TO: Montana Fish and Wildlife Commission

FROM: Mark E. Odegard; GrizGeo, LLC; Ennis, MT meo@grizgeo.com

Commissioners:

In my previous comments "FWP_Cmt1_201018", submitted Sunday, my fourth concern was that the introduction of "capping" on any commercial venture imparts additional value to that venture. In this case commercial use of the Madison River uses a permit process. With "capping" of the number of permits, each permit gains a value in real dollars even if the "capping" is done proportionally.

In this case permits are very similar to leasing in the oil industry. Each permit is like leasing time on and use of the river. In the oil industry we lease an acre of land for a specific time to use the land to drill a well and produce oil. When I was working an area in eastern Montana for a Denver oil company an acre was leasing for between $100 and $300 for a period of about 10 years. If a well was drilled (fishing with a client) and produced oil, a royalty was paid on the value of the oil produced. Royalties are usually between 5% and 30% but can go as high as 75% in certain areas of the world. Note, that taxes are also paid on the profits as well.

Capping of permits for the Madison without a significant benefit to all the citizens of Montana, not just the Madison River area, I feel constitutes a "taking" of a resource without much compensation. Commercial users are essentially getting a lease for little or no money, and having to pay little or no royalty. The citizens of the State should be compensated for this "taking".

In my finding out about the history of the Madison Valley and its use by Indigenous/"First Peoples" I learned that the Valley was not just the domain of a single tribe, but was used cooperatively by all the tribes as a "Common Hunting Ground" (administered by the Blackfeet). This was done without wars. With our (non-First Peoples) migration into this area, because the area did not "belong" to any one tribe, no compensation was given for our "taking". Therefore, I feel that any compensation to the State, derived from permits on the River, should be shared (50/50?) directly with tribes in Montana.

Yours Sincerely,

Mark E. Odegard

By the way, "taking" is a fancy word used by lawyers in the real estate industry for stealing.

The effects of climate change on the Madison River Area, Montana

"Prediction is very difficult, especially about the future."
Niels Bohr, Danish physicist (1885-1962)

Mark E. Odegard, PhD
Grizzly Geosciences
Ennis, MT
www.grizgeo.com

From the Executive Summary of the United states Global Change Research Program transmitted to the Congress and the President

"Observations show that warming of the climate is unequivocal. The global warming observed over the past 50 years is due primarily to human-induced emissions of heat-trapping gases. These emissions come mainly from the burning of fossil fuels (coal, oil, and gas), with important contributions from the clearing of forests, agricultural practices, and other activities."

"Warming over this century is projected to be considerably greater than over the last century. The global average temperature since 1900 has risen by about 1.5°F. By 2100, it is projected to rise another 2 to 11.5°F."

http://www.bozemanscience.com/ap-es-034-global-climate-change/

https://nypost.com/2018/10/01/trump-administration-says-climate-change-will-make-earth-a-living-hell-by-2100/

Climate action

A new report from the World Bank Group warns that climate change is poised to interrupt the world as we know it.

Group CEO and acting president Kristalina Georgieva said that weather- and climate change-induced disasters cost $220 billion worldwide during 2018.

The global financial organization also announced a $50 billion budget for climate adaptation and resilience. The funds will help deliver better forecasts, warnings and other information to the most vulnerable areas.

Houston Chronicle, 20 Jan 18

Climate Science and Belief

Science is not about belief.

Even Major Oil Companies Have Accepted This

Thursday, 20 September 2018

U.S. energy giants led by Exxon Mobil join global coalition to slow down climate change

"Exxon Mobil said Thursday it was joining a corporate coalition working toward the goals of Paris climate change agreement, the boldest move yet by the oil giant that has faced criticism for past attempts to cast doubts about climate change."

The Irving, Texas-based company is one of the newest members of the Oil and Gas Climate Initiative, described as a "CEO-led initiative which aims to lead the industry response to climate change".

"Houston-based Occidental Petroleum and San Ramon, Calif.-based Chevron also announced their memberships on Thursday. Founded in 2014, the coalition now includes 13 of the largest oil and natural gas companies representing 30 percent of the world's oil and natural gas production."

The Oil and Gas Climate Initiative says on its website that its members are "committed to the direction set out by the Paris Agreement on climate change. We support its agenda for global action and the need for urgency."

https://www.dallasnews.com/business/energy/2018/09/20/irving-based-exxon-mobil-joins-group-committed-paris-climate-change-agreement-zeroing-methane-emissions

Dallas Morning News

U.S. energy giants led by Exxon Mobil join global coalition to slow down climate change

Exxon Mobil said Thursday it was joining a corporate coalition working toward the goals of Paris climate change agreement, the boldest move yet by the oil giant that has faced criticism for past attempts to cast doubts about climate change.

