes at least 50 publications. These reports are commonly based on geologic mapping as well as analyses of rock and mineral samples. The sample description by location includes quantitative analyses of metal contents, thus providing valuable assistance to extraction companies as well as future explorers. The importance of the capabilities to support geologic research with mineralogical and chemical analyses cannot be disputed; however, such services are now being offered by private laboratories at competitive prices. As a result, state geological surveys, including NBMG, are able to redirect funds formerly used for laboratories to more productive uses.

Detailed geologic maps of specific areas that include qualitative and quantitative assessments of minerals involve a great deal of manpower to produce, and NBMG has been a leader in producing such maps. Nonetheless, many critical areas in the state have not been mapped at an adequate scale that fosters exploration and development. Further, most of the regional-scale or district-wide maps have not been updated in many decades. Such maps would facilitate future

[7]Gold Deposits of the Carlin Trend, NBMG Bulletin 111, Edited by Tommy B. Thompson, Lewis Teal, and Richard O. Meeuwig, 2003

[8]The Nevada Mineral Industry 2011, Nevada Bureau of Mines and Geology, Special Publication MI-2010, updated April 2012.

[9]An Economic Evaluation of Selected Undiscovered Precious-Metal Deposits in the Tonopah Quadrangle, Nevada OFR 31-88, U.S. Bureau of Mines, 32p.

development of mining, increase reliability of geologic interpretation, and reduce cost.

According to the U.S. Bureau of Economic Analysis, the portion of the State Gross Domestic Product (GDP, the sum of the value of all products and services and the net exports of the same) attributed to the minerals industry in 2011 was about $6.5 billion (about 5.0% of state GDP) (**fig. 6)**, and the industry generated about $437 million in tax revenues.[10] The mining sector's share of GDP in the state has been rising steadily over the past several years.

The minerals industry regularly uses NBMG's geologic maps and has acknowledged their value in letters written to NBMG. The industry employs 12,211 people in Nevada. Their average annual earnings are $83,172 or about 3 times the median per capita income in Nevada, and 1½ times the median household income in the state (NBMG Special Publication P-22). Jobs are also created or supported by the suppliers and vendors, and as a result of spending by these employees. For every mining industry employee, 1.5 additional jobs are created or supported. In terms of the dollar value of minerals produced, Nevada ranks at the top of all the states in the U.S. With a population of 2.7 million and the 2011 market value of minerals production of $7.7 billion, it amounts to $2,850 per Nevada resident (NBMG Special Publication MI-2010, published 2011).[11] **Current funding for NBMG at $1.0 million/year amounts to 37 cents per Nevada resident per year**.

Major gold mining companies usually concentrate geologic work near their operating mine because of their emphasis on production. Geologic maps prepared by NBMG help the industry zero in on smaller areas of high potential prospects and to relate the local geology with the geology of the broader districts, which delivers valuable indicators for successful mining. The industry's own geologic mapping efforts are commonly at 1:2,000 scale. It spends very little

Figure 4: Cumulative production potential as function of price per ounce of gold for the Tonopah quadrangle

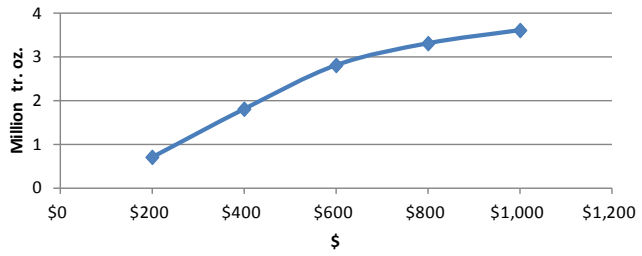
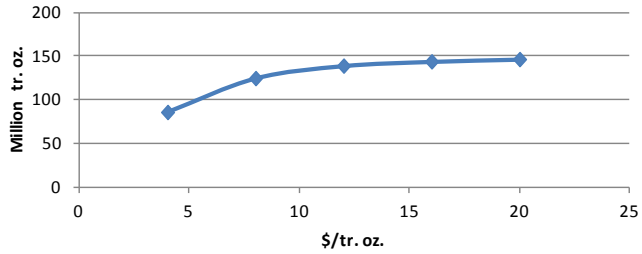


Figure 5: Cumulative production potential as function of price per ounce of silver for the Tonopah quadrangle



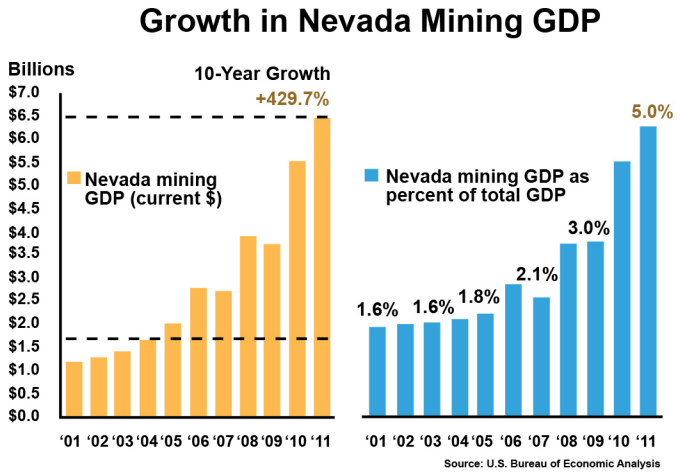


Figure 6: Nevada mining GDP.

[10] They include net proceeds of minerals and royalties, sales/use taxes, property taxes and modified business taxes.

[11] The market value of minerals produced in Nevada exceeds the industry's GDP. There is no contradiction, however, because GDP is the net addition to the value of domestic product by the industry after accounting for imports of goods and services. It thus represents the industry's economic contribution more accurately than the market value of minerals.

money on geologic research, often less than one percent of expenditures on production related research. Thus, the industry relies heavily on NBMG for production and publication of relevant maps and broad assessments of resource potential.

Most gold reserves are discovered by small (junior) companies and sold later to the larger companies. Junior companies are typically strapped for funds. They are therefore most in need of high-resolution geologic maps but are themselves unable to generate them due to lack of funds. The NBMG can further leverage the Nevada mineral industry production by way of providing the junior companies with adequate geologic maps, provided funds are available for this time-intensive work.

The minerals industry has substantial direct and indirect economic benefits for the state. For example, mineral rights for the industry generate "claim fees" collected by the Nevada Division of Minerals. Although there is no individual income tax in Nevada, the state benefits from the mineral industry employment that creates an economic multiplier effect as employees spend money, and the industry purchases goods and services within Nevada. Even when Nevada's mineral products are not consumed in Nevada, gold for example, their export has an economic multiplier effect on Nevada, because export of minerals attracts suppliers of products and services into the state. Recent studies on the magnitude of the overall multiplier effect are not known. However, a 1986 study by the Nevada Division of Minerals[12] estimated the external multiplier effect to be 2.25.

In addition to benefitting from its geologic mapping, the mineral industry benefits from NBMG's annual Mineral Industry report, which tracks some 150 projects from year to year. These reports are of particular utility to junior companies. Considerable effort is needed to assemble data commonly scattered at the offices of major and junior companies, and individual independent geologists. Considerably more manpower than is currently available at NBMG would be needed to continue major geologic mapping efforts and to generate the annual Minerals Industry report.

[12] NBMG Special Publication 009: The Economic Impacts of Nevada's Mineral Industry, John L. Dobra, 1986.

5.2 Energy

Nevada has some oil and gas reserves in eastern Nevada. According to the U.S. Geological Survey [13] about 1.6 billion barrels of oil and 1.8 trillion cubic feet of natural gas remain to be potentially discovered in the eastern Great Basin that includes portions of eastern Nevada. Current oil production of under 0.5 million barrels per year is down from the 1990s peak of 4 million barrels per year. Newer technologies, such as "fracking," could contribute to revival of the declining oil production in Nevada. Oil- and gas-related detailed geologic mapping in eastern Nevada would be crucial in supporting new developments.

Nevada generates 2.274 million MWh of electricity annually, according to the U.S. Energy Information Administration, of which natural gas produces the most (1.673 million MWh). The second largest source of electricity is geothermal, with 0.238 million MWh, followed by coal (0.192 million MWh) and hydroelectric (0.169 million MWh). Of these energy resources, only geothermal and some of the hydroelectric are derived from Nevada; the rest are from sources outside the state. About 10% of Nevada's electricity comes from geothermal sources.

The NBMG has played a lead role in providing the geologic knowledge base that has made geothermal energy commercially viable in Nevada. This knowledge base included detailed geologic mapping of individual geothermal systems, inventories of favorable settings for geothermal activity, systematic sampling of geothermal fluids for geothermometry, creating geothermal potential maps of the state, and cataloguing a wide variety of geothermal information into publicly accessible databases. A recent report by the Geothermal Energy Association[14] highlights the lead that the U.S. has in the world in the field of geothermal energy utilization. Of the world's installed geothermal electricity generation capacity of 11,224 MW, the U.S. has 3,187 MW, 469 MW of which are in Nevada or about 15% of U.S. total

[13] Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada, Utah, Idaho, and Arizona. (USGS Digital Data Series 069-L)

[14] Annual U.S. Geothermal Power Production and Development Report, Geothermal Energy Association, Washington, D.C. April 2012, 35p.

and about 4% of the world total **(fig. 7).** NBMG and the UNR's College of Science are at the center of geothermal research in the U.S and have the potential to become one of the world's leaders in this field.

New geothermal projects are making progress in Nevada as well. About 91 MW of capacity was completed in 2011 and the first quarter of 2012 in the U.S., of which about 33 MW are in Nevada. Currently, 59 of the 140 geothermal projects being developed in the U.S. are in Nevada, the highest number of any state in the U.S. (**fig. 8).**

The prospects for geothermal energy are good, because it incurs no fuel costs and carbon emissions are low. Geothermal technology is improving. The 2008 Geothermal Technologies Market Report by the U.S. Department of Energy reported that geothermal construction costs vary from $3,300 to $4,000 per kW capacity. Although fluctuations in prices of fossil fuels can result in periods of rising or declining competitiveness, according to the Renewable Energy Policy Project (REPP)[15], the cost of geothermal energy in 1999 was already competitive with other forms of

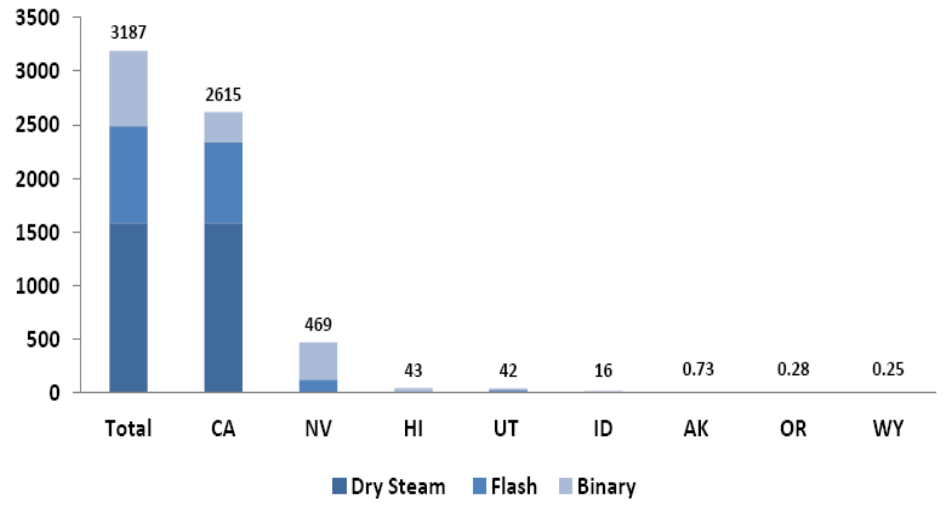


Figure 7: March 2012 U.S. installed geothermal capacity (MW).

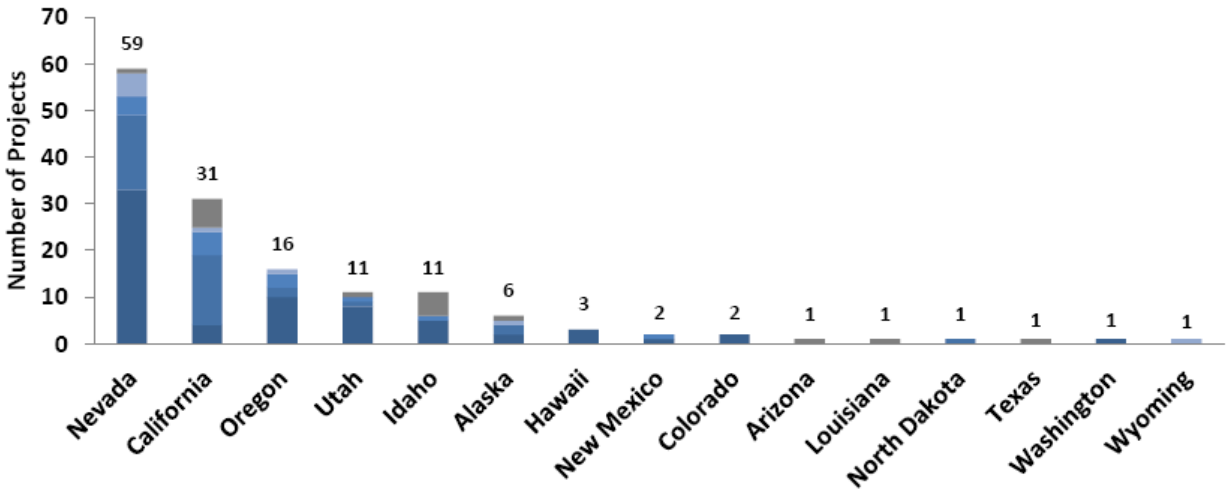


Figure 8: Number of geothermal projects in development by state and phase.

[15] Geothermal Energy for Electric Power A REPP Issue Brief by Masashi Shibaki, with Fredric Beck, Executive Editor, December 2003.

energy (**appendix B - tables 1-4).** The prices of geothermal electricity fluctuated between 5 and 9 cents per kWh from 1985 to 2010, averaging about 7 cents **(fig. 9).** According to the Energy Information Administration (EIA), current average electricity prices in Nevada range from 5.5 cents/kWh for industrial customers, 8.85 cents/kWh for commercial, and 12.1 cents/kWh for residential customers. Geothermal electricity prices are thus competitive with other sources of energy.

Geothermal construction activity has increased, and costs are expected to decrease. Non-polluting geothermal power can also help generate revenues by way of carbon tax credits. Many countries tax CO_2 emissions, a greenhouse gas. This is also under consideration in the U.S. Companies that emit less CO_2 than "permitted," can sell the difference to those who emit more than their permitted quota (cap and trade). Geothermal already produces 10% of Nevada electricity and is well situated to gain economically from this advantage. As a result, geothermal power plants are expected to become an increasingly competitive alternative to conventionally generated fossil-fuel electricity in the future. Vendors supplying the geothermal industry are scattered in 40 states. The economic logistics of long distances have encouraged many of these vendors to move to or near Nevada from 2007 to 2010, adding to Nevada's economic growth and diversity.

The installed geothermal capacity in Nevada has more than doubled since 1997 to 437.9 MW, bringing additional economic benefits to the state. Geothermal energy uses vary depending upon water temperature, but they are not solely dependent on hot water from depth. The primary uses are electricity generation, district heating, and vegetable dehydration. The focus of geothermal research at NBMG is on finding sources of hot water for the generation of electricity. Research and technology developed by NBMG scientists has directly led to discovery of 12 new geothermal systems. The leasing fees paid by the industry to the Bureau of Land Management (BLM) from 2007 to the present (September, 2012) amounted to $52.11 million, of which the State of Nevada received 75% or $39 million **(table 1).**

In addition, once in operation the plants pay property taxes worth some $0.2 million per year for each plant. Fifteen geothermal power plants are currently operating in Nevada, paying up to $3.0 million collectively in property taxes.

NBMG's research to facilitate geothermal exploration and development has many components. For example, detailed geologic mapping has been employed to identify geologic faults with high geothermal potential and determine which patterns of faulting are most conducive to geothermal activity. Geochemical research on different types of geothermometers and systematic sampling of springs has been critical for garnering better estimates of the maximum temperatures at depth for many geothermal systems. In addition, NBMG has been a leader in preparing databases of geothermal information across the entire state and region. These databases are widely used by companies for geothermal exploration and for making decisions on which areas to bid for leases. Several different data sets were recently combined into a geothermal potential map of the state, which is also widely used by industry.[16] Because of the relatively small size of geothermal companies, compared to the oil and gas or minerals industry, all geothermal companies active in the region have been utilizing NBMG's maps, reports, inventories, and databases for exploration and development. Geothermal companies are simply not large enough to develop this information on their own and thus rely heavily on NBMG continuing these efforts.

Future progress in geothermal energy requires research in areas other than geology as well. Herein lies significant potential for collaboration with other scientific fields such as engineering, physics, and chemistry at UNR such that the geothermal center at UNR becomes one of the world's leaders. Demand for expertise from NBMG/UNR may grow worldwide as a result of the need for much greater contributions from renewable resources to mitigate the growing problems associated with CO_2 emissions and global climate change.

[16]NBMG Map 161, NEVADA GEOTHERMAL RESOURCES. Robin Penfield, Lisa Shevenell, Larry Garside, and Richard Zehner, 2010.

The geothermal program at NBMG has generated some $15 million in grants since 1996. Most grants require match funding from NBMG, which has increasingly become difficult due to budget cuts and loss of manpower. Scientists at NBMG have recently been forced to turn down external funding due to the lack of matching funds.

At least half a dozen graduate students working on geothermal projects are currently being advised by NBMG geothermal faculty and scientists. The program has received international acclaim as attested to by letters received from all over the world. If NBMG and UNR are to remain at the forefront of geothermal research in this country

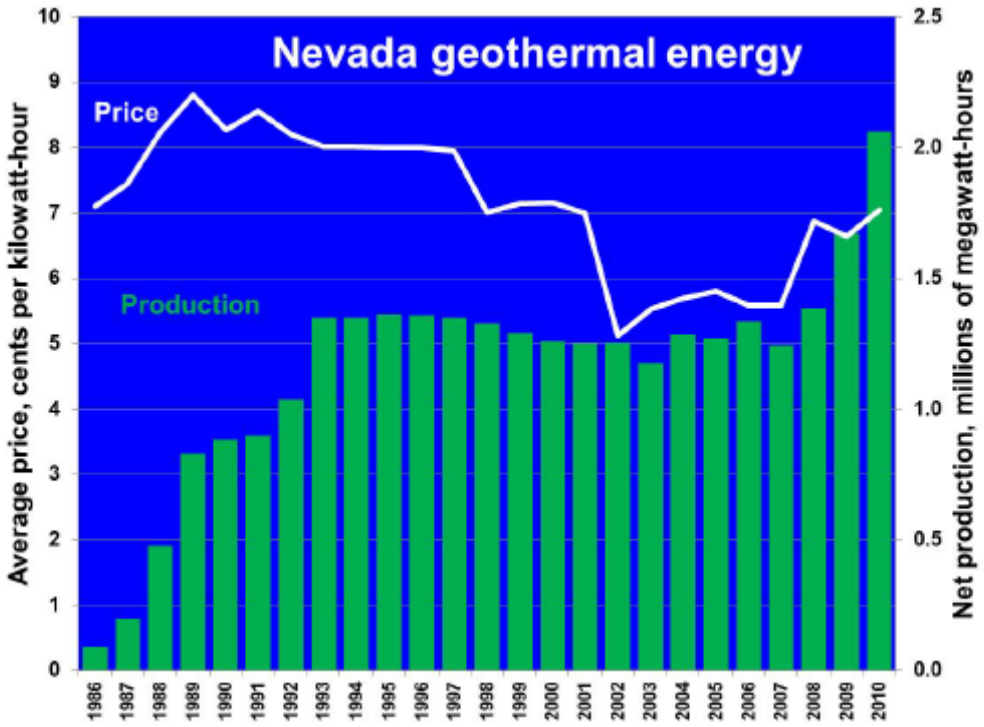


Figure 9: Nevada geothermal energy production and prices 1986-2010. (Source: NBMG Special Publication MI-2010, published 2011).

Table 1: Geothermal leasing fees paid to BLM and the State of Nevada 2007-2012.

Year	Parcels offered	Parcels sold	Acres	Total receipts	Average per acre	75% to Nevada
2007	43	43			$95	$8,752,365.75
2008	35	35			$268	
2009	108	82		$8,909,445	$28	$6,682,083.75
2010	114	75		$2,762,292	$13	$2,071,719.00
2011	51	17	42,627	$456,353	$11	$342,264.75
2012	33	8	27834	$112,540	$4	$84,405.00
Totals:	384	260			$70	$39,088,693

and expand into playing an important international role, the decrease in funding should be reversed. Short courses could also be offered to interested parties within and outside the United States.

5.3 Water

Water is a scarce Nevada resource. The state averages about 9.5 inches of precipitation annually, most of it as snow. The population of Nevada has been growing at among the fastest rates in the nation over the past few decades. Two out of 17 counties (Clark and Washoe) consume 87% of water in Nevada. The surface water supply is getting scarce, which may mean increased reliance on groundwater. Lake Mead is the major supplier of surface water to southern Nevada and various rivers emanating from the Sierra Nevada (e.g. Truckee and Carson rivers) supply most of the water to the Reno-Carson City urban corridor. The water levels in Lake Mead fluctuate over time. Currently, it is at its lowest level since Hoover Dam was built. Likewise, the water quantity in the Colorado River is also decreasing. Excessive pumping of groundwater causes subsidence and cracks hazardous to buildings and structures. The recharging of groundwater is generally impractical because of the lack of water availability, nor does recharging significantly reverse subsidence.

The total water withdrawal in Nevada has changed only by about 0.6% annually from 1995 till 2010 and is projected to remain essentially unchanged at about 4.39 million acre-feet per year in the present decade. Since 1995, the Nevada population grew from 1.5 to about 2.7 million. Although per capita water consumption in Nevada has declined 50% in the last 15 years, major cities like Las Vegas are purchasing water rights from ranchers far away in east-central Nevada. This activity is a sure indicator of the impending supply bottlenecks despite recent successes in demand management and conservation.