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Until now, the group did not include any firms based in the U.S., currently estimated to be the world's largest producer of crude oil.

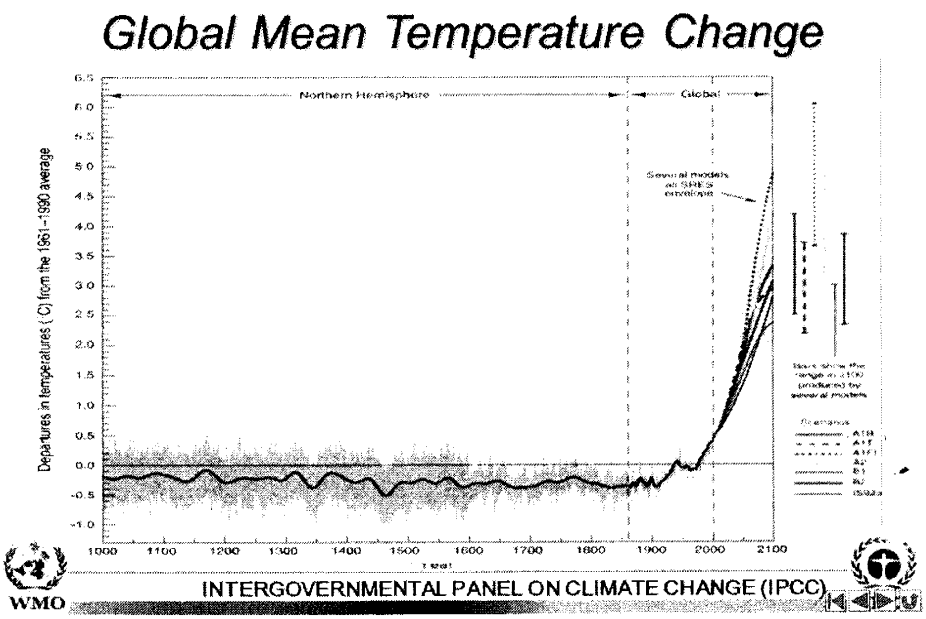
"It will take the collective efforts of many in the energy industry and society to develop scalable, affordable solutions that will be needed to address the risks of climate change," Exxon Mobil chairman and CEO Darren Woods said in a statement. "Our mission is to supply energy for modern life and improve living standards around the world while minimizing impacts on the environment."

The importance of the Oil and Gas Climate Initiative is heightened since these are the companies responsible for a large percentage of world's greenhouse gas emissions.
Fossil fuel combustion accounts for nearly 94 percent of U.S. carbon dioxide emissions, according to data from the Environmental Protection Agency. Oil and natural gas production, as well as abandoned wells, contribute nearly one-third of U.S. methane emissions.
The nonprofit CDP, formerly known as the Carbon Disclosure Project, calculated that 25 companies are responsible for 51 percent of industrial greenhouse gas emissions. Nine of those companies are now part of this global coalition.
The Oil and Gas Climate Initiative says on its website that its members are "committed to the direction set out by the Paris Agreement on climate change. We support its agenda for global action and the need for urgency."

The group is also working toward zero methane emissions, according to its website. Methane is a powerful greenhouse gas that contributes to man-made climate change.
Exxon Mobil officials announced in May a goal of reducing methane emissions by 15 percent in the next two years. The company also set a 2020 deadline to reduce flaring of natural gas by 25 percent.
Although this coalition predates President Donald Trump's administration, it does reflect a broader pushback against the U.S. decision to withdraw from the Paris agreement. Individual companies, including Exxon Mobil, and other corporate coalitions have announced action to combat climate change and support of the agreement.
The Paris agreement seeks to limit the rise in global temperatures to "well below" 2 degrees Celsius above preindustrial levels.
Investors — sometimes via proxy fights — have also demanded that companies publicly disclose how climate change could affect their finances. Last year, a shareholder resolution insisting that Exxon Mobil give a fuller assessment of its climate change risks passed with 62 percent.
The leadership of Exxon Mobil, which opposed that resolution, announced in December that it would release a more detailed climate-risk assessment.
Without #CCUS, the @IEA says the level of cuts needed to keep global warming to 2 degrees Celsius probably can't be achieved. This is why we're investing in innovative, economically viable & scaleable solutions to separate, capture, utilize and store co2.
https://t.co/kbVHLvQUc8
— OGCI (@OGCInews) July 31, 2018
Besides focusing on member contributions to climate change, the Oil and Gas Climate Initiative created a $1 billion fund to invest in technologies that could reduce emissions. So far, the fund has targeted companies that could make fossil fuel use less polluting or offset emissions, rather than replacing traditional fuels.