About 981 million gallons of groundwater are used every day in Nevada according to the National Groundwater Association (NGWA) or 358 billion gallons per year. This is about 25% of the total water usage of 1,431 billion gallons per year (4,392,000 acre-feet per year); the rest is surface water. The pattern of water consumption has shifted towards more M&I (municipal and industrial), domestic, and commercial uses and away from power generation and agricultural irrigation.

The NGWA also reported that in 2010 about 1,500 individuals found employment in Nevada's groundwater sector. Their firms noted about $110 million in business activity. All those working in this industry use geologic maps and other expert services of the NBMG faculty and staff on an ongoing basis. Managing groundwater involves geologic research a) to find water sources and b) to manage them by educating users about the impacts of pumping. The NBMG has limited resources available to commit to hydrogeology. It is, however, evident from the above discussion that it would be in the vital interest of the state to attend to geologic research related to water resources. Groundwater currently being pumped is thousands of years old. There is no feasible way to prevent permanent depletion unless conservation based on geologic research is further enhanced and practiced.

5.4 Natural hazards

5.4.1 Earthquakes

The NBMG has mapped hundreds of Quaternary faults, identified dozens of paleoearthquakes using trenching studies, and investigated every major or damaging earthquake in Nevada. It has turned this information into earthquake hazard and planning maps, public awareness maps, and earthquake planning scenarios. The Quaternary faults that have been mapped and paleoearthquake information are used directly in the U.S. Geologic Survey's National Seismic Hazard Map, which is used for determining building codes. NBMG studies of the effects of historical earthquakes are used to make realistic earthquake scenarios for disaster planning, develop emergency response exercises, and motivate seismic preparedness and mitigation.

The earthquake-related research at the NBMG involves identification of faults where earthquakes

originate. NBMG continually produces new geologic maps that show the locations of young active faults, most of which were either unknown or poorly understood prior to the mapping. This allows communities, industry, and commerce to plan appropriately for construction (e.g., building setbacks), infrastructure development, and mitigation of potential hazards through engineering and design.

This work has helped in providing valuable input for planners throughout the state. In Las Vegas, for example, no earthquake hazard was deemed to exist until NBMG research identified faults in the area. For development planners, as well as rescue services, it made a significant difference in terms of preparations to minimize damage as well as providing help in the aftermath of any earthquake. NBMG's Special Publication 20[17] has been used at least 8 times to train citizens and officials. It contains a detailed analysis of the plausible consequences of a hypothetical magnitude 7.1 earthquake along the northern Carson Range in the Reno-Carson City area. Special Publication 36[18] thoroughly documents the effects of the Wells earthquake. Open-File Report 09-8 estimated the probability of and estimated losses from earthquakes near Nevada cities.[19] There are at least 7 Nevada communities with more than 65% probability of a magnitude 6 earthquake within 50 kilometers in 50 years. The damage in these communities from such earthquakes is estimated to total $5.8 billion, with Reno impacted to the order of $2.0 billion. If timely warnings and preparedness training could prevent even 1% of the estimated damage to Reno, it would save $20 million to the citizens of the city and the State of Nevada. Beyond the monetary losses there remains the ethical issue of saving human life and the value we assign to each life.[20] During a major earthquake swarm in the western Reno area in 2008, NBMG scientists were a major part of an effort to encourage the mitigation of earthquake risks. This ultimately resulted in lower level damage to homeowners when a magnitude 5 earthquake struck. The main tool for information on seismic mitigation was a booklet prepared by the NBMG titled "Living with Earthquakes in Nevada." The benefits from the prevention of damage from a single earthquake would be greater than several years of total public funding received by NBMG.

Outreach based on research, such as in the earthquake areas, has enormous human and economic benefits to the society by way of preventing injuries (and the resultant medical expenses), loss of life, and minimizing damage to economic assets. Although the latter can be reliably estimated after the fact, it is impossible to put a dollar value on any loss of human life. To these ends, the NBMG has produced two public pamphlets, "Earthquakes in Nevada and How to Survive Them" and "Living with Earthquakes in Nevada." NBMG has also supported and played major roles in the Nevada Earthquake Safety Council and the Nevada Hazard Mitigation and Planning Council.

Experiences and data gathered after an earthquake help scientists to modify and improve their recommendations for damage prevention and rescue planning. The iterative changes in recommendations make them more effective while at the same time cost less to modify from episode to episode. Investments in earthquake research thus bear the potential of increasing marginal benefits. This seemingly counterintuitive, economic benefit is remarkable. However, it also requires continued commitment.

[17]Planning Scenario for a Major Earthquake in Western Nevada-Craig M. dePolo, Jim G. Rigby, Gary L. Johnson, Steven L. Jacobson, John G. Anderson, and Thomas J. Wythes, NBMG Special Publication 20, 128 p.

[18]The 21 February 2008 Mw 6.0 Wells, Nevada Earthquake. NBMG Special Publication 36, edited by Craig DePolo and Daphne D. LaPointe, 2011, 508 p.

[19]Estimated Losses from Earthquakes near Nevada Communities, Jonathan G. Price, Gary Johnson, Christine M. Ballard, Heather Armeno, Irene Seelye, Linda D. Goar, Craig M. dePolo and Jordan T. Hastings, NBMG Open-File Report 09-8, 2009, 46 p.

[20]Better Warnings for the Consequences of Earthquakes-Bringing Seismic Hazard and Risk Assessment to Policy. Max Weiss, Earth Magazine, June 2012, p. 44-51.

5.4.2 Floods

Although Nevada receives only 9.5 inches of average precipitation annually, most of which falls as winter snow, flood hazards can emanate from melting snow, heavy summer thunderstorms, and prolonged wet periods. Heavy summer thunderstorms commonly induce flash floods, rock slides, and debris flows. Las Vegas is particularly prone to this type of flooding. It should also be noted that the mountain ranges in Nevada receive much higher amounts of precipitation than the valleys. Heavy rains and/or melting snows within or emanating from the mountains commonly cause flooding in the major cities and towns within the valleys. The state government and communities responsible for safety of life and property rely on topographic and geologic maps for planning, whether it concerns urban expansion or infrastructure development. The benefits lie in the prevention of damage and in better planning of rescue operations.

NBMG has produced a number of maps that relate directly to flood hazards. An excellent example is the geologic map of Ivanpah Valley to the southwest of Las Vegas. A detailed Quaternary map illustrating flood hazards was produced by NBMG for this area (House et al., 2010)[21], because Las Vegas is planning to build a new airport here. Ivanpah Valley is an enclosed basin that contains a playa (dry lake bed) and is thus prone to flooding during wet periods. The geologic map of the valley will be used by Las Vegas to plan the location of the airport and associated infrastructure to mitigate the flood hazard. In addition, NBMG studied and published a major report on the New Year's 1997 flood along the Truckee River and its tributaries resulting from heavy rains on a deep snowpack (Rigby et al., 1998)[22]. These floods affected about 64,000 acres of land in Nevada, cost two lives and caused damage estimated to be between $167 and $619 million. Studies such as this can help future land use planning and avert damages. A number of urban maps have also been produced by NBMG. Ideally, funds need to be made available to study the effects of flooding in many parts of Nevada, if and when it occurs. Such studies assist in infrastructure planning and mitigate the effects of future floods on lives and property.

5.4.3 Radon

Radon is a radioactive gas, a decay product of radium, which in turn is a decay product of uranium. It occurs in all natural rocks but its concentration in the outdoor air is low enough to be harmless. However, it can seep into homes and attain concentrations that are harmful to health. According to the U.S. EPA, indoor air with a radon concentration greater than 4 pCi/L(pico Curie/liter) requires remedial measures. A 1990-91 NBMG[23] report determined that about 1 in 5 Nevada homes exceed safe levels of radon concentration. Some 47% of tested homes had concentrations of 1.0 to 3.9 pCi/Liter **(fig. 10)**. Thus, some percentage of these homes may need remedial measures as well. In general the remedy consists of prevention by better sealing of basements and crawl spaces, and improved ventilation.

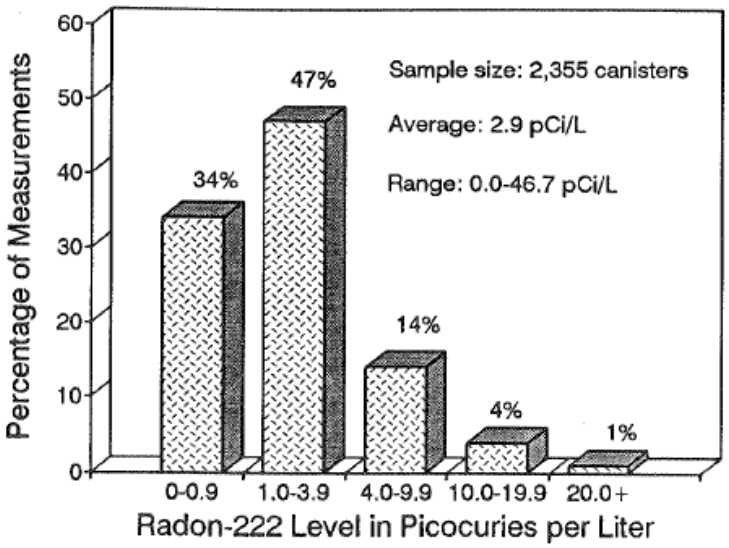


Figure 10: Results of radon survey of Nevada homes (1990-91).

[21]NBMG Report 53, Geologic Assessment of Piedmont and Playa Flood Hazards in the Ivanpah Valley Area, Clark County, Nevada; P. Kyle House[1], Brenda J. Buck[2], Alan R. Ramelli[1;1]Nevada Bureau of Mines and Geology, University of Nevada, Reno,[2]Department of Geoscience, University of Nevada Las Vegas, 2010.

[22]SP23, The 1997 New Year's Floods in Western Nevada, by Jim G. Rigby, E. James Crompton, Kate A. Berry, Unal Yildirim, Scott F. Hickman, and David A. Davis, 1998.

[23]Radon in Nevada–A Natural Hazard. NBMG Educational Series No. 18.

About 20,000 lung cancer deaths in the U.S. are attributed to radon exposure each year. These are largely preventable deaths because remedial measures, especially when incorporated at the time of home construction, are relatively inexpensive.[24] Retrofitting houses with remedial measures can be more expensive and disruptive. However, for homes with moderate radon concentrations, simple ventilation steps such as sealing cracks, covering sump pumps, and venting pump wells directly outside of the basement are inexpensive and operationally feasible. Controlled statistical studies on how prevention measures save lives and medical costs would be needed to establish the monetary benefits of such steps. However, regardless of the benefit/cost ratio it makes sense to take such steps, because the price of not doing so would be paid in terms of serious illnesses or human lives. The publishing of the educational series report on radon and how to mitigate its risks by NBMG makes a direct contribution to the health and well-being of Nevadans.

5.4.4 Environmental concerns

In the past, industrial facilities were commonly granted permission to do business without adequate studies to ascertain if their impact on the environment and/or on human well-being would be detrimental. The result often was soil and water contamination with disastrous consequences for life and property. In a previous study in two Illinois counties several such sites were located. The federal Environmental Protection Agency's (EPA) Superfund and Brownfields programs were designed to fund the cleanup of such sites.

The Superfund is an EPA program to identify, investigate and clean up uncontrolled or abandoned hazardous waste sites throughout the United States. A Brownfield is defined as land, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

Of the two Superfund sites in Nevada–Carson River Mercury Site and Anaconda Mine–only the Carson River site is on EPA's priority list. NBMG has studied the Carson site and reports are available[25],[26]. However, no information is available on the dollar amounts spent on the cleanup effort. The site has been extensively studied, and some cleanup steps have been taken in the past 15-20 years. How much money has been spent on these steps is unknown.

According to the EPA's Brownfields 2011 Assessment Grant Fact Sheet for Nevada, the following amounts were sanctioned as assessment grants **(table 2).** The 2011 Brownfields grants for the three Nevada sites totaled $575,000.

Table 2: Nevada Brownfield Grants.

Recipient	EPA region	State/Territory	Grant type	Year (FY)	Hazards	Petroleum	Job training
Carlin, City of	9	NV	Assessment	2011		$200,000	$0.00
Nye County	9	NV	Assessment	2011		$300,000	$0.00
Symphony Park Master Association	9	NV	Cleanup	2011		$75,000	$0.00

[24]Reducing Radon in Nevada Homes. NBMG Educational Series No.21.

[25]Lechler, P.J., Miller, J.R., Hsu, L.C., and Desilets, M.O., 1995, Understanding Mercury Mobility at the Carson River Superfund Site, Nevada, USA: Interpretation of Mercury Speciation Results from Mill Tailings, Soils, and Sediments: Proceedings of the 10th International Conference on Heavy Metals in the Environment, Hamburg, Germany, v. 1, p. 315-318.

[26]Lechler, P.J., Miller, J.R., Hsu, L.C., and Desilets, M.O., 1997, Mercury Mobility at the Carson River Superfund Site, West-central Nevada, USA: Interpretation of Mercury Speciation Data in Mill Tailings, Soils, and Sediments: Journal of Geochemical Exploration, v. 58, p. 259-267.

Undoubtedly, funds many times these will be needed to satisfactorily cleanup the above sites. How much of this and the potential future costs could have been avoided if adequate geological knowledge had existed and been used is a matter of conjecture. However, it is obvious that some of these costs would have been avoided in addition to some of the costs that may have been incurred in the meantime to remedy human health issues and damage to flora and fauna resulting from the polluted sites. A more complete inventory of potentially hazardous sites would be a desirable undertaking.

In addition to the Brownfields and Superfund programs, other cleanup programs such as the Underground Storage Tank (UST) program, also exist and cost millions of dollars more. In these cases the contamination of soil and groundwater are among the major concerns. In Illinois, geologists at the Illinois State Geological Survey (ISGS) have developed "contamination potential maps" that help in the risk assessment and pre-emption effort. Maps similar to these would be a desirable addition to the NBMG program in the future. The collective problem of many leaking underground storage tanks could potentially be expensive even though each individual cleanup may not be expensive. The most common remedy in the case of a leaking tank is to remove and transport the contaminated soil to a "safer" location. However, the liability issue remains, because "your name is written on that soil" as one Illinois official described. Prevention, therefore, is the cheaper option, and geologic information is the most helpful means by which to plan preventive measures.

Another example of the environmental use of geologic information is the recent effort to categorize the Greater Sage-Grouse habitat by the Nevada Department of Wildlife. A request was made to NBMG to advise the Governor's office about the mineral resources and exploration history/activity in areas of Nevada considered to serve as the habitat for the Sage-Grouse. In a series of three maps the NBMG was able to show the partially overlapping and common close proximity of the habitat to 1) mineral and geothermal occurrences, 2) active mines locations and power plant locations, 3), mining claims and geothermal leases, and 4) exploration activities (**appendix C).** Geology thus plays a critical role in aiding planners in making educated and balanced decisions, as well as taking into account the environmental and economic interests of the state. Apart from the risk of causing the extinction of rare species of animals or plants, the risk of making costly errors possibly leading to litigations can be considerably reduced with the use of proper geologic information prior to decision making. NBMG continues to play a major role in contributing useful geologic information and maps to these efforts.

5.5 Science education

NBMG's educational series includes generalized maps for K-12 grades as well as for public education. Teacher's packages, posters related to geology and resources, field trip guides, CD-ROMs, and videos are also available. Some of the guiding documents can be used with GPS systems. "The Science of the Comstock" guidebook provides information on the historic Comstock Lode gold and silver deposit of the 19th century. NBMG thus also provides valuable assistance to education and tourism in Nevada.

As of 2010, tourism was the second largest industry in Nevada,[27] after the real estate sector. It could possibly be the largest after the recent crisis in the housing industry. The tourism sector employs 30% of Nevadans **(table 3).** In a sense, tourism is the largest export sector. It exports recreation services to out-of-state customers from all over the world. Almost a quarter of Nevada's tax revenues are generated by the tourism industry. Recognizing its importance, the NBMG publishes maps and guidebooks with special reference to

[27]Nevada Travel Impacts 2003-2010. Dean Runyan Associates, 2011, 67p.

Table 3: Overview of Nevada Tourism Industry's Economic Impact.

Year	2006	2007	2008	2009	2010
Total travel spending ($Billion)	54.7	55.8	52.8	45.4	51.5
Jobs in travel industry	494,000	496,000	480,000	436,000	441,000
Travel jobs % of total	31	30	29	29	30
Tax revenues from travel ($Billion)	2.7	2.9	2.7	2.5	2.6
Travel tax revenue as % of total	26	25	25	24	24
Travel as % of Nevada GDP	13.2	13.1	12.7	11.9	12.3

the geology of the state[28],[29],[30]. Users include state and national park officials, various representatives of the tourism industry, and private individuals. Many of these users also buy maps and other publications. The NBMG's Special Publication SP35, which describes in layman's terms the geologic and historical features along the Highway 93 corridor running through southern and eastern Nevada, is the latest excellent addition to the guidebook series of publications. NBMG has published similar guidebooks for the Reno and Las Vegas areas. The NBMG's ability to continue to provide assistance and guidance to travellers in Nevada will be critically dependent on future funding.

[28]"A Geologic and Natural History Tour through Nevada and Arizona along U.S. Highway 93, with GPS coordinates" Joseph V. Tingley, Kris A. Pizarro, Christopher Ross and Philip A. Pearthree, NBMG Special Publication SP 35.

[29]Traveling America's Loneliest Road, a Geologic and Natural History Tour through Nevada along U.S. Highway 50, with GPS Coordinates, by Joseph V. Tingley, Kris Ann Pizarro, 2010. NBMG Special Publication 26.

[30]Geologic and Natural History Tours in the Reno Area (Expanded Edition) by Joseph V. Tingley, Kris Ann Pizarro, Christopher Ross, Becky Weimer Purkey, and Larry J. Garside, 2005. NBMG Special Publication 19.

5.6 Geologic research

Overview: Fundamental to NBMG's work in all the areas discussed above–minerals, energy and water resources, natural hazards and urban growth, environmental concerns, public health, and tourism–is geologic research. Research productivity by NBMG is high, as measured by publications, presentations, and awarded grants (**figs. 11 and 12**).

Publication productivity (publications per state-funded scientist) has nearly doubled between 1993 and 2010, and the number of presentations given by NBMG scientists tripled between 2002 and 2010. NBMG scientists have been publishing in the top scientific journals, as well as in the NBMG peer-reviewed and open-file series. The scientific impact of peer-reviewed journal publications by NBMG authors increased nearly ten-fold from 1992 to 2010 (**fig. 13**).

NBMG has also been very successful in obtaining external grants and contracts. From 2004 to 2010, annual new awards for NBMG scientists ranged from $1.5 million to $7.0 million. In total, NBMG attracted ~$28 million in external grants over this seven-year period and expended $24.7 million, amounts larger than any

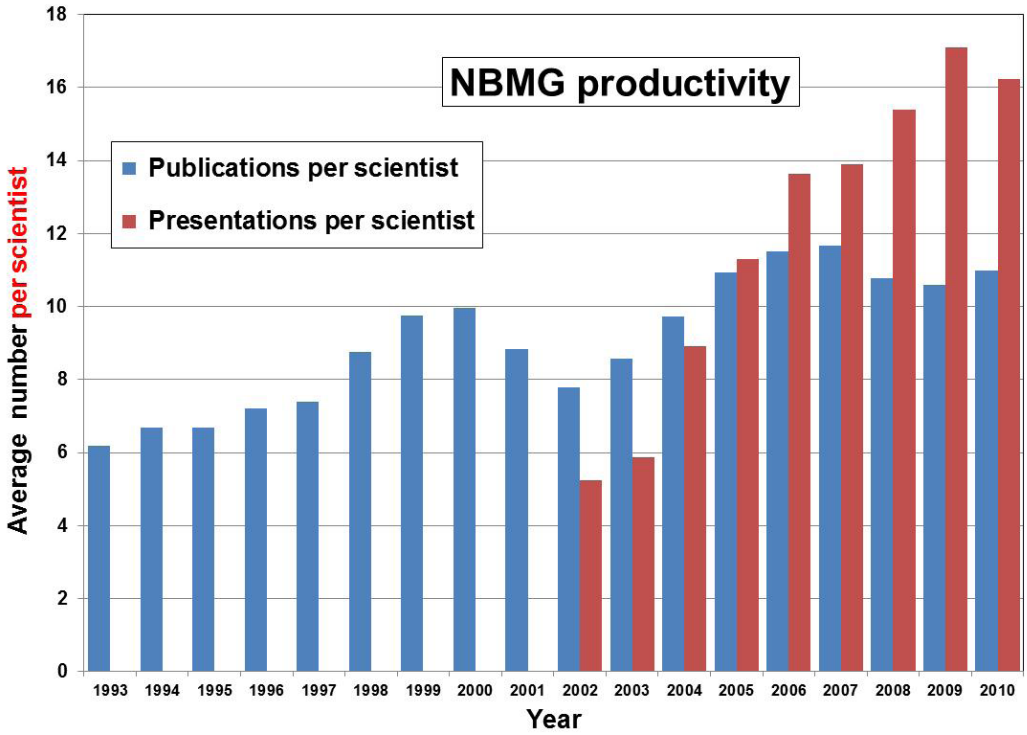


Figure 11: Three-year moving averages of publications and presentations per state-funded NBMG scientist.

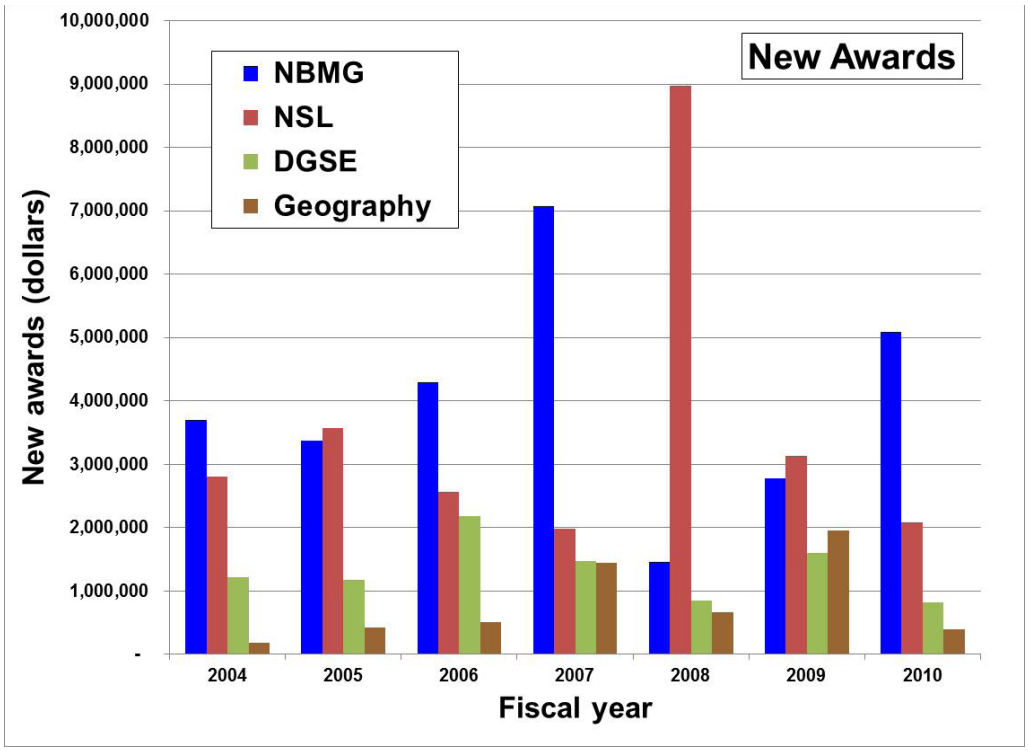


Figure 12: Annual new awards for geoscience units at UNR (Source: UNR Office of Sponsored Projects.)

of the other geoscience units at UNR (**fig. 14**). In 2010, NBMG averaged $500k in new awards per state-funded scientist. Between 2004 and 2010, for each state dollar, NBMG has attracted $1.86 ($2.27 in 2010) in new external grants, spent $1.65 ($1.44 in 2010) from external grants and contracts, and contributed $0.28 ($0.30 in 2010) to indirect costs. The recently imposed budget cuts to NBMG will clearly impact this level of productivity.

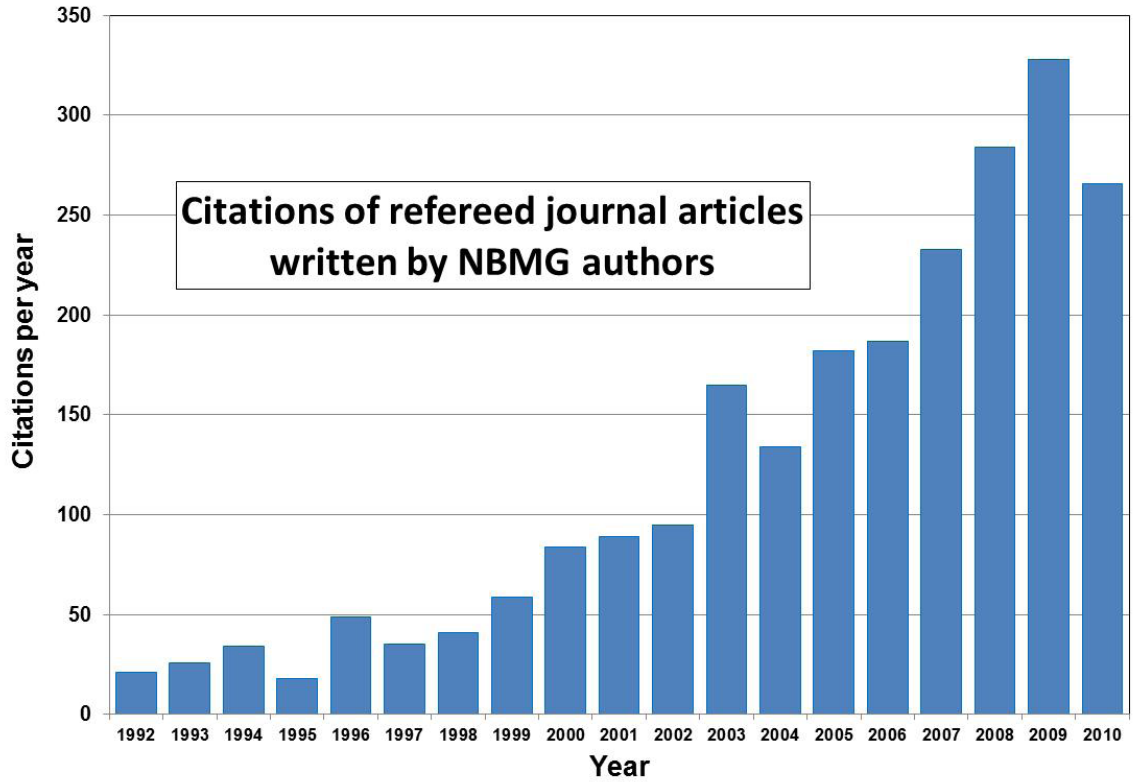


Figure 13: Citations of externally peer-reviewed journal articles with at least one NBMG author.

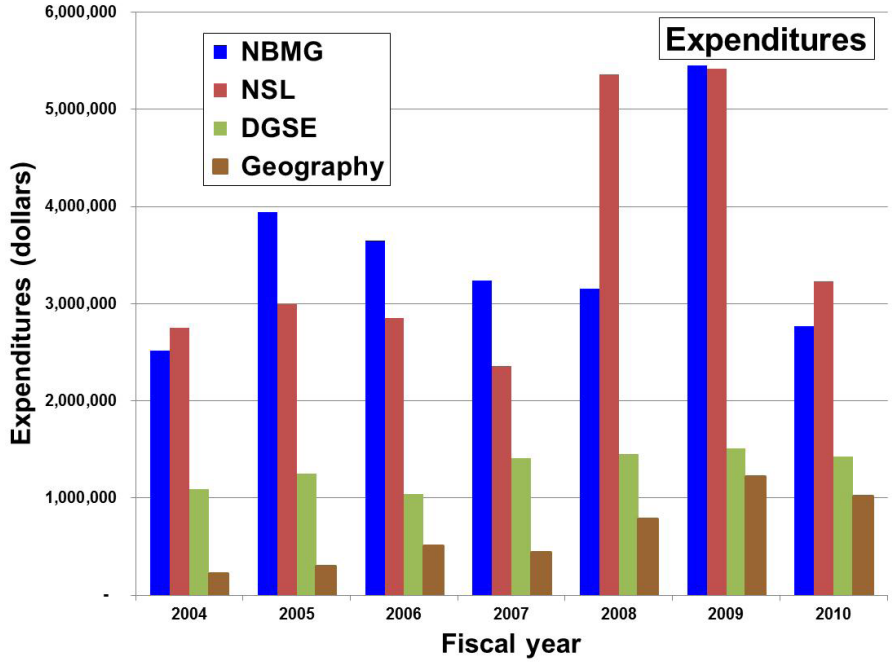


Figure 14: Annual expenditure from contracts and grants by the geoscience units at UNR (Source: UNR Office of Sponsored Projects) .

On the basis of research productivity, as summarized in NBMG's biennial reports (which are available through **http://www.nbmg.unr.edu/**), NBMG currently has excellent programs in economic geology, geodesy, Quaternary geology, structural geology, and geothermal exploration. NBMG faculties in these areas are internationally recognized. For example, the Nevada Geodetic Laboratory (NGL), housed within NBMG, has an international reputation with applications across a wide spectrum of topics, including earthquake hazards, climate change, tsunami warnings, and data processing for the global positioning system. NBMG is the only state geological survey in the country that has a geodetic laboratory and geodesists on its staff.

Geologic Mapping: Geologic maps identify the distribution, geometry, relative age, thickness, and depth of the various rock units, faults, landslides, and many other geologic features relevant for both basic and applied research.

Quoting from the Geological Society of America's position statement on the value of geologic mapping:

> "Geologic maps are tools portraying interpretive, three-dimensional views of rock, sediment, and soil units that depict their distribution and age relationships. They provide information on Earth's structure and other features at and below Earth's surface and offer baseline data for petroleum, coal, and industrial and metallic mineral resources. Geologic maps can also show how the physical environment has been impacted by human activity. Our understanding of issues important to society, such as natural hazards, water resources, and soil conservation, is also grounded in geologic maps. The preparation of geologic maps is a fundamental skill unique to the science of geology.
>
> Geologic maps provide a context for testing scientific theories, hypotheses, and models. They stimulate scientific thinking, questions, and ideas and promote further development of geologic methods and techniques. Geologic mapping at appropriate scales creates a framework within which biologic, climatologic, and other scientific data can be considered in the context of geologic information, yielding increased understanding and encouraging further multidisciplinary scientific investigations. Geologic maps are also valuable teaching tools in earth-science classrooms."

Geologic maps produced by NBMG and other state geological surveys are accessible to everyone, and are typically carried out with public funding. Geologic maps are a typical "public good." (For a brief discussion on economics of "public goods" and "private goods" see **appendix D**). Cost-benefit studies show that modern geologic maps save developers and engineers about $50,000 for every project occurring within a standard mapping area of 56 square miles. Typically, many projects utilize a single map, multiplying these cost savings many times over. The maps, and data collected to make them, are of great value, because society can use them in perpetuity. Analyses have calculated the value of the geologic maps to be 25 to 39 times the cost of the mapping (**http://www.isgs.uiuc.edu/maps-data-pub/publications/ky-flyer/ky-flyer.shtml**).

Nevada is a complex, geologically varied, resource-rich state that requires a diverse and well-staffed geological survey to conduct geologic mapping. Because of the complexities, geologic mapping is more time consuming in Nevada than in most other parts of the country. However, due to the abundant resources, the economic benefits of this work are far greater in Nevada than is typical elsewhere. Geologic maps and related reports on applied research continue to be excellent incentives for protracted economic development.

Geologic mapping at the scale and overall coverage needed for applied and basic research is clearly a role for state geological surveys, such as NBMG, because the public benefits in many ways and this work is time intensive, requiring dedicated staffs of geologists, as well as cartographic and GIS specialists. In addition to field work, completion of an accurate, modern geologic map typically involves 1) extensive sampling and analysis of rock units, 2) integration of well data and geophysical surveys, 3) incorporation and analysis of relevant historical data, aerial photography, and satellite imagery, and 4) infusion of knowledge from surrounding regions. Thus, geologic mapping is not typically performed by companies, which limit their work to small areas of immediate interest to their

specific projects, nor by geology professors in academic departments because of the time-intensive nature of the work. Publication of one geologic map commonly requires many months of dedicated work over a period of one to several years. Teaching loads and publication productivity expectations generally preclude academic faculty from contributing significantly to geologic mapping efforts. Nonetheless, it is important to reiterate that the private sector and academic research rely heavily on geologic maps produced by state geological surveys for many purposes, including 1) understanding the geological framework at various scales, 2) assessments and exploration of mineral, energy, and water resources, 3) evaluation of natural hazards, 4) infrastructure planning, and 5) urban development.

Detailed geologic mapping is therefore a fundamental mandate of NBMG, involving its scientists and cartographic/GIS staff for production of the maps and the Information Office for their distribution and sales. NBMG's track record on producing high-quality geologic maps is impressive. In the past 20 years, NBMG has published 121 new geologic maps. The scientific and practical impact of geologic maps published by NBMG is immense. Even so, much of the state remains to be mapped, as only about 20% of Nevada has been mapped at scales adequate for resource assessments, natural hazard evaluations, and insights into fundamental basic research questions **(fig. 15).** In essence, about 80% of Nevada lacks adequate, modern geologic maps. The needs and desired scales of geologic mapping are documented through the user response survey to be discussed later in this report.

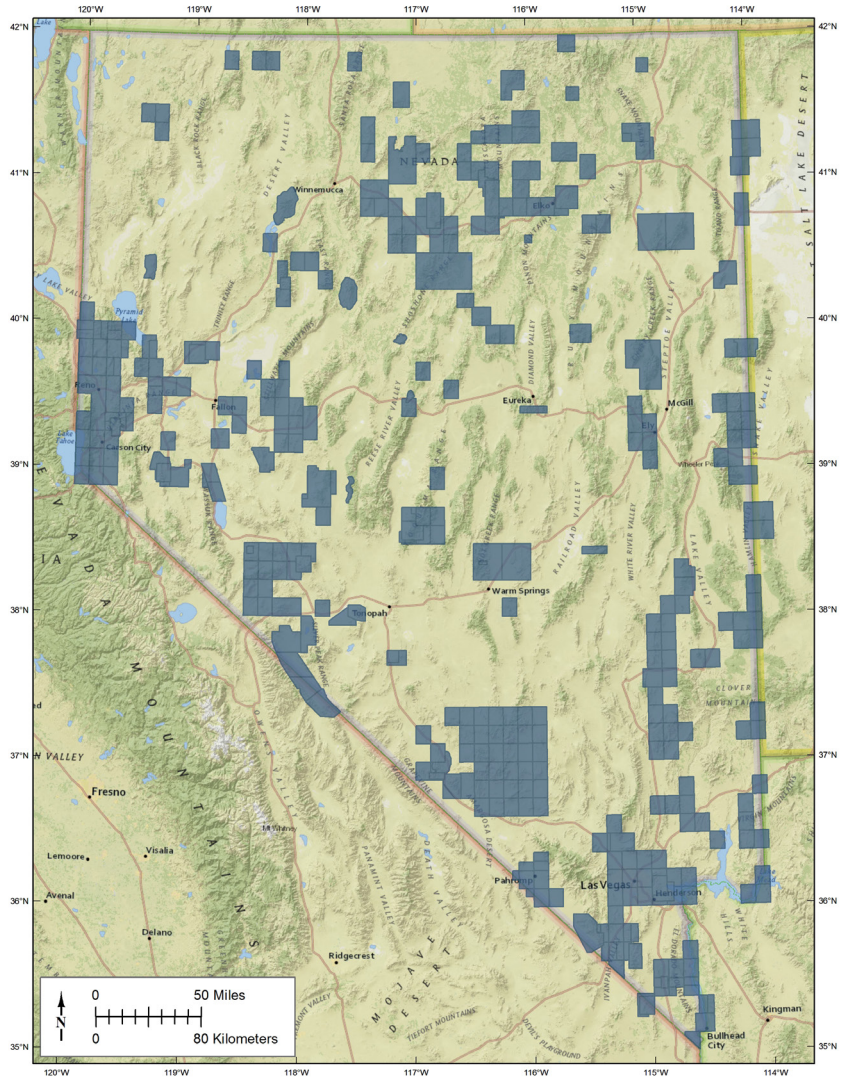


Figure 15: Areas of detailed mapping (1:24,000 scale) in Nevada, as of 2012, shown in dark blue. This work has been carried out primarily by NBMG and the USGS.

Geologic mapping by NBMG has been funded primarily through the STATEMAP program of the National Geologic Mapping Initiative (administered by the USGS) and partly by grants and contracts from other federal agencies and private industry. The STATEMAP program requires a 100% match in state funds **(fig. 16)**. However, recent budget cuts have left NBMG with only four full-time equivalent positions capable of conducting geologic mapping. Thus, NBMG has a limited ability to carry out what is probably its most critical mandate. Slower progress on geologic mapping will clearly impact economic development and public safety within the state.

6. Results of the Nevada user survey on geologic information

A 20-part questionnaire (**appendix A**) was sent to 1,820 individuals who are current or potential users of geologic information generated by the NBMG scientists in Nevada. This approach to value assessment involves the following:

- Compile the various uses buyers have for maps and other forms of geologic information.
- Ask what they would willingly pay for maps if they were not available from NBMG.
- Ask for estimates of how much money they might allocate for geologic information (maps and other) to purchase from other sources.
- Ask for examples of actual projects in which they used geologic maps and for estimates of what percentage of the projects required geologic information.
- Ask what reasons, other than availability or price, they saw in using geologic information generated by scientists working with the surveys.
- Solicit suggestions for future priorities for NBMG programs.

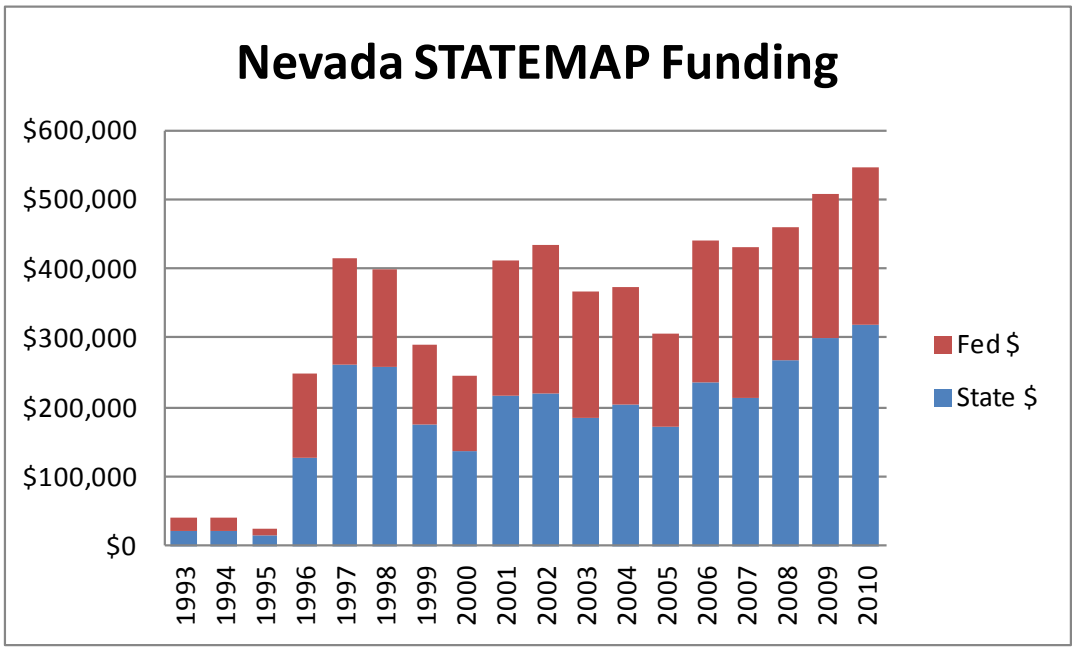


Figure 16: State and federal sources of Nevada STATEMAP program.

Geologic maps are the most familiar form of geologic information. Other forms include written reports, guidelines for hazard prevention and remediation, environmental impact assessments, and resource histories and assessments. Relatively less obvious to the casual observer are geologic samples such as hand specimens, drill cores and cuttings, fossils, air photos, chemical and mineralogical analyses, assays, and GIS data sets stored and made available at little or no cost to the public at the Great Basin Science Sample and Records Library (GBSSRL).

Similar studies from Illinois, Kentucky and Spain were aimed at assessing the value of geologic maps to users. In Ohio, the study was broadly conceived but less direct than the present approach. The inclusion of all forms of geologic information in a direct canvassing of users in Nevada is the first such known attempt to assess user perceptions of the usefulness and value of geologic information. The present study also differs from the past attempts in that it is intended to assess what users perceive as the needed future directions of geologic research and how NBMG should allocate its limited resources. To this end the users were also asked if they considered it useful and appropriate to change the name from Nevada Bureau of Mines and Geology (NBMG) to Nevada Geological Survey (NGS).

Eighty-four surveys were returned, corresponding to a response rate of ~4.6%. Although the response rate is smaller than in Kentucky it is comparable to or exceeds the rates experienced by marketing as well as medical research organizations.

In this section, we present the findings of the survey and attempt to interpret them in qualitative as well as quantitative terms. The results are organized under the same subcategories as listed in the questionnaire.

Question #1: Which characterizes your organization best?

Almost all types of organizations responded to the survey with the exceptions of the transportation and tourism industries and the city governments **(fig. 17).** However, the visitor tabulation by the GBSSRL staff **(appendix E)** and the response to the activities-related question indicates that city and regional planning as well as transportation sector are also regular users of geological information **(figs. 18–26**).

Prominent among the respondents in figure 17 were the mineral resources industry, especially the junior companies and the independent consultants, followed by small energy resources companies (e.g. geothermal). This is an indication of the benefits derived by organizations with lower budgets, but also the organizations most involved in exploring and detecting new resources. At first glance, large resource companies appear to be less dependent on NBMG research. However, in reality the large companies ultimately buy out the holdings of the junior companies and thus benefit from NBMG's research. Significantly, geotechnical firms also use NBMG products and services. The values derived from NBMG's work spread across the state's economy, as indicated by the broad response.

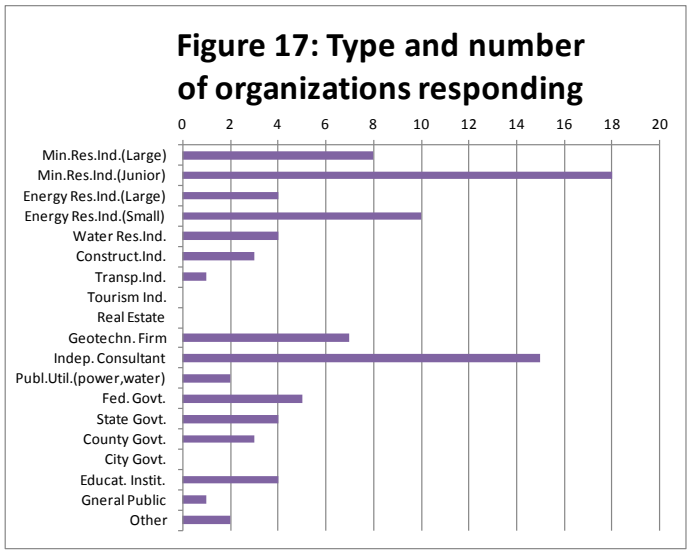


Figure 17: Type and number of organizations responding

Question #2: Which activities in your organization require geologic information?

Given the dominance of metals in the Nevada minerals production, it is not surprising that metals and specialty minerals are prominently represented. They are followed by the groundwater and geothermal industries **(fig. 18)**.

From the importance of the metals and groundwater exploration, development, and production, it follows rationally that the environmental impact statement (EIS) is the area of most interest in the environmental consulting sector. The EISs are increasingly required by law and are helpful in informing the public, and protecting the environment **(fig. 19),** the latter with significant potential cost savings.

Nevada is an earthquake-prone state. Related hazards of landslides are also of concern. Subsidence is primarily connected to groundwater exploitation, whereas the interest in soils may be connected to subsidence as well as engineering geology and geotechnical issues **(figs. 20 and 21).** Unlike in the previous two graphs, however, the interest is more evenly spread across most areas of hazard mitigation and prevention, as well as engineering applications, city and regional planning, an indication that civil society is just as interested in geological information as the industries. User responses indicate that many are simultaneously interested in multiple hazards and prevention.

It is in the civil society applications where the benefits of having geological information pays the most valuable returns because of their immediate concerns with life and property; yet these are also the areas where monetary quantification of benefits is most difficult. Hazards-related geologic research also helps in the area of property valuation and land acquisition **(figs. 22, 23 and 24).**

In the research and education sector, respondents assigned high importance to basic and applied research. College and university education is also recognized; however, K-12 education appears to be lagging **(fig. 25)**. This is the age group needing greater attention, because they are literally the future of Nevada. The future

Figures 18 throuth 26 represent activities requiring geologic information as carried out by users of NBMG products.

Figure 18: Resource exploration, development, and production

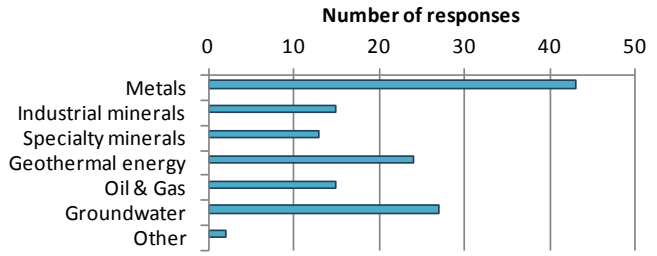


Figure 19: Environmental consulting

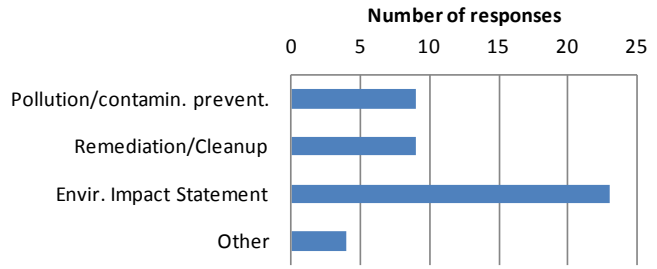


Figure 20: Hazard mitigation/prevention

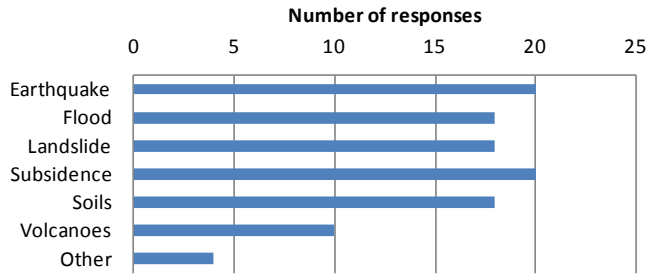


Figure 21: Engineering applications

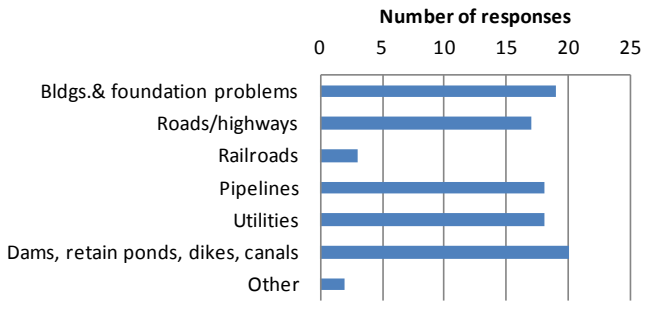


Figure 22: City planning

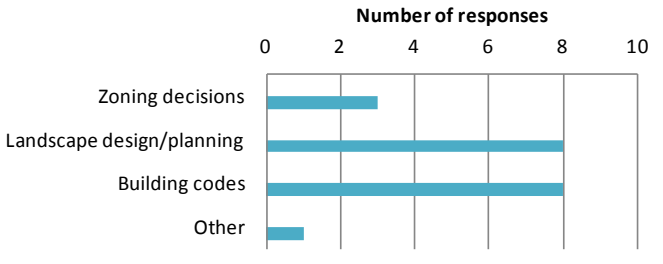


Figure 23: Regional planning

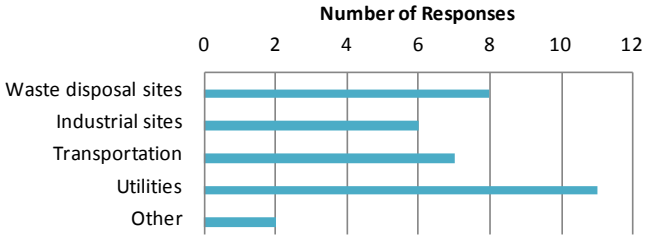


Figure 24: Property valuation

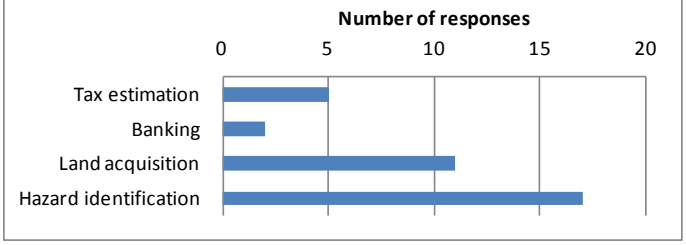


Figure 25: Research and education

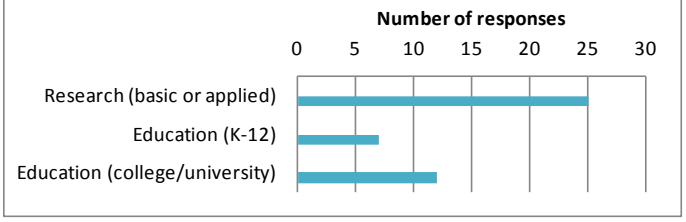
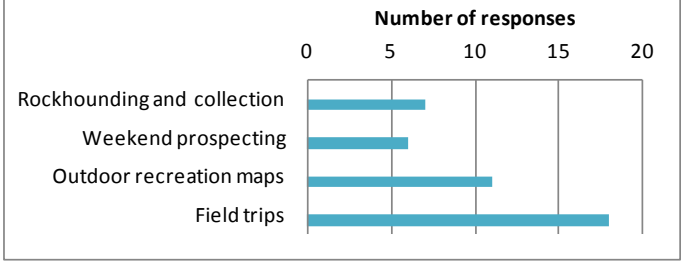


Figure 26: General public



citizens, scientists, politicians and government officials would be able to make informed decisions if geology is taught in K-12 grades, with the accompanying economic benefits.

Considerable interest also exists in the hobby and recreation areas of the general public **(fig. 26)**. Citizens seem to have a high level of interest in the geological field trips. Organizing field trips for the general public can be a productive public education as well as public relations tool not only for NBMG but also for UNR.

Question #3: What percentage of your work in the past 5 years depended on geologic information and research?

Most frequent user responses indicate that they need geologic information for almost all the projects, although projects with lesser needs of geologic information were also reported **(fig. 27)**. When asked about the need of geologic information on the basis of the dollar value of projects, two clusters of responses emerged **(fig. 28).** One group reported that <10% of project dollars were spent on geologic information, but an almost equally large group reported spending >90% of project dollars on geologic information. One possible interpretation of this would be that the high percentage is attributable to consulting projects or to junior companies that necessarily need to focus on geology, whereas larger companies handle projects that focus on project implementation and therefore spend a smaller percentage of the project budget on geology. The time allocated to get the geologic information was reported to be more uniformly distributed **(fig. 29).** However, a plurality of responses were in the >90% and <20% time categories, reflecting the spending trend.

The user responses support the observation that junior companies, independents, and smaller budget projects depend more directly and more heavily on geologic information from the NBMG than larger companies, but the need for it remains pervasive.

Question #4: In what form do you use geologic information?

Most users indicated multiple preferences. Digitized geologic information is slightly more preferred than in paper form **(fig. 30).** The NBMG's planned future emphasis on digitization thus reflects user preference as well. The number of responses in favor of physically accessing air photos, cuttings, drill cores and assays also points to the appropriateness of recent emphasis at NBMG on collection and curating and the investment in the new building for the GBSSRL.

Question #5: How does NBMG research benefit your organization or industry? Please provide specific examples.

The responses indicate many aspects of value provided by NBMG. Some refer to the fact that the needed information is available only at NBMG. Others emphasize the time and cost savings. Smaller companies are especially dependent on NBMG for geologic information. Most agree that NBMG's work helps with placing their projects in context with the larger geologic picture. Researchers elsewhere learn from ideas and innovations coming from the NBMG. The following selected responses are direct quotes from the user survey.

- The history and geology of old mining districts to better understand how the geology and mineral deposits influenced the success and/or failure of the districts.
- The NBMG provides a well-organized source of geologic information (saving us time and money).
- Valuable information for exploration, mine development and hazard assessments.
- Exchange of ideas with professional colleagues.
- NBMG has background info no other institution has.
- Mining reports and statistics benefit us in communicating with financial markets.
- NBMG staff often supervises student research projects, the subject of which is often pertinent to our work.
- Raw geologic data, such as geologic maps, are used in evaluating properties, acquisitions and sales, and mining exploration proposals.
- Provides an unbiased base from which to start investigations/evaluations of geological projects.

- I have specifically utilized information found only at the NBMG for my graduate research.
- I have used NBMG geologic maps to evaluate the evolution of the Colorado River.
- I have used NBMG geologic maps to evaluate the structural geology and metallic mineral resources of the Black Mountains in Arizona, across the Colorado River from Clark County in Nevada.
- NBMG provides important regional scale data for geothermal exploration, and to advancing geothermal exploration science.
- History of wells drilled for oil and gas.
- Publications by NBMG scientists for Nevada often suggest new scientific techniques that are relevant for data collection, processing, and/or interpretation for the geology of Colorado.
- Geologic maps are a key to initial investigations for groundwater conditions, including likely zones of enhanced or decreased permeability.
- NBMG has been a source of information for the geophysics division of Zapata Incorporated for >30 yrs. –mining, ground water, geothermal – projects too numerous to list.
- For a small exploration company entering Nevada, the small-scale mapping base, reports of mining/ exploration activity and the old district files are critical in focusing the effort. As the majors are focused on brownfields exploration and counting on acquiring major new discoveries from juniors, this is crucial to the development of new mines and districts.
- The NBMG is a strong supporter of the Nevada Division of Emergency Management's Hazard Mitigation Program. It supports much of the GIS-related work such as risk assessment for earthquake, flood and to some extent wildfire.

Figure 27: Percent of projects needing geologic information

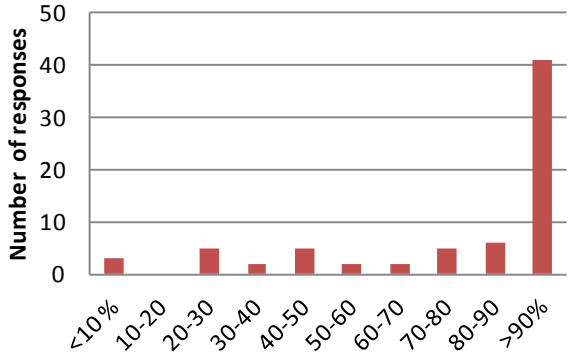


Figure 28: Percent of project $ value depending on geologic information

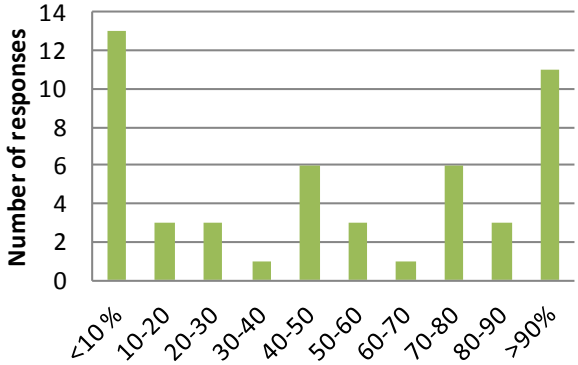


Figure 29: Percent of time attributable to geologic work

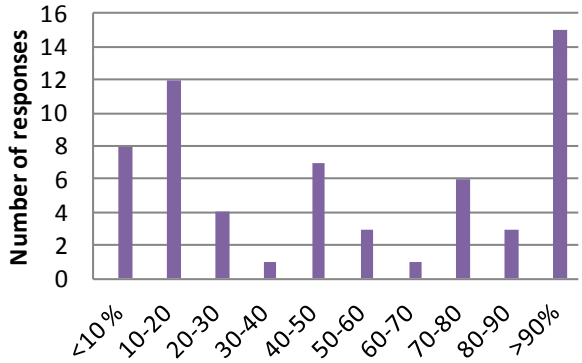
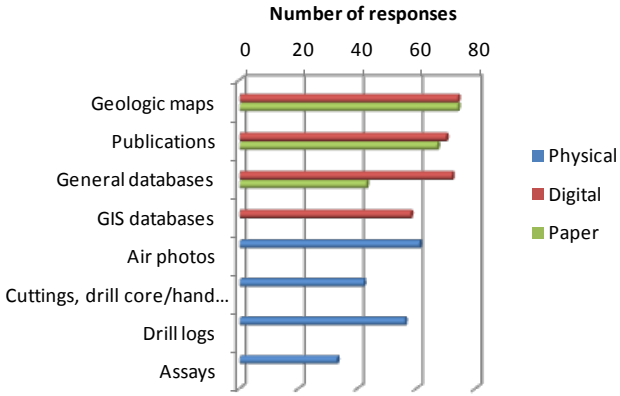


Figure 30: Form of geologic information used



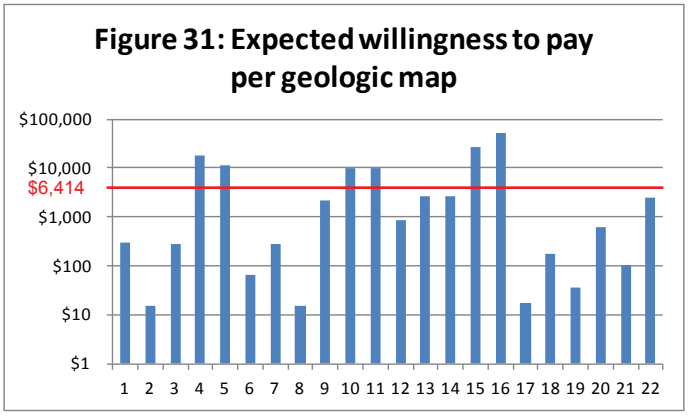
Question #6A: If you use NBMG geologic maps, please name a specific project(s) for which geologic maps were used.

The long list of projects using geologic maps is a vivid indication of the depth and breadth of the impact made by NBMG in Nevada. Some areas are mentioned repeatedly; however, these are different projects reported by different users and demonstrate where increased activity is taking place.

- Kennedy mining district in eastern Pershing County.
- Lyon, Douglas, Churchill, and Mineral county data.
- Rufus project in Humboldt County, Tonopah mining district history.
- Garfield Flats.
- Salt Wells, NV.
- Bottle Creek, Rye Patch, Pogonip Ridge and National Mine Projects.
- Comstock-Billy the Kid Pit.
- Wood Hills.
- 13 acquisitions/sales, 50 plans of operation and a dozen mineral materials projects.
- Las Vegas hydrogeology. CWP/In-state groundwater project.
- Historical research.
- Goldfield, Tonopah, Mindoro.
- Bl placer; Eldorado bar placer; fire creek au; Carlotta mine cu; Brady placer; Kennedy district evaluation; El Korincho (Zacatecas) evaluation; several submittal evaluations.
- Atlanta_florida_canyon_getchell_stillwater_eugene_mtns_spruce_mountain_humboldt_range.
- Brady's, Desert Peak, Desert Queen, Dixie Valley, Beowawe, Steamboat, Soda Lake, San Emidio, Reese River, McCoy geothermal areas.
- Yerington porphyry copper district geological mapping of hydrothermal alteration zones.
- Carlin deposits, north-central Nevada. Zircon geochemistry of late Eocene intrusions associated with gold deposits.
- Pequop South Project 2011, Map 171, McArthur Project 2007 Geologic Map of the Yerington 1 district, Map 77, Mineral Hill 1998, Map 97.
- Master's Thesis: Exploring the Dixie Meadows geothermal system in Dixie Valley, Nevada.
- Copper/silver exploration project in Mineral County.
- Barite property evaluations in Elko and Lander counties.
- Precious metals property evaluations in Humboldt, Mineral, Esmeralda and Elko counties.
- McCoy, Cove, Eureka, Tybo districts.
- Nature and origin of the Bouse Formation and Hualapai Limestone considered as possible radon sources in southern Nevada.
- Lincoln Hill precious metal and industrial mineral project making new discoveries for creating jobs in Nevada.
- Geothermal exploration in the San Emidio Desert and vicinity.
- Practically every residential and commercial subdivision in Clark County, including resort property development on the Las Vegas Strip.
- Blackburn oil field, Pine Valley, Railroad Valley.
- Cove, McCoy area, Mt. Jefferson, Round Mountain.
- Dixie Valley EGS geothermal exploration.
- Coyote Springs MSHCP; Nevada Hospital Association Broadband Environmental Assessment; Kirkwood Meadows Energy reliability EIS.
- Star, Lake.
- General Moly, Mt. Hope Mine and Liberty Mine, Robinson Nevada Mining Company, White Pine County regional hydrologic database (GIS).
- The soon to open I-580 extension.
- Sandman, Long Canyon, general Elko County area.
- Pequop Mountains groundwater investigation in support of mineral development. Las Vegas area groundwater studies (six different projects). Various mine water supply and dewatering projects in Elko County, White Pine County, Humboldt County, Eureka County, Lander County.
- NSF- and ACS-funded projects to Duebendorfer (NAU) from early 1990s to early 2000s and Umhoefer (NAU) in late 2000 through early 2012.
- Tonkin Springs, Gold Bar.
- Mt. Hope prospect, General Moly, Central.
- Desert Peak and Brady's geothermal areas.
- Munitions/hazardous materials at Nevada Test Site; robotic data gathering.
- Ely Energy Center Water Resources Department and Yucca Mountain Rail Corridor (design and EIS support).
- Truckee Meadows geothermal. Railroad Valley oil exploration and production.
- Geology of parks and public lands.
- Locating wells in Verdi, Lemmon Valley, Spanish Springs and Truckee Meadows basins.
- Trinity Silver, Dutch Flat, Dome Hitto, Bullion Mtn., Antelope Ridge, Pasco Canyon.
- Southern Nevada water authority pipeline project to Spring Delamar, Dry Lake, and Cave Valleys; Smoke Creek Desert project for a power plant.

Question #6B. Had the maps not been available from NBMG, how much would you have willingly spent to obtain the same information?

In order to assess the monetary value of geologic maps, users were asked to provide three value estimates – maximum, minimum and their best estimate – of how much they would willingly pay. About a quarter (22) of the total number of respondents (84) provided all three estimates **(fig. 31)**. The estimates were used to calculate the "expected" value. (For the discussion of the statistical theory underlying this "**triangular probability distribution," see appendix D**.)



The expected "willingness to pay" values indicate a wide range from $15 per map to a high $50,000, with the average expected "willingness to pay" per map of $6,414. In a previous section we discussed map values from other studies. In Kentucky, for example, the "willingness to pay" per map was estimated at $342.

Many more users reported one or two of the three values they were asked to estimate. As a result, the numbers could not be used to calculate expected values. However, it is instructive to take a look at the summary of what they reported **(table 4).**

Question #6C: What mapping scale best serves your needs?

The respondents had no difficulty indicating their most preferred mapping scale. They overwhelmingly prefer the 1:24,000 geologic maps **(fig. 32)**. Many would prefer more detailed mapping, as is indicated by their choice for the 1:5,000 and 1:10,000 scales. The cost of mapping rises with the scale of mapping. Future mapping plans will need to strike a balance between map scale and funds available. The descriptive responses also suggest that some of the older available 1:24,000 maps should be revisited and remapped because mapping techniques and knowledge of geologic principles have evolved since the original work was done.

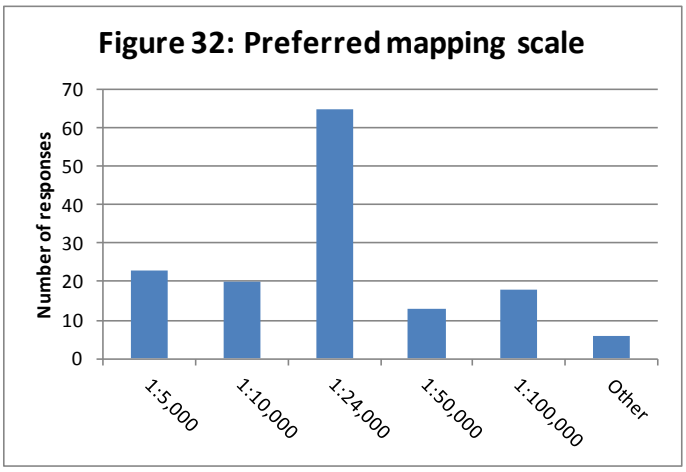


Table 4: Reported map values by all respondents.

	Highest reported	Lowest reported	Average
Maximum	$200,000	$15	$16,013
Minimum	$20,000	$3	$2,494
Best Estimate	$100,000	$15	$9,320

Note: The "Best Estimates" reported by 4 of the respondents were not included in Table 7. The absence of "Max" and "Min" reporting by these users and the extremely high "Best Estimates" they reported made it difficult to reconcile them with the rationale of the estimation methodology.

Question #7, 8 and 9: If you visit the Great Basin Science Sample and Records Library (GBSSRL) how often do you visit? How useful/ productive are your visits to GBSSRL? How useful is online access to digitized geological information?

Weekly or monthly visitors to the GBSSRL are few **(fig. 33)**. However, a majority reported at least one visit per year or more, and they overwhelmingly reported the visits to be highly useful **(fig. 34)**. The visitor's preference for digitized information was almost unanimous **(fig. 35)**. In fact, the relatively low frequency of visits indicates that many users obtain what they need via NBMG's website. Web visit data presented in **appendix E** confirm that many more people visit the website than visit the office in person. NBMG intends to increase digitization of all products in the future. As user needs are increasingly fulfilled through the NBMG website, pricing policies for information should possibly be reconsidered, as currently nearly all products are free on the Web.

Figure 33: Frequency of GBSSRL visits

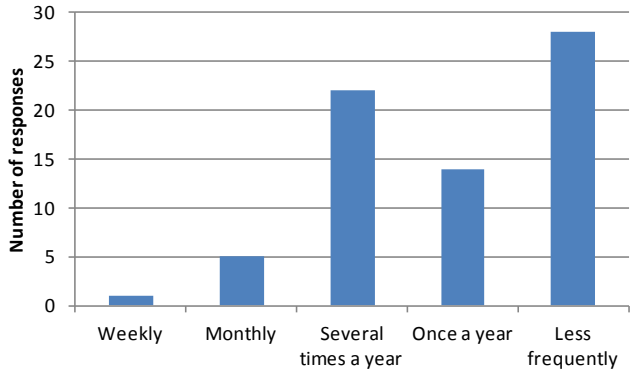
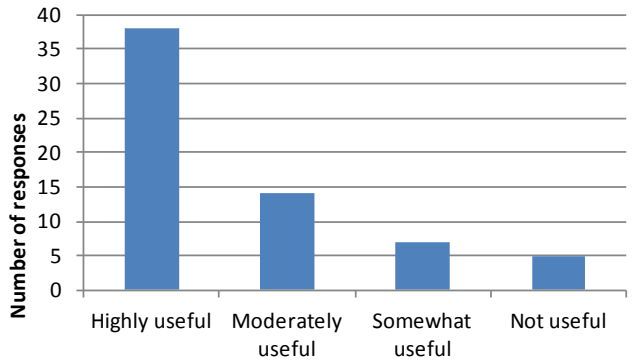


Figure 34: Usefulness of GBSSRL visits



Question #10. How do you obtain geologic information if not available from NBMG?

When geologic information (maps as well as other forms) is not available with the NBMG, the most frequent response was for doing their own field work **(fig. 36)**. An almost equal number would incur expenses by contracting the NBMG or another organization or hire a consultant. Only a small number reported getting the information from other sources, several of them from the USGS. It is evident from these responses that considerable expenses would have to be incurred if geologic information were not available free or at low cost from the NBMG.

Figure 35: Usefulness of online digitized information

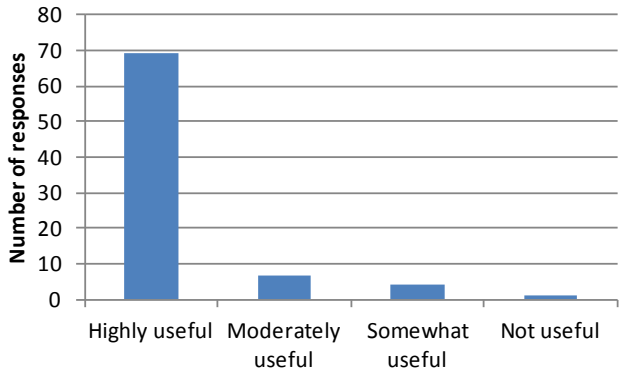
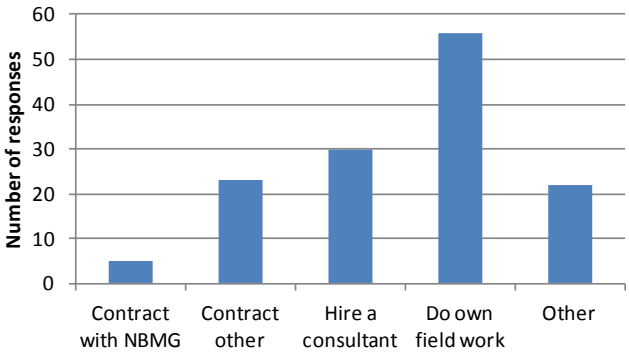


Figure 36: Source of geologic information when not NBMG



Question #11. How much would you typically spend in the above case?

As in the case of geologic maps, users were asked to estimate the amounts they would spend to get the geologic information (maps and all other forms) if it was not available with the NBMG. In this case too, about one-quarter of the respondents reported the maximum, minimum and best estimates. Although the reported values varied widely, their average expected value was $11,574, or almost twice the average for maps **(fig. 37),** an indication that NBMG publications, samples, assays and laboratory services are considered to be as valuable as geologic maps. In reply to the question on examples of projects for which geologic information from NBMG was used, users reported at least 188 projects, even though the project description was more general than specific. The value of geologic information would be on average $11,574, and the cumulative value for 188 projects would be about $2.18 million. Another, more cautious, way to look at the value is to take into account the number of respondents to this question. For the 21 respondents alone the amount they potentially saved would be $243,000, assuming that they used it for a single project each.

When responders reported only one or two of the three value estimates, the average value of geologic information amounted to $20,957 per respondent **(table 5).**

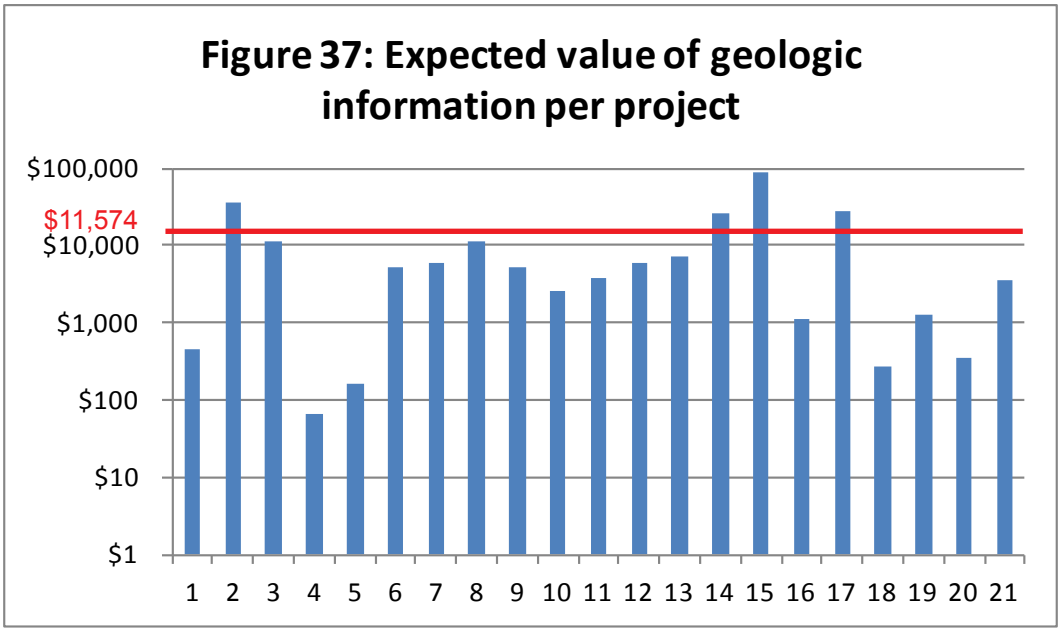


Table 5: Values of geologic information as reported by all respondents.

	Highest	Lowest	Average
Maximum reported	$1,000,000	$25	$43,742
Minimum reported	$50,000	$20	$6,970
Best estimate reported	$200,000	$25	$20,957

Question #12: Describe briefly if and how geologic information from NBMG influences the quality of your decisions.

The best way to summarize the user responses about quality would be: "Unbiased, scientifically outstanding and large basis of organized information that puts local geology in the larger areal context and improves quality of decisions."

- The NBMG information is the best available and is scientifically credible.
- Most is peer reviewed which is important for the scientific credibility.
- In many cases it is the first reference and place to go for mineral exploration decisions.
- Quantity of available data related to quality of my work; NBMG has lots of it.
- Unquestionable professional and technical quality of NBMG scientists.
- It contributes to making more informed decisions.
- NBMG data support or substantiate the client's data.
- Studies of ore deposition to provide a framework for our evaluation of individual exploration properties.
- Often NBMG data are only data available.
- Without them we wouldn't do any business in Nevada.
- More information = more knowledge = more power = better decisions.
- Information from Nevada is very important in understanding the geothermal resources of Colorado.
- Allows for better quick assessments of likely groundwater conditions and permeability pathways and/or barriers.
- Information is mandatory for decision making!
- The information provided by NBMG influences our engineering recommendations.
- Information allows correlation and projection of geology from the regional scale to the local exploration project scale.
- Excellent, peer-reviewed products of NBMG provide reliable information.

Question #13: Describe briefly if and how the reference to NBMG as source of geologic information influences the credibility of your work in the view of your audience.

The overall user assessment is that the scientific reputation of NBMG, the regional extent of NBMG research, and their independence raises credibility of decisions when cited.

- The quality of the NBMG's scientists, research, and publications are highly respected throughout the geologic community. As such, the credibility of the information gained from them is beyond reproach.
- NBMG information is the most credible in nearly every case.
- The reference of the NBMG gives a high degree of independent confirmation.
- Very few entities can claim equal expertise in Basin and Range geology/geophysics/geochemistry.
- Having an independent source helps establish our credibility.
- We get good acknowledgement and praise for using and quoting the information from NBMG.
- Comparison of geothermal resources in Colorado to those in Nevada is very important in establishing the credibility of Colorado's geothermal resources.
- I equate NBMG information to the soils information from the NRCS—I would be helpless without it—it is fundamental information critical to any work in Nevada.
- It provides an unbiased reference point to recommendations made by our company. It provides validation to models for use in regulatory requirements and applications.
- Reference to NBMG is regarded seriously and is important when engaging consulting companies, reporting to regulatory agencies, or when providing public presentations.

Question #14: Give an example, if you can, of how the quality of your decision is influenced if geologic information is not available from any source.

Here we asked a previous question on quality in a different way to assess the consequences of not having geologic information. As the responses indicate, they could be serious to disastrous.

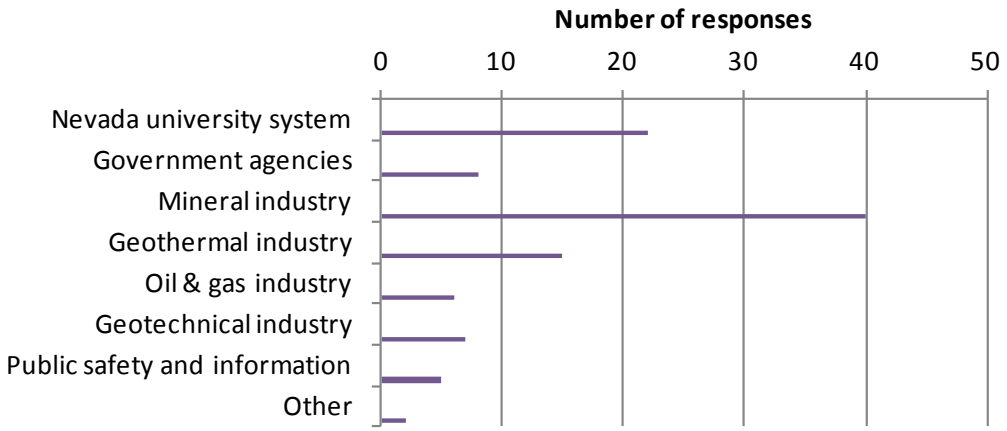
- Without geologic information, decisions become just "best guesses"!
- If data are unavailable, there is either a cost in obtaining it, or a cost due to increased risk in resource analysis without it.
- Loss of credibility.
- I recently constructed a groundwater flow model in which the calculations depended significantly on the depth of the aquifer. Without a geologic map of the area, which contained a cross section, I would not have been able to estimate the aquifer depth, and the model results would have been based on a guess. The credibility of the model was increased because I had a good estimate of the formation depth.
- In the absence of external unbiased research publications, we are left to review only the findings of a developer's hired consultant.
- Earthquake, flood, wildfire, landslide, expansive soils, etc. are all natural hazards faced in the state. The information is essential to the state in making a decision on how to use the nominal amount of funding allocated to hazard mitigation purposes.

Question #15. In your view, how would you rate the current value of NBMG's research contributions to various entities? Use number 1 for highest, 2 for next lower, etc.

In order to assess how qualitatively valuable the NBMG research is to various entities in the state, users were asked to assign ratings, starting with #1 for the highest value, from the point of view of the entity listed. The results of the top three ratings are presented in the following three graphs.

Survey respondents consider that the top rating (#1) for the NBMG research should be for the mineral industry, followed by the Nevada university system and the geothermal industry; other entities follow **(fig. 38)**. The second highest rating (#2) for the NBMG research should be for the geothermal industry, followed by the mineral industry and the oil and gas industry **(fig. 39)**. From the third highest rating (#3) on down the differences between entities become less pronounced, although government agencies, oil and gas industry and the Nevada university system are mentioned more frequently than others **(fig. 40).** Data on the lower ratings are collected but not presented here.

Figure 38: NBMG research - Value rating 1 vs. entities



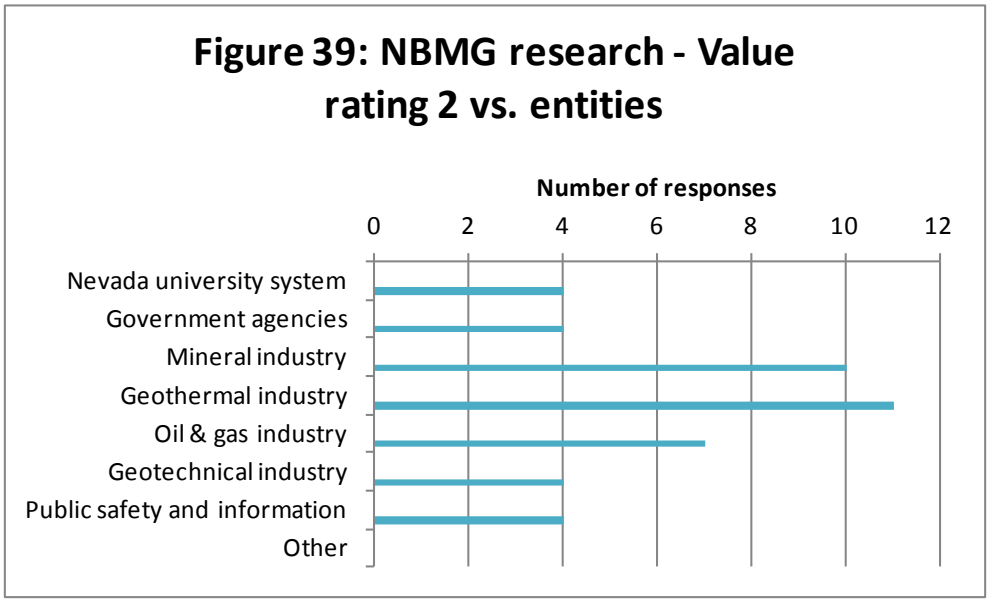


Figure 39: NBMG research - Value rating 2 vs. entities

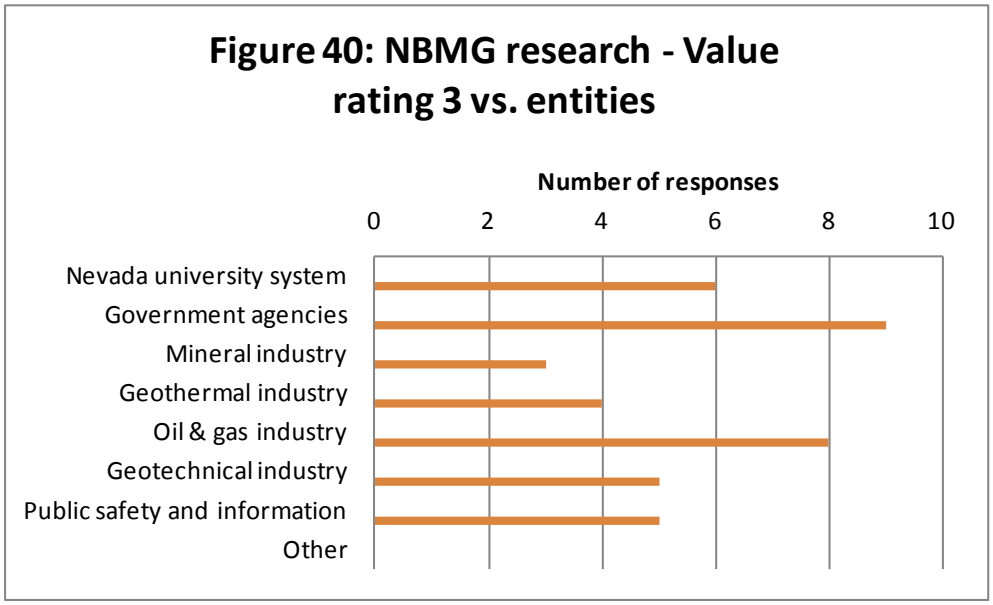


Figure 40: NBMG research - Value rating 3 vs. entities

Question #16: In your view, which specialized areas should receive prioritized attention of NBMG? (Use number 1 for top priority, 2 for the next lower, etc.)

Respondents assigned the priority rating #1 most frequently to research, 1:24,000-scale maps and collecting and curating, especially to digitization of existing maps and databases **(fig. 41)**. In the assignment of priority #2 the response is less differentiating among specialized areas but continues to favor mapping, collect/curate, digitization and research **(fig. 42)**. Finally, the priority rating #3 is skewed in favor of the areas collect/curate and digitize **(fig. 43)**.

Figure 41: Priority rating 1 by specialized area

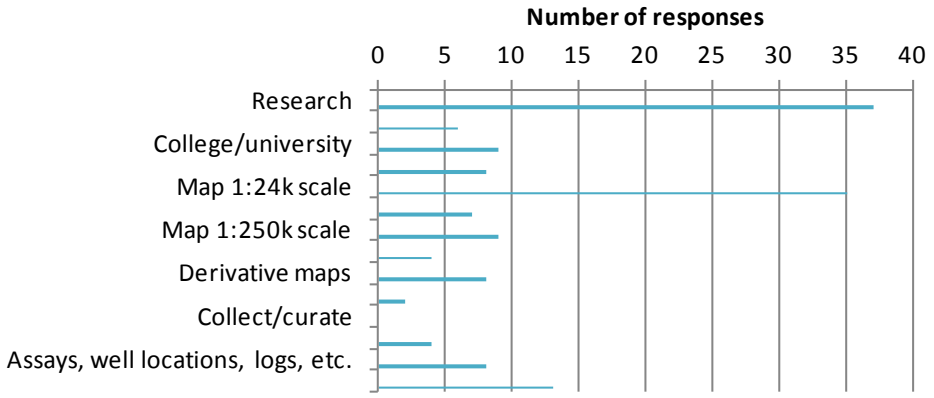


Figure 42: Priority rating 2 by specialized area

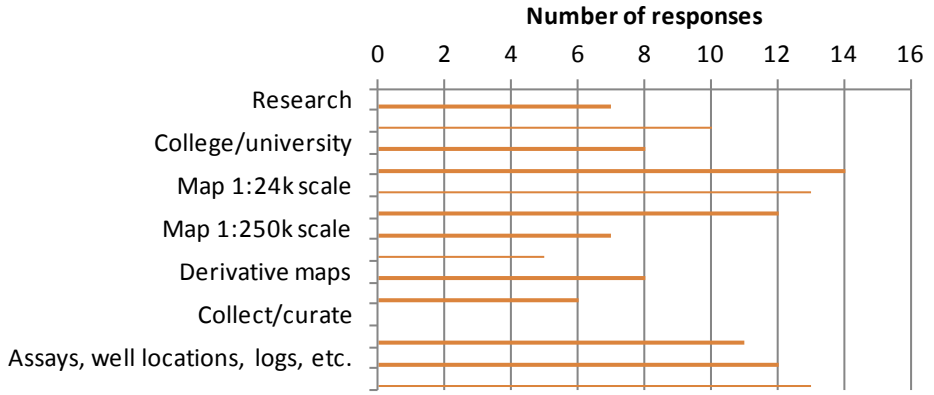
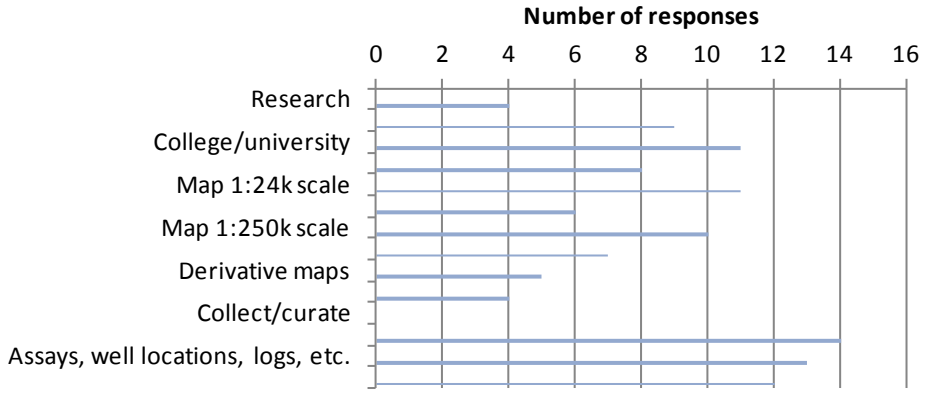


Figure 43: Priority rating 3 by specialized area



Question #17: Help us prioritize geographic areas that should be given priority for future work. List counties, urban areas, or regions of Nevada.

- Urban areas, especially outlying areas that may be developed or used in 10-20 years.
- Nye, White Pine, Elko, Humboldt, Pershing Washoe, Esmeralda, Mineral and Storey counties.
- Battle Mountain-Eureka trend of gold, copper, Pequop Mountains area – the next gold trend?
- Old mining districts and current exploration areas.
- Humboldt, Pershing and White Pine counties.
- Regions surrounding the Black Rock Desert.
- Counties of interest-Elko, White Pine, Eureka, Lander, Humboldt.
- Lyon, Mineral, Douglas, Carson City, Washoe counties.
- Dayton area, lower Comstock in general.
- Redo the state map.
- Statewide need to enhance and update our mapping of Tertiary volcanic units.
- Cortez district.
- Mesquite, Laughlin, Boulder City.
- Walker Lane.
- Northwest and east-central Nevada.
- Carbonate shelf of eastern Nevada; NNW and SSE projections of Carlin Trend.
- Blind geothermal systems in the Great Basin and N. NV.
- Update geologic map of Nevada; current map was published 1978.
- Detailed geologic maps at 1:24K that encompass areas of known regional high-heat flow such as the remaining unmapped Hot Springs Mountains and Stillwater Range.
- All areas surrounding Southern Nevada Water Authority (SNWA) water rights applications not currently being acted upon.
- Strengthen graduate teaching, integration with Mackay and training of geologists, geophysicists and engineers for the mining, geothermal and oil industries.

Question #18: Beyond NBMG's available products and services, what would you like NBMG to do in the future? (Examples would be types of studies, publications, training courses, or databases to be added.)

Although many of the suggestions are addressed in some form by NBMG, they indicate that users expect added emphasis on them. Suggestions include activities that take place with low visibility, such as collect/curate samples and data, and mineralogical-geochemical analyses. Others emphasize short courses for professionals and professional registrations.

- Focus on compiling geologic information digitally and create interactive maps that can be used on the Internet.
- Provide quality analytical services, including X-ray diffraction and QEMSCAN-SEM analysis for ore characterization and mineral identification.
- All other entities have strongly reduced student involvement. NBMG could use students more effectively.
- Geomorphic modification (for the restoration of streams for habitat) is the largest growing component of the hydrology division of GSA. NBMG should get involved.
- Public training, especially helping the layman understand more about mining.
- Geologic quadrangle maps.
- Additional research on geohazards. Seismic studies both hazard & risk based.
- Training courses.
- MSHA classes and instructor training.
- Consider offering gold exploration short courses for the mineral companies. This could be a source of income for the NBMG.
- Promote the creation of a Professional Geologist (PG) or Registered Geologist (RG) certification in Nevada.

Question #19: In your judgment, how much would student participation in NBMG research/ field studies reduce the training requirements when they enter the jobs market after graduation?

Student participation in NBMG research/field studies is believed to significantly/moderately reduce the training requirements when they enter the jobs market after graduation **(fig. 44)**. This indicates cost savings to employers and a better career start for graduates. Studies elsewhere have shown that total life-time earnings depend on starting salaries. Student participation in research is often a requirement in some European countries.

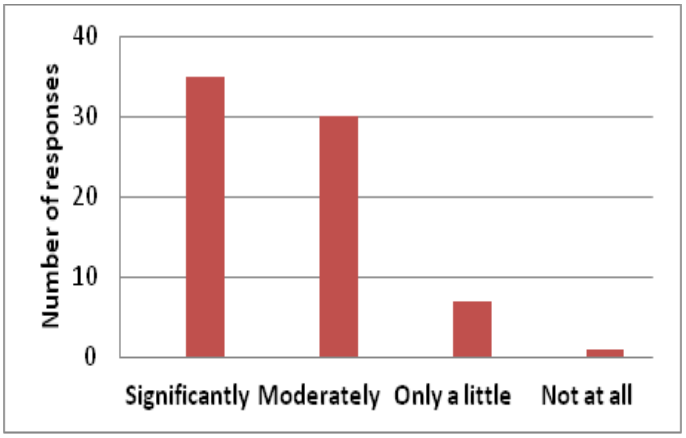
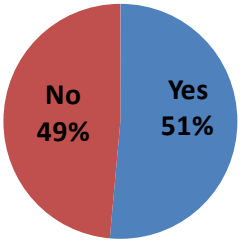


Figure 44: How much would student participation in NBMG research/field studies reduce the training requirement?

Question #20: Do you believe NBMG should change its name to the Nevada Geological Survey? Please provide comments on the possible name change.

The opinion on a name change is evenly divided **(fig. 45)**. Those who favor a name change believe that it would be more reflective of the broad mission, and consistent with the national trend. Those who favor the current name believe that retaining the word "mines" is important because Nevada is a mining state. The detailed comments reflect these feelings. A review of names of similar institutions from other states, discussed later in the report, also remains inconclusive.

Figure 45: Should NBMG become Nevada Geological Survey (n=70)



- The state and UNR have shown over the last 10 years that having "mines" in the title is a drawback. Plus, a "State Geological Survey" is a more understandable and theoretically a broader concept for the state policymakers and legislators.
- NBMG would alienate its friends in the mining industry and would further deviate from its main duties as defined by its enabling legislation if it removed the "Mines" from its name.
- Not being funded by state, so why "state" in name?
- The name "Nevada Geological Survey" is more encompassing than NBMG.
- Public views NBMG as a tool of mining industry,(so change will be better).
- (No, because)"mines" are basic to Nevada prosperity past and present.
- Public perception of mining is negative. Name change would mitigate that perception.
- Mining is important to Nevada. It should be reflected in the agency's name.
- The mission is broader than mining so the name should be similarly broad and NGS would be appropriate.
- No, because Nevada is a gold and silver state and explorationists are the main users of the NBMG.
- I feel that the name change better conveys the range of services provided by the NBMG.
- It is a waste of taxpayer dollars to change the name.

7. Assessing the benefits

Benefits of geologic research can be assessed qualitatively as well as quantitatively. The user survey has provided us with some input on both these aspects, details of which are presented in the previous section. Users have highlighted the qualitative benefits they derive from NBMG research in the following ways:

- NBMG's research is crucial in areas as diverse as finding, developing and producing minerals, planning for and mitigating natural hazards, conduct environmental planning and remediation, urban planning, engineering applications, tourism, and research and teaching.
- Most users have testified that their work depends on geologic information from NBMG to various degrees, and saves them substantial amounts of time and money.
- Users believe that using NBMG's research increases the quality and lends credibility to their work. Many respondents have testified that without the geologic maps, data and reports from NBMG, they simply would not be able to work.

The impacts of the qualitative benefits of geologic information are mentioned first because, although often unnoticed and frequently dismissed because they cannot be measured in monetary terms, they are, in some ways, more pervasive and long lasting. However, monetary benefits of geologic information can be assessed and are equally impressive.

The monetary benefits of geologic information, as presented in the user survey, indicate the following:

- Users of detailed geologic maps in Nevada, on average, would willingly pay $6,414 per map, although individual users reported a range from $15 to $50,000 per map.
- The value of all geological information–maps, publications, data sets, access to samples and assays etc.–on average was reported to be $11,574 per a typical project. The range of values reported was from $20 to $1 million.

In comparison to Nevada, users of geologic maps in Kentucky reported in a previous study that they would on average pay $342 per map.

We discuss below what these numbers translate to when applied to the actual number of maps sold. A similar interpretation for all geologic information, unfortunately, eludes a simple extrapolation, even though it makes intuitive sense.

A total of 121 new 1:24,000-scale geologic maps have been published since 1994 (including the year 1994). In addition, about 136 of the same scale previously published geologic maps were published in digitized form. The mapping program is jointly funded from state and federal money. As figure 16, earlier in the report, indicates, the State of Nevada provided a total of $3.35 million and the federal contributions totaled $2.65 million from 1994 through 2010. The total STATEMAP expenditures amounted to about $6.0 million. Every state dollar spent on mapping by the State of Nevada leveraged on average about 80 cents of federal money. Out-of-state funds coming to Nevada have an economic multiplier effect of about 2.25. With the multiplier effect, the actual benefits of the federal funding for mapping for the state, therefore, would be the equivalent of about $6 million.

In 2010 dollars the STATEMAP expenses would be about $7 million. The average mapping expenditure for the 121 new maps amounted to about $90,000. NBMG faculty currently estimates mapping costs at about $200,000 per map. Digitization of existing maps is estimated to cost an average of about $6,000 per map. The digitization of the 136 existing maps would be cost equivalent of 9 to 10 new geologic maps. Therefore, the total number of new map equivalents would have been about 87 to 88.

As illustrated in appendix D, the benefits of a public good are cumulative. The **tables 6 and 7** indicate that in the Jan. 2009 – Apr. 2012 period alone over 15,000 NBMG publications were sold in addition to 9,000 USGS maps or a total of 25,000. **Figure 46** shows a steady sales record over the years for the last 15 years. Almost $2 million worth of publication sales have been recorded in this period.

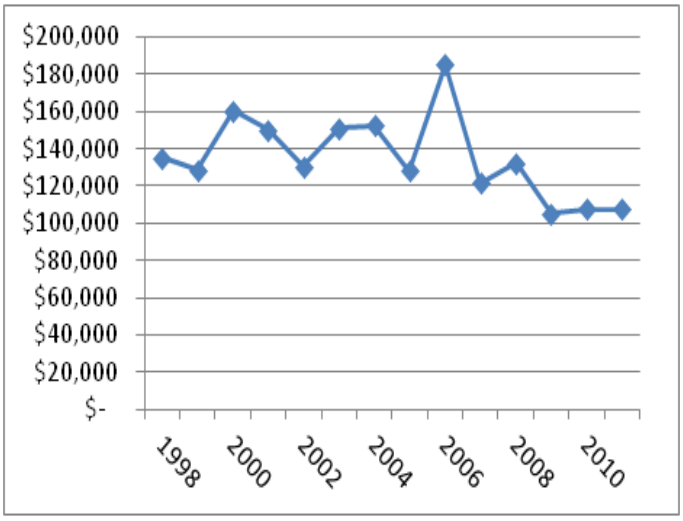


Figure 46: Revenues generated by NBMG through sales of maps and publications.

Tables 6 and 7 show the sales data for NBMG and USGS publications and maps respectively for the January 2009 to April 2012 period.

Table 6: NBMG publications sold, Jan. 2009-Apr. 2012

Dept. Name	Qty Sold	Ext Price
Special Publications	4,525	58,714.63
Bulletins	2,262	39,569.70
Maps	1,475	16,213.50
Open-File Reports	297	9,374.75
Reports	206	2,055.70
Urban Maps	211	1,238.00
Postcards and Notecards	5,394	1,054.55
Field Studies Maps	74	440
Educational Series	840	417.35
Pamphlets (Major Mines)	94	251
Mineral Industry	13	143
Historical Maps	6	115
Lists	7	39.2
	15,404	**129,626.38**

Table 7: USGS topo maps sold by NBMG, Jan. 2009-Apr. 2012

Dept. Name	Qty Sold	Ext Price
NV - 7.5 minute (1:24,000)	6,359	49,862.80
30 x 60 minute (1:100,000)	1,599	14,222.30
CA - 7.5 minute (1:24,000)	733	5,712.00
15 minute (1:62,500)	312	2,763.20
500K (1:500,000)	126	1,942.70
1 x 2 degree (1:250,000)	180	1,515.50
30 x 60 minute (100K) rolled	3	27.00
NV - 7.5 minute orthophoto	1	8.00
	9,313	**76,053.50**

The survey of users of NBMG's products and resources indicates an average of $6,414 expected "willingness to pay" per map in Nevada. Applying the average estimated map value of $6,414 per map reported by Nevada users, the total value of maps sold in the 40-month period would be about $13 million. Using the cost of mapping of $90,000 per 7.5' quadrangle, the ratio of the value of benefits to the cost of mapping would be 147:1. If the higher mapping cost estimates by some of the NBMG faculty members of $200,000 for some maps is used, the ratio of the benefits to costs calculates to be about 66:1.

There could be two reasons for the benefit/cost ratio in Nevada to be so much higher than in Illinois, Kentucky or in Spain. First, the Illinois study was limited to two counties, both largely non-mining areas, and the benefits were discounted by 75% because of retrospective uncertainties. Second, Kentucky primarily produces coal, a relatively low unit-value mineral. In comparison, Nevada not only is the most important minerals-producing state in the country but also one of the largest producers of gold and silver in the world. The users sense a value premium for geologic information in Nevada as a result of the high-value mining in Nevada. Furthermore, geologic information has other high-value uses in Nevada. For example: Nevada is more prone to earthquakes than most other states with correspondingly higher damage potential, which would be a reason to value geologic information

more than others do elsewhere. Nevada is also a leader in the utilization of geothermal energy. A benefit of increased use of geothermal energy, though unquantifiable at this time, accrues to the entire world in the long run because of geothermal's contribution towards mitigation of climate change. The more important significance of the estimated benefits is in the recognition that users consider benefits to exceed cost quite substantially.

A note of caution: Survey results from another states, such as Kentucky, should be treated with caution. Conditions in Nevada are not the same as elsewhere. Also, one has to be cognizant of possible biases emanating from the subjects' desire to continue to benefit from public-funded research. On the other hand, users are also aware that an inflated value statement can evoke the response that in view of the high value the user could be expected to pay more for the maps. Therefore, it is believed that the survey results do provide useful estimates of value. Thus, the benefits reported in those studies can be trusted for qualitative and rational reasons, while using caution in the reported numbers and comparisons between states. However, it is not difficult to see that even if the actual benefits were to be a fraction of the estimated ones, they are high and a valuable indicator for future policy-making and funding.

8. A look to the future of NBMG at UNR

There are important commonalities in the missions of the College of Science at UNR and the NBMG, and many potential synergies between NBMG and the other geoscience units. The most important common factor is the commitment to geologic research. NBMG has a strong record of research, as evidenced by the number of peer-reviewed publications per scientist, amounts of external research grants obtained annually, and the high quality of research reflected in the number of citations. The user survey also assigns research the highest priority. In terms of these academic standards alone, NBMG has been the strongest geoscience unit at UNR in recent years. In part it is the result of relatively minor obligations in teaching. On the other hand, NBMG scientists conduct geologic mapping that consumes much time but offers fewer opportunities to publish in peer-reviewed journals.

Traditional areas of NBMG activity involve mineral resources, earthquake and other hazards, geothermal energy, and environmental concerns. These aspects are also reinforced by the user survey as priorities. Increasingly, NBMG research products and data have been digitized and made available online. The user survey supports the increased digitization as the need of the future. The response frequency to the survey from smaller companies and individual consulting geologists indicates that NBMG products and services are especially desired by the financially weaker sector of companies. Qualitatively, as well as in monetary terms, the benefits of NBMG's research and services are rated highly in the user survey. Recent funding cuts have affected NBMG's ability to continue to keep up with its past record.

The service aspect of the NBMG mandate requires applied and derivative research to mitigate hazards, assess the quantitative, qualitative and economic potential of resources, and to use geologic knowledge to avoid/mitigate damages/risks to the environment. Human actions that may potentially be harmful to life, property or the environment may be modified if geologic knowledge is used adequately and in a timely fashion. Several aspects of the research and service activities of NBMG have been shown to benefit the state and UNR in this report. Users of NBMG products and services have confirmed how the quality and credibility of their work are positively influenced by NBMG's research. In monetary terms, users have reported their value assessment by the high prices they would have to pay for geologic information if it were not available from NBMG.

The College of Science and other geoscience units (DGSE and NSL) also embrace outreach. However, the more significant mission of the College and DGSE, after research, is teaching. The NBMG charter involves teaching more in the context of the general population of Nevada than the student population, whereas the College's primary focus is on educating students. As a result, the charters of NBMG and UNR's College of Science are complementary, and together they

expand their outreach to a larger population. The College has pledged to integrate NBMG with the other geoscience units and to a greater degree with the teaching mission of UNR, while preserving the core mission of NBMG

Although NBMG faculty have collectively taught various courses in the past and some have advised numerous graduate students, various programmatic and personnel reasons have prevented NBMG from greater participation in teaching in the past. These include the relatively small number of state-funded FTE at NBMG to cover the many needs of a large, rapidly growing state with abundant natural resources, urban-growth issues, widespread earthquake and flood hazards, and groundwater issues. However, NBMG faculty clearly recognize the needs and benefits of focusing more effort on educating undergraduate and graduate students and therefore embrace the change to become more intimately involved in the teaching mission. There are several teaching niches that can be filled or embellished by NBMG faculty, including summer field camp (the DGSE capstone course), structural geology, tectonics, economic geology, geodesy, geology of Nevada courses, geomorphology, and geothermal exploration.

Because NBMG faculty are experts in the geology of Nevada, more teaching by them will greatly benefit both undergraduate and graduate students and allow these students to contribute more directly and more rapidly to understanding Nevada's resources and hazards if employed in the region following graduation. Conversely, students will also increase their market value and lifelong earnings potential, if they receive hands-on field training that NBMG scientists can impart. Ultimately, the state should reap economic benefits from this arrangement. Not surprisingly, the user survey indicates that increased student involvement in NBMG research is beneficial from the point of view of their future employers. In addition, student involvement in NBMG field research could be increased with the greater commitment to teaching by NBMG faculty.

Although greater involvement of NBMG in the teaching mission has enormous benefits, it is important to note that the clienteles of the College and NBMG differ somewhat. The NBMG charter is explicitly statewide. As an institution born out of and tasked with the statewide study of geology and providing services, it needs to be examined to what extent their legal mandate can or should be altered and the ramifications of such changes. UNR is also a statewide institution but with a different target audience compared to NBMG. Although, both entities–UNR and NBMG–produce geologic knowledge, from an economic perspective there is a difference between what the NBMG and the UNR have to offer. Taxpayer money supports NBMG as well as UNR; however whereas the NBMG customers can obtain NBMG products at little or no cost, UNR students and their parents pay a higher price in the form of tuition.

Another difference between the customers of the two entities is the way in which they benefit. Whereas college education is known to add to lifelong earnings, NBMG customers benefit from expenses they do not have to incur directly (avoided costs). The indirectness in which they benefit also influences their "willingness to pay" for what they receive. The more ideally suited a product is to be called a public good, the lower the "willingness to pay" on the part of the customer. On the continuum between private and public goods, NBMG products and services stand closer to the latter category, because their benefits are indirect and nearly free, and yet desirable from the societal point of view.

The above discussion shows that it makes economic and social sense to preserve the capabilities of NBMG while also integrating it more heavily with the teaching mission. The commonalities and differences make it necessary to develop ways in which the greater integration of NBMG with the other geoscience units can be accomplished successfully. Programs can be developed to harness expertise from NBMG and the other geoscience departments of the College to make a difference in the lives of Nevadans and contribute to its economy.

An example of how it can be accomplished is offered by one NBMG faculty's ideas on earthquake research. According to this vision, NBMG geologists and geodesists will work with Nevada Seismological Laboratory in developing state-of-the-art seismic hazard characterization to reduce the losses from earthquakes. The awareness and motivation for mitigation for a hazard that occurs relatively infrequently but has a high consequence, requires a constant, united-front, and promotion of that hazard to society. This joint team of earthquake scientists will continue to put their scientific information into an understandable format for the general public that will influence them to take sensible precautions for earthquakes. This will include new forms of media, such as computer animations. It is also notable that there are a high percentage of earthquakes in Nevada that have foreshocks and thus, the potential exists for the earthquake team to identify precursory earthquake activity and forecast earthquakes. This would be an important societal tool. The earthquake team is poised to document future earthquakes in detail, as it did in 2008 with the magnitude 6.0 Wells, Nevada earthquake. Earthquake events are the ultimate laboratory where geologic, seismologic, and engineering ideas are tested, and a thorough documentation of them allows us to be more effective in promoting and achieving an earthquake-resilient society. A complete scientific picture of earthquakes, including seismology, geology, and geodesy will lead to the maximum benefit for society by reducing our losses to these events.

Collaborations such as this will require that consideration be given to reconciling the academic with the service aspects. The service components at the core of the NBMG mission, including time-intensive geologic mapping and resource assessments, do not necessarily result in peer reviewed papers and therefore expose NBMG faculty to career disadvantages within the academic environment. Therefore, successful integration will mean not only that the core missions of NBMG and the other geoscience units are preserved but conditions are created to ensure that the personnel who carry out the integration by adapting to the new joint mission, including an increased commitment to classroom teaching, can do so without enduring long term negative implications. This is essential in order to make the change sustainable.

In conversations with NBMG scientists, some expressed the possibility of combining the requirements of the academic and public environments by selecting mapping projects that also offer the opportunity to conduct basic geologic research resulting in peer-reviewed papers. In fact, most currently practice this approach on some projects. However, such an approach risks excluding from the mapping program some areas of importance to the economy and public well-being. To ensure that this does not happen, external funding is essential. The NBMG faculty has demonstrated their ability to attract external funds provided the required matching funds are available. The matching funds must come from the state as part of the UNR allocations.

The College and the NBMG will need to work out performance evaluation criteria to ensure that NBMG scientists retain interest in mapping and service work. The current practice of working with "role statements" could serve as the basis on which to develop more concrete criteria. Some organizations in other states in similar situations have managed to balance the two sides by creating parallel but equal paths to college careers. The process of integration need not be a zero sum game provided adequate financial support and consideration for the NBMG's value to the state are given.

A useful budgetary mechanism to facilitate the scientific integration is to provide a modicum of autonomy to the NBMG by way of creating (reinstating?) a line item for NBMG's annual outlays that would allow greater flexibility in the allocation of limited state funds in the service of the mission of the NBMG. Other state surveys, such as Illinois, New Mexico, Oklahoma, and Texas, within universities have this line item, based on the recognition that it is difficult to run a statewide program without it.

NBMG has provided estimates of state-funded FTE personnel needed to fulfill the required

aspects of the charter (Open-File Report 10-14, p. 28). The current numbers are inadequate. NBMG faculty members have testified that they have been forced to reject external funding for a lack of FTE faculty and matching funds. Practical questions such as the funding of mapping activity will need innovative approaches. Most of the state is still not mapped at effective scales, and many existing maps are dated and in need of revision. To succeed in the long term, however, the matching-fund bottleneck has to be dealt with.

A question has been raised as to whether the integration of geoscience units at UNR can be achieved while at the same time retaining the core mission of NBMG and its dynamic image among its clientele. In this context, it has been discussed whether a name change from Nevada Bureau of Mines and Geology to Nevada Geological Survey would be beneficial towards that objective. Studies on how state surveys fare when situated in state agencies versus within universities are not available. However, observations in other states indicate that state geological surveys as research agencies are better suited to be university based than within state agencies because, unlike NBMG, most state agencies have administrative, regulatory or service functions, but relatively little in research functions.

When organizations choose a name for themselves they consider the nature of their business, the clientele and the market precedence.

Nature of business: Commercial organizations have a product or service to sell for profit. They are funded in the open market either by individuals, shareholders, or bank loans. Charitable groups have boards of trustees and usually depend on donations. Government agencies most commonly have regulatory functions and report to a political entity. Government agencies with a research and development mandate, such as the national laboratories, are often autonomous institutions with some public funding. Some of them are also involved in higher level education. Universities and colleges, with teaching and research as their mandates, depend on a combination of government funding, grants from public and private sources, and tuitions charged to students. The NBMG, mandated by state law to conduct research and provide services, occupies a unique position in that it is situated within the University of Nevada but was not mandated to teach in the way the universities are. The NBMG traditionally was state funded. Research grants augment the funding. The NBMG has no provisions to charge tuitions or to offer degrees.

Clientele: As a non-profit state agency, but without any regulatory function, the NBMG straddles the educational and commercial worlds because some of its products–geologic knowledge and its interpretation–benefit profit-making industries and thus the entire economy. The NBMG also supports formal education within UNR and less formal education of the public. Service and outreach are major aspects of NBMG and its counterparts in other states. The clientele of the NBMG is largely, but not entirely, outside the university and needs to be able to identify NBMG as a dynamic and capable institution that they can trust.

Precedence: Considering the nature of NBMG's business and its clientele, outside and within the university, it seems appropriate to allow its uniqueness to be expressed in its name. A review of the state geological surveys and agencies that function like them, but are not necessarily named as they are, is presented in **figure 47**. It shows that over two-thirds of them begin their names with the name of their state. An almost equal number of them call themselves "Geological Survey." About one-third are situated within a university, although it is not known exactly how many of them have a budget line item in the university. Twenty-eight state geological surveys still remain inside a state agency, and eighteen are in universities. Some of those within state agencies have regulatory functions. In four cases it is not identifiable from their websites whether they are part of a university or a state agency.

Considering that the NBMG retains a strong service and community outreach function and is the premium entity charged with conducting

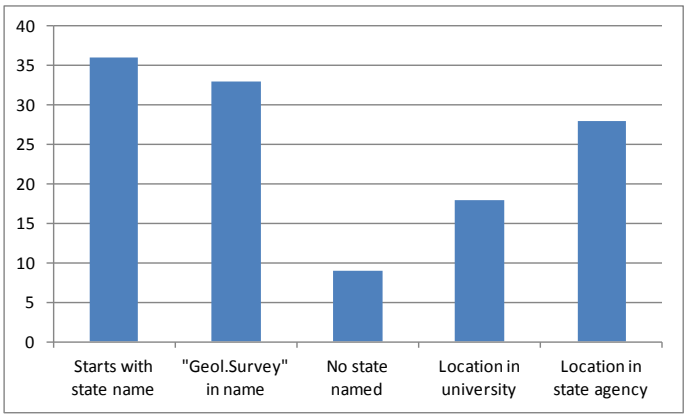


Figure 47: Characteristics of names of state geological surveys

statewide geologic research for the safety and economic well-being of Nevada, a name change along the trend reflected in figure 47 seems justified even though the survey of the users of NBMG research products is inconclusive on the issue. The name Nevada Geological Survey or a similar construct would appropriately reflect its functions and do justice to its dynamic nature. Some have expressed concern about the industry's response to omission of the word "mining" from the name. Others estimate that the industry, with decades of association, knows the NBMG and is unlikely to respond negatively.

Many state geological surveys, including the NBMG, have advisory boards consisting of individuals from the industry and governmental and non-governmental institutions. The purpose of having a board is twofold; on the one hand the board acts as an independent body to reassure the public that their money is being used wisely and on the other hand the board also acts as the sounding board and an independent spokesman for the geological survey. At the same time, the board should not be perceived as a parallel authority to the University's administrative structure but as a supportive one.

Board membership, ideally no more than ten, ought to be representative of the target groups served by the geological survey. In Nevada, these would include the mining industry, the geothermal industry, and city governments in addition to other relevant state and local agencies. The board's involvement has to be an active one. For example, it is useful to invite board members to make regular presentations on campus in addition to presenting the Survey's own research to them. The venues for board meetings have to change from time to time. Twice yearly meetings help retain active interest without making them routine. Education thus needs to be taken to corporate board rooms and city administrations.

9. Conclusions

The objectives of the study were to assess the value of the work of the Nevada Bureau of Mines and Geology (NBMG) to the State of Nevada and to the University of Nevada, Reno, to find ways to facilitate its integration in the College of Science at the University of Nevada, Reno, and to discuss their common path into the future.

After an exhaustive study of NBMG's recent past record, a questionnaire campaign was conducted to assess who uses the NBMG's products, how they are used, and how the users value them. In addition, the past publications and product sales records were studied. User response to the survey indicates that users assign high monetary and qualitative value to the geologic information they receive from the NBMG. In monetary terms, users have indicated that the benefits far exceed the NBMG budget. In qualitative terms, the user benefits are expressed as a clear asset for the improvements in quality and credibility of work they are involved in. The benefits to the general public in the safety and security areas are only inadequately measurable in monetary terms. Benefits to industry are easier to present in monetary and qualitative terms because of their commercial impact.

For a successful integration of the NBMG and the College of Science, it is essential that adjustments are made by both entities. The primary adjustment on the part of the NBMG would be to accept a greater role in classroom teaching. The user survey also provides input

on the future research and service priorities for the NBMG. The College of Science would need to unequivocally accept the NBMG mandate of service to the public. The accommodation of the service mandate of NBMG would require the College of Science to attend to the matching funds issue, the long term career prospects of NBMG scientists, and the question of a moderate degree of autonomy to the NBMG within and under the authority of the College.

Finally, a name change for the Nevada Bureau of Mines and Geology would be justified in order to reflect its statewide mandate and to impart a more dynamic identity.

Appendix A. User survey and assessment

Benefits of Nevada Bureau of Mines and Geology (NBMG):

Geologic Research, Information, and Services

1. Which characterizes your organization best?

- Mineral-resource industry—large company (production ± exploration, e.g., metals, industrial minerals)
- Mineral-resource industry—junior company (exploration/development ± minor production, e.g., metals, industrial minerals)
- Energy-resource industry—large company (geothermal, oil and gas)
- Energy-resource industry—small company (geothermal, oil and gas)
- Water-resource industry
- Construction industry
- Transportation industry
- Tourism industry
- Real estate
- Geotechnical firm
- Independent consultant
- Public utilities company (power, water supply)
- Federal government agency
- State government agency
- County government agency
- City government
- Educational institution
- General public
- Other (specify)

2. Which activities in your organization require geologic information?

Resource exploration, development, and production

- Metals (e.g., gold, silver, copper, molybdenum, etc.)
- Industrial minerals (e.g., aggregate, limestone, barite, etc.)
- Specialty minerals (e.g., lithium, vanadium, rare earth elements)
- Geothermal energy
- Oil & gas
- Groundwater
- Other (specify)

Environmental consulting

- Pollution/contamination prevention
- Remediation/cleanup
- Environmental impact assessment
- Other (specify)

Hazard mitigation/prevention

- Earthquake
- Flood
- Landslide
- Subsidence
- Soils
- Volcanoes
- Other (specify)

Engineering applications

- Buildings and foundation problems
- Roads/highways
- Railroad
- Pipelines
- Utilities
- Dams, retaining ponds, dikes, canals
- Other (specify)

City planning

- Zoning decisions
- Landscape design and planning
- Building codes
- Other

Regional planning

- Waste disposal sites
- Industrial sites
- Transportation
- Utilities
- Other

Property valuation

- Tax estimation
- Banking
- Land acquisitions
- Hazard identification

Research and education

- Research (basic or applied)
- Education (K-12)
- Education (college or university)

General public

- Rock-hounding and collecting
- Weekend prospecting
- Maps for outdoor recreation (e.g., hiking, hunting, fishing, orienteering, etc.)
- Field trips (e.g., general geology, Earth Science Week, etc.)

3. What percentage of your work in the past 5 years depended on geologic information and research?

- By number of projects _____(%)
- By dollar value of a typical project _____(%)
- By time input _____(%)

4. In what form do you use geologic information?

- Geologic maps (circle one or both)
  - Digital
  - Paper copies
- Publications (circle one or both)
  - Digital
  - Paper copies
- General databases (circle one or both)
  - Digital
  - Paper copies
- GIS databases
- Air photos
- Cuttings and drill core samples, hand samples
- Drill logs
- Assays

5. How does NBMG research benefit your organization or industry? Please provide specific examples. (Use separate sheet if necessary.)

_____

_____

_____

_____

6. If you use NBMG geologic maps, please provide the following information as far as possible.

A. Name a specific project(s) for which geologic maps were used.

_____

_____

_____

_____

B. Had the maps not been available from NBMG, how much would you have willingly spent to obtain the same information? (We know that this is a difficult question to answer, but please give us your best estimate.)

- Maximum $_____
- Minimum $_____
- Best estimate $_____

C. What mapping scale best serves your needs?

- 1:5,000
- 1:10,000
- 1:24,000
- 1:50,000
- 1:100,000
- Other (specify)

7. If you visit the Great Basin Science Sample and Records Library (GBSSRL is NBMG's information and publication sales office and sample repository) to get above information, how often do you visit?

- Weekly
- Monthly
- Several times a year
- Once a year
- Less frequently

8. How useful/productive are your visits to GBSSRL?

- Highly useful
- Moderately useful
- Somewhat useful
- Not useful

9. How useful is online access to digitized geological information, such as GIS data, scanned maps and reports, etc?

- Highly useful
- Moderately useful
- Somewhat useful
- Not useful

10. How do you obtain geologic information if not available from NBMG?

- Contract with the NBMG
- Contract with another organization
- Hire a consultant
- Do your own field work
- Other

11. How much would you typically spend in the above case? (Please estimate as best as you can.)

- Maximum $_____
- Minimum $_____
- Best estimate $_____

12. Describe briefly if and how geologic information from NBMG influences the quality of your decisions. (Use separate sheet if needed.)

_____
_____
_____
_____

13. Describe briefly if and how the reference to NBMG as source of geologic information influences the credibility of your work in the view of your audience. (Use separate sheet if needed.)

_____
_____
_____
_____

14. Give an example, if you can, of how the quality of your decision is influenced if geologic information is not available from any source.

_____
_____
_____
_____

15. In your view, how would you rate the current value of NBMG's research contributions to various entities? Use number 1 for highest, 2 for next lower, etc. Please circle areas that you would like to see enhanced.

a. Nevada university system (research and education)
b. Government agencies (state and federal)
c. Minerals industry
d. Geothermal industry
e. Oil and gas industry
f. Geotechnical industry
g. Public safety and information
h. Other

16. In your view, which specialized areas should receive prioritized attention of NBMG? (Use number 1 for top priority, 2 for the next lower etc.)

- Research (e.g., geologic framework studies; resource assessments; natural-hazard assessments, such as earthquakes, floods, landslides; etc.)
- Education
  - K-12 education
  - Higher education (university or college)
  - General public outreach (e.g., field trips, information on natural hazards)
- Geologic mapping (preferred scale or emphasis)
  - 1:24,000 scale (quadrangle maps)
  - 1:100,000 scale
  - 1:250,000 (revise county maps)
  - 1:500,000 (revise geologic map of Nevada)
  - Derivative maps for specific resources/ purposes
  - Other
- Collecting and curating of samples, drill core, and cuttings
- Collecting and curating data, such as assays, well locations and logs, mining district files, air photos, etc.
- Digitizing existing maps, preparing GIS databases etc.

17. Help us prioritize geographic areas that should be given priority for future work. List counties, urban areas, or regions of Nevada.

_____
_____
_____
_____

18. Beyond NBMG's available products and services, what would you like NBMG to do in the future? (Examples would be types of studies, publications, training courses, or databases to be added—use separate sheet if needed.)

_____
_____
_____
_____

19. In your judgment, how much would student participation in NBMG research/field studies reduce the training requirements when they enter the jobs market after graduation?

- Significantly
- Moderately
- Only a little
- Not at all

20. Do you believe NBMG should change its name to the Nevada Geological Survey?

- Yes
- No

Please provide comments on the possible name change:

_____
_____
_____
_____

Appendix B. Cost of power plants by source of energy

Table B-1: Conventional Baseload Power Direct Capital Costs

Resource	Capital Cost ($US1999/kW)
Geothermal	$1,150–$3,000
Hydropower[27]	$735–$4,778
Coal[28]	$1,070–$1,410
Nuclear[29]	$1,500–$4,000

Table B-2. Operating and Maintenance Cost Comparison by Baseload Power Source (U.S. cents/kWh)

Resource	O&M Cost (cents/kWh)
Geothermal	0.4–1.4
Hydropower[31]	0.7
Coal[32]	0.46
Nuclear[33]	1.9

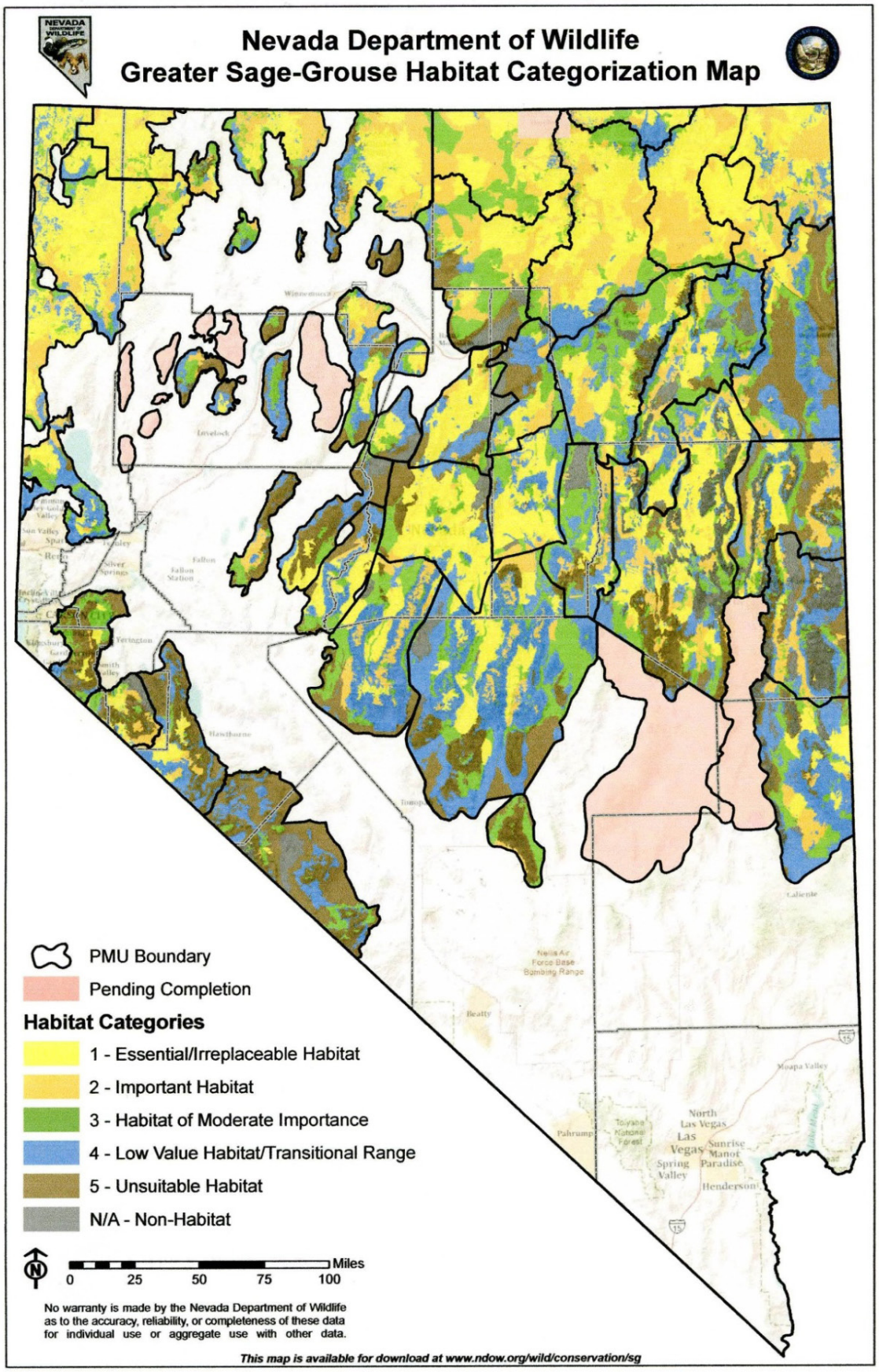
Table B-3. Levelized Cost Comparison of Baseload Power by Source

Resource	Levelized Cost (U.S. cents/kWh)
Geothermal	1.5–7.0
Hydropower	0.5–2.4
Coal	2.0–5.0
Nuclear	1.5–3.0

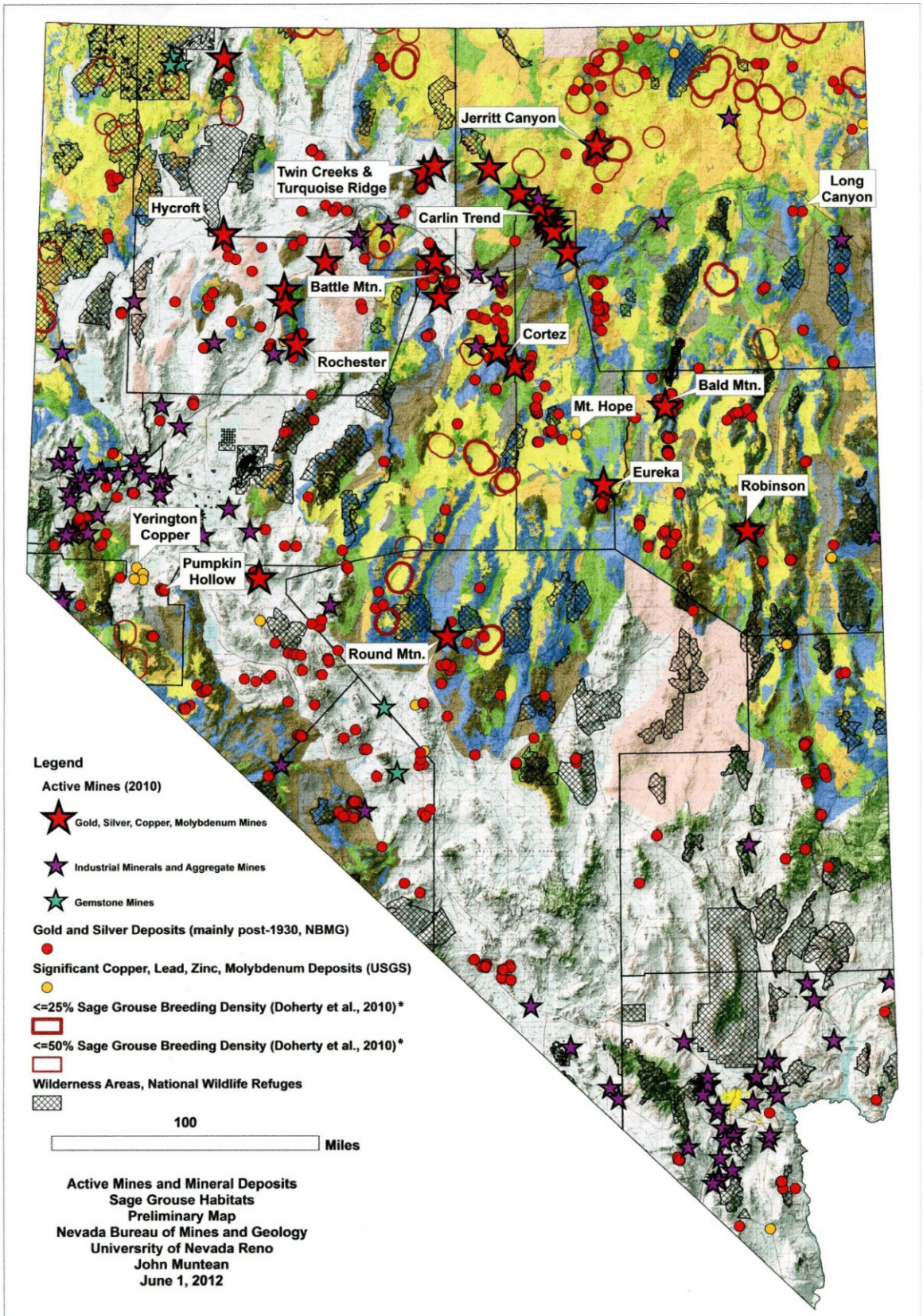
Table B-4. Employment Rates by Energy Technology

Power Source	Construction Employment (jobs/MW)	O&M Employment (jobs/MW)	Total Employment for 500 MW Capacity	Factor Increase over Natural Gas
Wind	2.6	0.3	5,635	2.3
Geothermal	4.0	1.7	27,050	11.0
Solar PV	7.1	0.1	5,370	2.2
Solar thermal	5.7	0.2	6,155	2.5
Landfill methane/digester gas	3.7	2.3	36,055	14.7
Natural gas	1.0	0.1	2,460	1.0

Appendix C-1. Sage-Grouse habitat categorization map

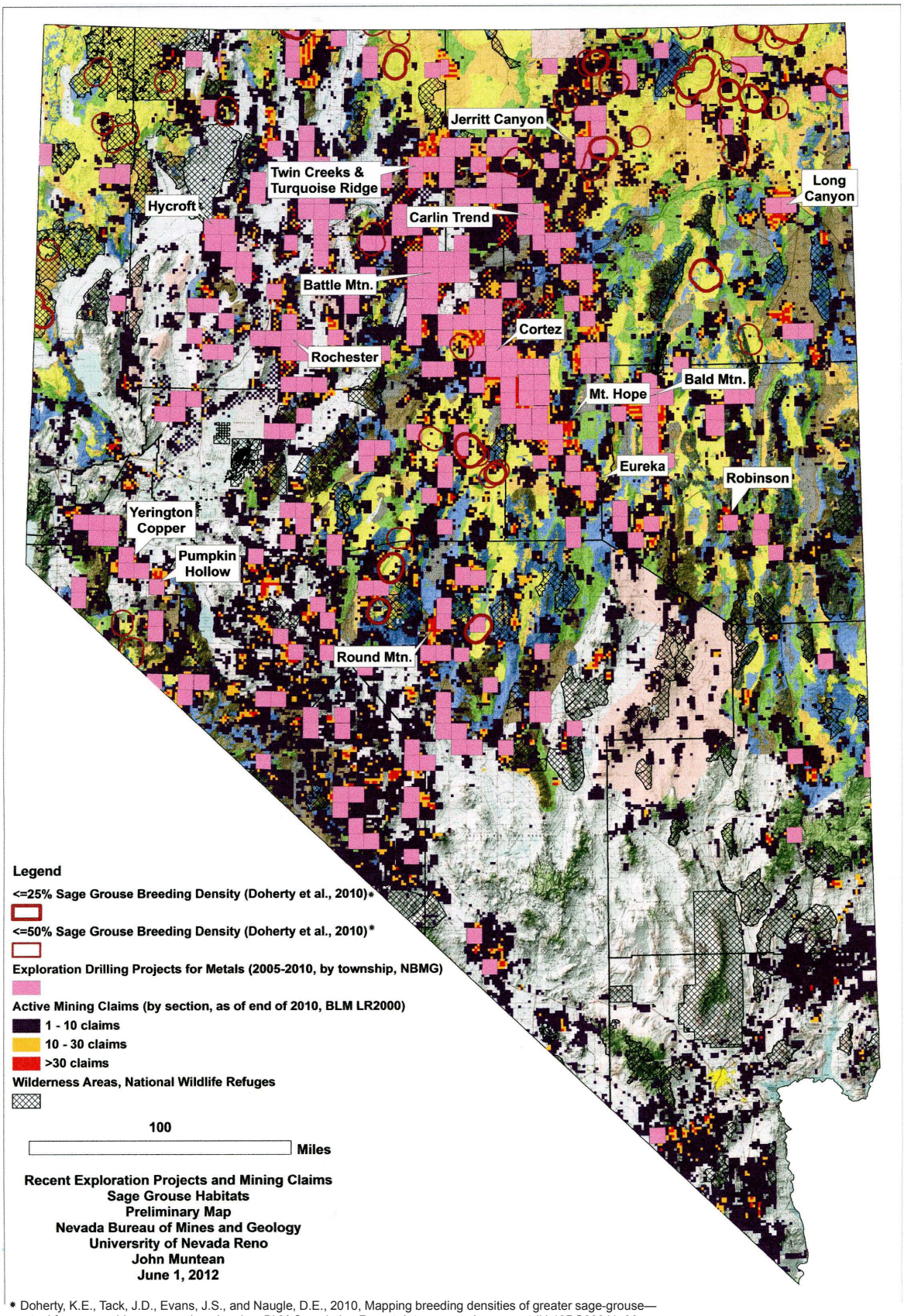


Appendix C-2. Sage-Grouse habitats and active mines and mineral deposits



* Doherty, K.E., Tack, J.D., Evans, J.S., and Naugle, D.E., 2010, Mapping breeding densities of greater sage-grouse—a tool for range-wide conservation planning: BLM Completion Report, Interagency Agreement # L10PG00911, 30 p.

Appendix C-3. Sage-Grouse habitats and recent exploration projects and mining claims



* Doherty, K.E., Tack, J.D., Evans, J.S., and Naugle, D.E., 2010, Mapping breeding densities of greater sage-grouse—a tool for range-wide conservation planning: BLM Completion Report, Interagency Agreement # L10PG00911, 30 p.

Appendix D. Public vs. private goods

To be able to differentiate between a "private good" and a "public good" we need to understand two concepts: Rival vs. Non-Rival goods and Excludable vs. Non-Excludable goods.

An apple, when eaten by me is not available to you to eat too. Either I can eat it or you can. It is called a **rival good**. I can **exclude** it from your consumption at little or no cost to me. An example of **a non-rival good** would be the national defense. It is available to everyone at the same time. Any attempt to exclude a few citizens from being protected would be very costly. National Defense is thus also **non-excludable**.

A private good is both rival and excludable. A public good is non-rival and non-excludable.

What about geologic knowledge, often though not always, presented as maps? It is non-rival because you and I can use the same map at the same time without in any way diminishing it. It is also non-excludable because you can buy it at a relatively small cost. Thus, geologic maps, presenting the results of geologic research, are a near ideal public good.

Because public goods are non-rival and non-excludable, they provide little opportunity to the investor to earn significant returns on investments. The investor in this case is the entire society, to which they provide value, as is evident from other examples such as national defense or fundamental research in sciences. Their value is difficult to measure and represent in the same way their costs are or in the same way the value of most private goods can be judged by the profits they generate. Therefore, only a long term perspective allows societies to invest in public goods. It is easy to see that geologic maps have a high social value and real economic benefits even if it is difficult to quantify those benefits in monetary terms.

Any public good faces the problem called the "free rider syndrome." At least some of the users, and possibly a significant number of them, can refuse to pay the true price that reflects its actual value, because they know that the product will be available whether they pay for its production or not. The assessment of the value of public goods must, therefore, rely on indirect but plausible methods.

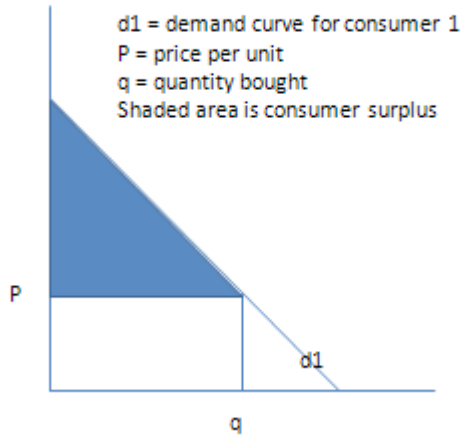
A plausible and easily understood approach to the assessment of value of public goods is to look at the "avoided cost." For example, vaccination programs save lives and eliminate or greatly reduce medical expenses to treat illnesses. Even though it is obvious that a great deal of benefits are derived from vaccinations, it is not easy to express them in monetary terms, especially when it comes to lives saved. Geologic knowledge, similarly, delivers benefits that can be more easily seen when we look at the costs that users of this knowledge avoid. Costs are avoided when a mining company is able to use maps produced by NBMG, to focus on more promising areas of mineralization without having to study the extended areas themselves. Costs are avoided by the same rationale by the geothermal industry. Costs are also avoided or minimized when earthquakes strike, if geologic information provided by NBMG is used to take mitigation steps, and plans are developed for the rescue and relief operations.

Because "public goods" are non-rival and non-excludable (unlike private goods), the benefits of "public goods" are the cumulative value of all units of that good used by the society. Their benefits, therefore, are cumulative. For instance, the cost avoided by one map user does not preclude other map users from avoiding costs as well. The benefits or value each user derives can thus be added in order to assess the total benefits to users and thus to the society.

The value to a consumer is represented by the "consumer surplus." As illustrated below, the consumer's demand curve (d1) indicates what quantity he/she will purchase at the market price P. He would be willing to pay a higher unit price for the first unit than any subsequent unit; hence the downward slope. He does not purchase more than q units because he believes that the value to him of the (q+1) th unit is lower than the price he will pay for that additional unit. The blue

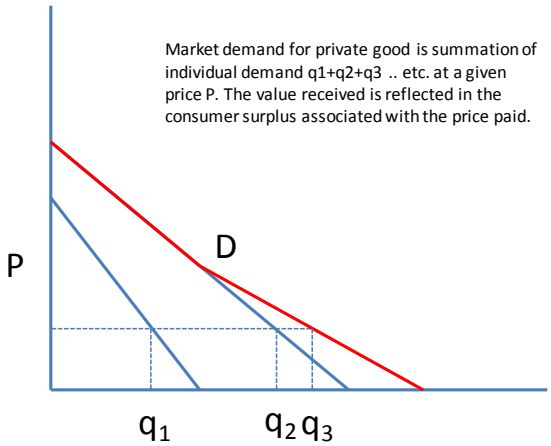
shaded area under the demand curve represents the "consumer surplus" for this consumer. The consumer surplus exists for private as well as public goods.

Consumer surplus



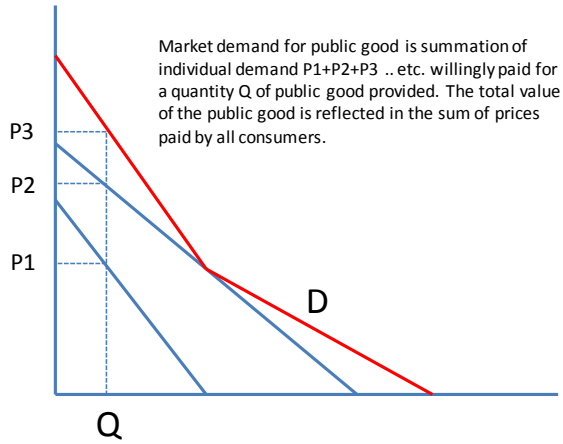
The consumer surplus determines the value a consumer perceives to receive from the purchase. In case of the private good, rival and exclusive, the consumer decides how much to buy depending upon the price he must pay per unit. The consumer surplus associated with the price is the indicator of the value he perceives to get. The total market demand for private goods is derived by identifying the quantities that individual buyers would be willing and able to purchase at different prices. The red line D in the diagram below is the market demand curve.

Total demand for private good



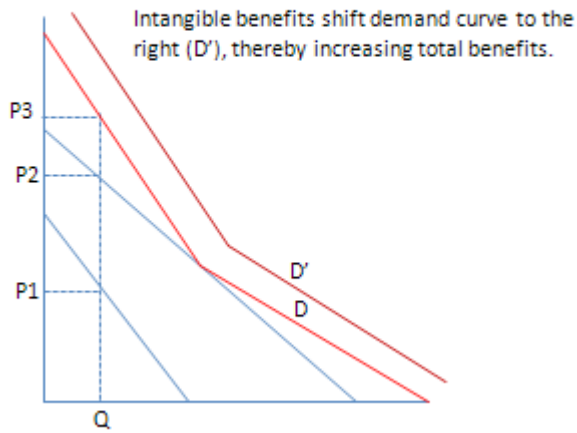
The non-rival and non-exclusive consumption makes the derivation of the demand for public goods a different story. Everyone can enjoy the benefits of a public good simultaneously. The consumption by one person does not prevent the consumption by another. As such, the value society receives from a public good is the sum of the value received by all who enjoy the benefits.

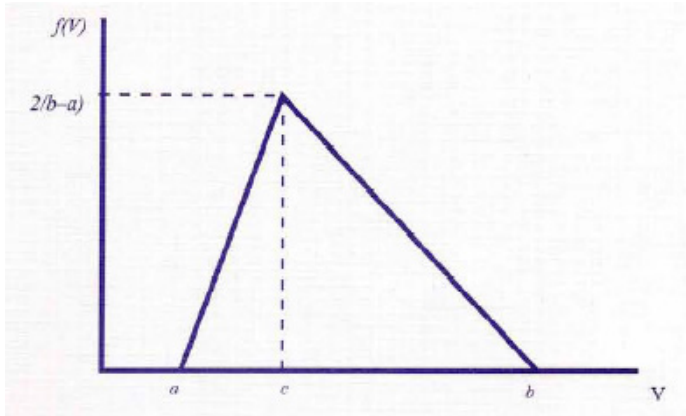
Total demand for public good



Some studies discuss the effect of "intangible" benefits received by the buyer as well as the society at large when public goods are produced and made available. To the buyer, the benefits could be "convenience" or increased "credibility" of the results of their projects etc. In theory, such benefits are implicit in the buyer's decision to buy the product, whether private or public good. On the other hand, this assumption may not be part of the decision to buy a public good, because there is no "market" as such for public goods. Intangible benefits of public goods may be such things as improved public health or stress reduction from visiting parks or perceived security from the defense forces. From the society's perspective such benefits could be considered as the cause for shifting the demand curve towards the right in the above diagram and adding to the benefits as a result. Benefits of this nature are impossible to quantify. Therefore, benefit-cost studies of geologic information recognize their existence by listing such benefits without attaching monetary value to them.

Intangible benefits





Assessment under uncertainty

When the number of observation data points is inadequate to form a continuous probability distribution, the estimation of the expected value of the variable is a high-risk proposition. Often, one has to work with subjective estimates of the variable's value provided by experienced individuals. Three estimates are usually solicited: a high (b), a low (a), and a most likely or best estimate (c). In such cases, a probability function is assumed to be triangular in shape, the best possible approximation of the normal distribution. The most likely estimate (c) satisfies the condition a<c<b. The triangular probability density function as depicted below is f(V), where V is the expected value. The probability that V will take a value between 'a' and 'b' is given by 2/ (b-a). V is computed by summing up all the known values multiplied by their individual probabilities, i.e. by. In practice, V is often computed simply as the mean (average) of a, b and c. For details, see "Uncertainty & Risk Analysis – A Practical Guide from Business Dynamics." PricewaterhouseCoopers, MCS (April 1999).

Appendix E. Statistics on visitors to GBSSRL

Serving the needs of research scientists as well as the industry and the public is The Great Basin Science Sample and Records Library (GBSSRL). Housed in its own new building away from the UNR campus, the GBSSRL holds a wealth of rock and core samples, maps, photographs, field notes by scientists, well records, historic documents and artifacts of interests to scientists, planners, industry and lay citizens alike. The GBSSRL thus fulfills an important function of providing basic information required for anyone interested in the minerals of Nevada, the earth hazards or simply in tourism. Scores visit the GBSSRL every month.

Over 3,000 individuals visited the GBSSRL in the three year period from April 2009 through April 2012, averaging about 4 each working day. An analysis of the purpose of their visit indicates a wide range of interests, even though it does not reveal whether they purchased any maps or publications and what they intended to do with their purchases. **Figure E-1** shows that visitors are most interested in topographic maps, with about one-third of all visitors showing interest. Among the other major groups are visitors from the mining, geothermal, and oil & gas industries. The NBMG program discussed thus far under various headings shows the congruence of the visitor's preferences and the NBMG program categories. A more detailed picture of user preferences and priorities, to be discussed later on, emerges from the analysis of data compiled from the questionnaire responses.

As important as the quantity of sales is the wide array of purposes for which geologic information in Nevada is used. The GBSSRL staff has documented the purposes of use in **Table E-1**. The work of NBMG reaches all walks of life of the citizens and the industry in Nevada. The range of users in Nevada is very similar to those confirmed by larger statistical studies in Kentucky, Ohio, and Spain, as is confirmed by our own questionnaire survey analysis.

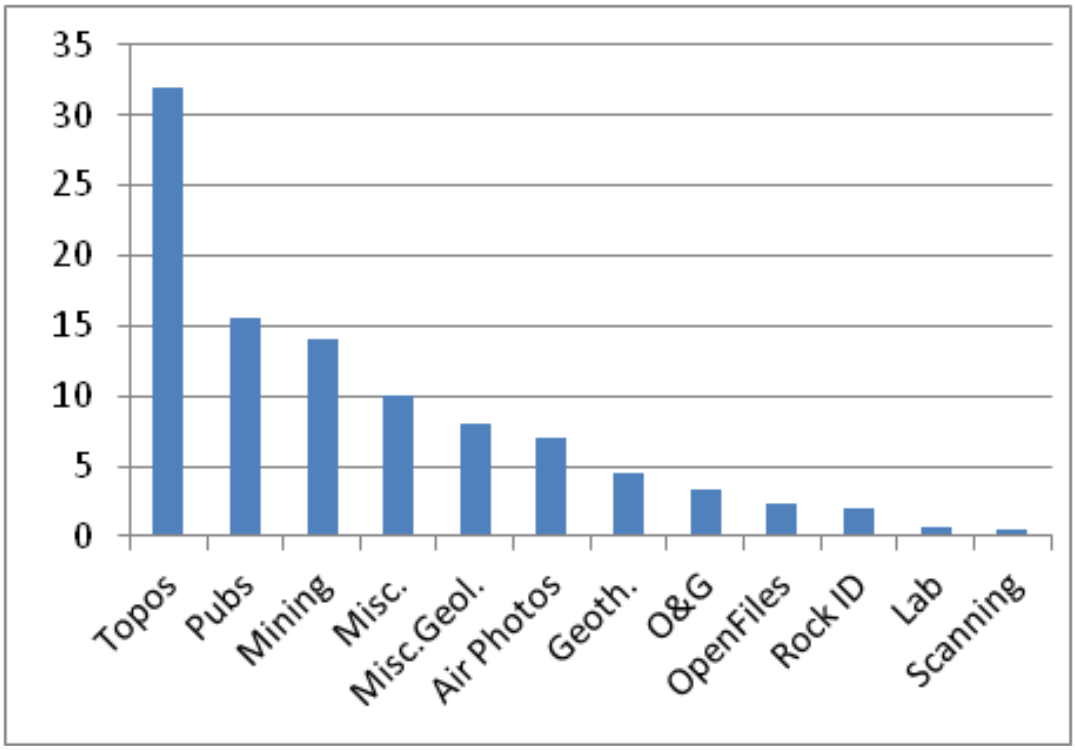
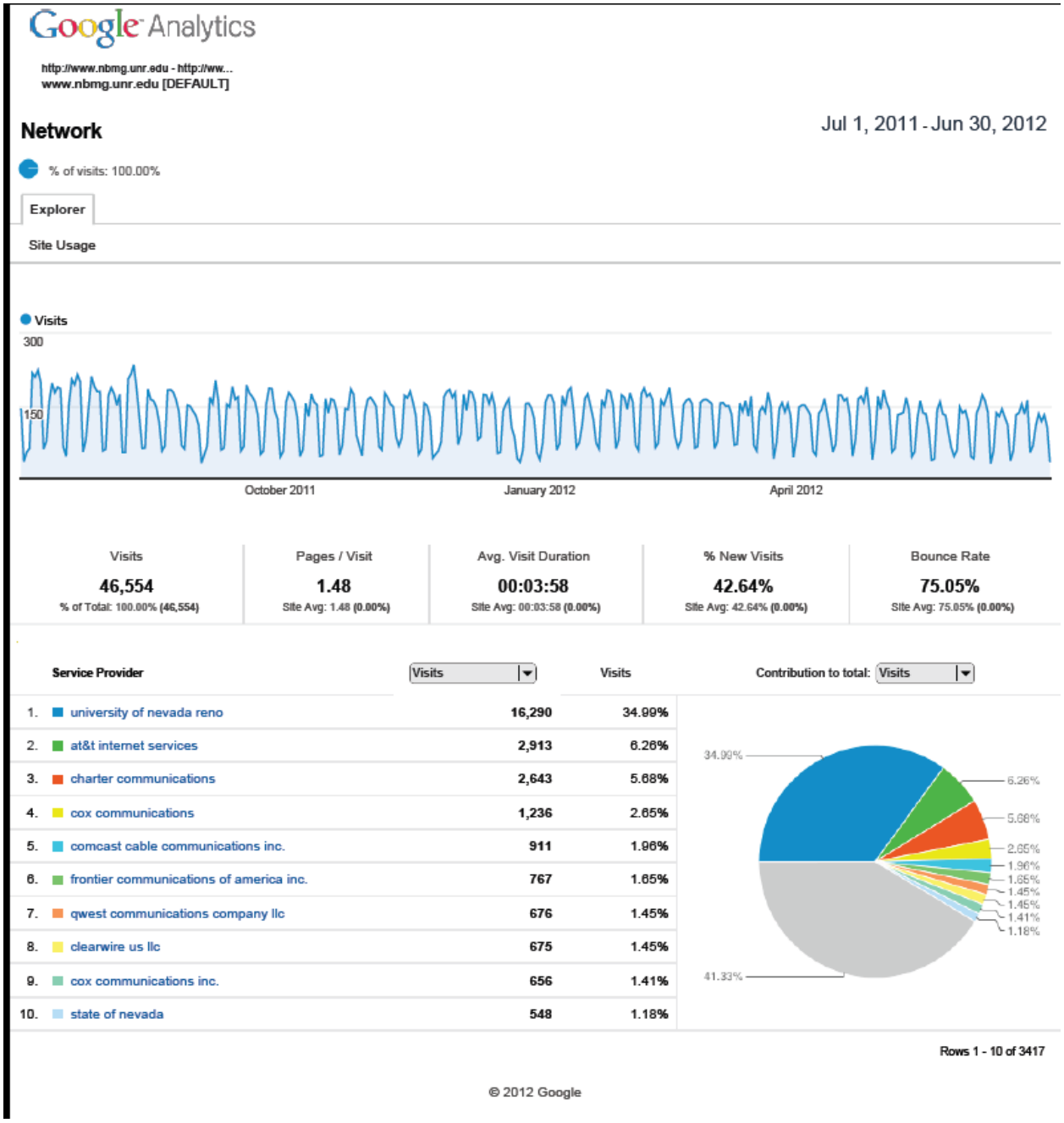


Figure E-1: Percent visitors to GBSSRL by purpose of visit. There were 3012 visitors from April 2009 to April 2012.

Table E-1. What types of customers use services at Great Basin Science Sample and Records Library?

Type of customer	Service provided
Geological consulting companies	Geological publications, topo maps, air photo search, core and cuttings, custom scanning projects, mining district file research (online or in office)
Geothermal companies	Publications, topo maps, cuttings, databases
Mining companies - local and foreign	Background info on Nevada geology for exploration research, custom scanning projects, mining district file research (online or in office), topo maps
Oil & gas and drilling companies and consultants	Background info on Nevada geology for exploration research, custom scanning projects, NBMG is official distributor for Nevada Petroleum and Geothermal Society publications
Archaeological companies and consultants	Geological maps, topo maps for plotting sites
Teachers	K-12 info--maps and kits for teaching, old topo maps free for Topo Bingo
Local, and state, and U.S. government	Distribution of earthquake safety booklets and information, popular guidebook series for resale, geological information, topo maps for Search and Rescue
Insurance companies	Earthquake information, earthquake hazard maps, topo maps for legal locations
Homeowners	Earthquake information, earthquake hazard maps, topo maps for legal locations
National parks	Popular guidebook series for resale
State parks	Popular guidebook series for resale
Local and state businesses	Popular guidebook series for resale, earthquake information
Outdoorsmen: hunters, hikers, rockhounds, prospectors, geocachers, and EarthCachers	Topo maps, publications
Students - K-12 through college	Answer requests sent to our NBMG Public e-mail, UNR students come in for research, topo maps for geology and engineering class projects
Tourists in Nevada	Popular guidebook series, EarthCachers info, rockhounding info, topo maps
University professors	Research for field work, topo maps for summer field work, bring students by on field trip tours
General public	Rock and meteorite ID, need info for trip planning, topo maps
Local rock and mineral group	Publications, topo maps, educational outreach booth at their annual show
Law firms	Research, topo maps for legal needs

Online use of NBMG's website indicates an equally widespread use by people other than those who personally visit NBMG premises. Google Analytics records show 46,554 Web visitors to NBMG site in the year July 1, 2011 to June 30, 2012. About 42.6 % of the visitors, or 19,850, were new. The single largest proportion (35%) of web visits was from UNR. Yet, and significantly, 65% were from outside the university system.