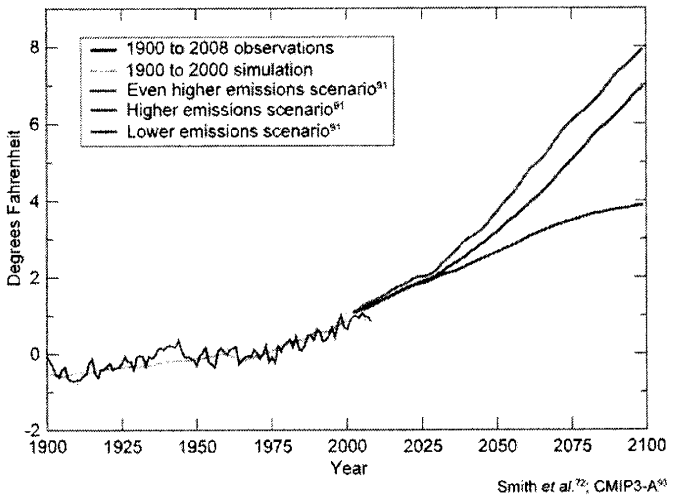
The Environmental Defense Fund described that amount as not enough.
"We must dramatically reduce the total amount of fossil fuels we use — coal, oil, and natural gas — and dramatically ramp up deployment of renewable resources — solar, wind — and aggressively pursue energy efficiency and vehicle electrification," wrote Mark Brownstein, the group's vice president of climate and energy.

Display of past and possible future global temperature.



Display of recent and possible future global temperatures. A more recent estimate.

With the US withdrawal from the Climate Accords the "Lower emissions scenario" is no longer probable. This predicted a 4 degree rise by the end of the century. Current projections are for at least a 7 degree rise.



Smith *et al.*[72]; CMIP3-A[93]

Observed and projected changes in the global average temperature under three IPCC no-policy emissions scenarios. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. A wider range of model types shows outcomes from 2 to 11.5°F.[66] Changes are relative to the 1960-1979 average.

https://nypost.com/2018/10/01/trump-administration-says-climate-change-will-make-earth-a-living-hell-by-2100/

What about the Madison River area?

This is from an article in the Mountain Journal, September 10, 2017:

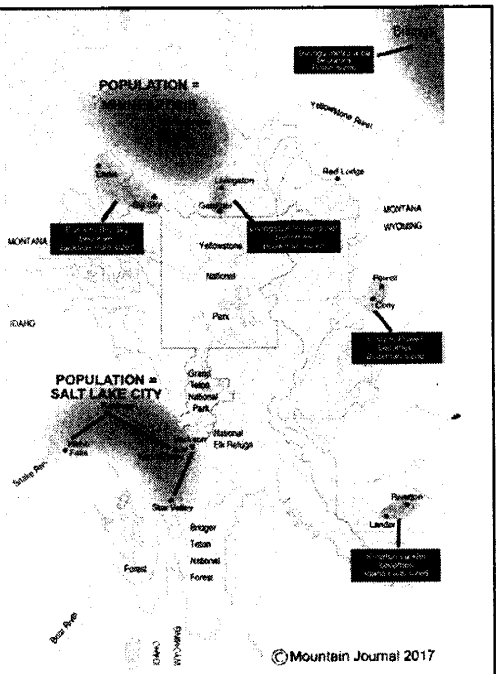
"Just based on current population growth patterns the Ennis-Big Sky area is projected to grow to about the size of the current Jackson, WY area by 2065."

"Bozeman/Gallatin, by 2041, will equal the size of Salt Lake City proper (minus its suburbs). Even more sobering, in less than half a century, 2065, based on the same rate of annual growth, there will be a population of 420,000 here, equal to present-day Minneapolis proper. And Carpenter says that could actually be a conservative estimate, with this scenario arriving faster than people think."

The Bozeman area growth will most-likely be limited by water supply. The projected population increase will "spill over" into areas with adequate water such as the lower Madison River.

What about the Madison River area?

Just based on current population growth patterns the Ennis-Big Sky area is projected to grow to about the size of the current Jackson, WY area by 2065. Bozeman is projected to become the size of Minneapolis.



Predicted population growth in Greater Yellowstone Ecosystem by 2065

https://mountainjournal.org/the-wildest-ecosystem-in-america-faces-death-by-too-many-people

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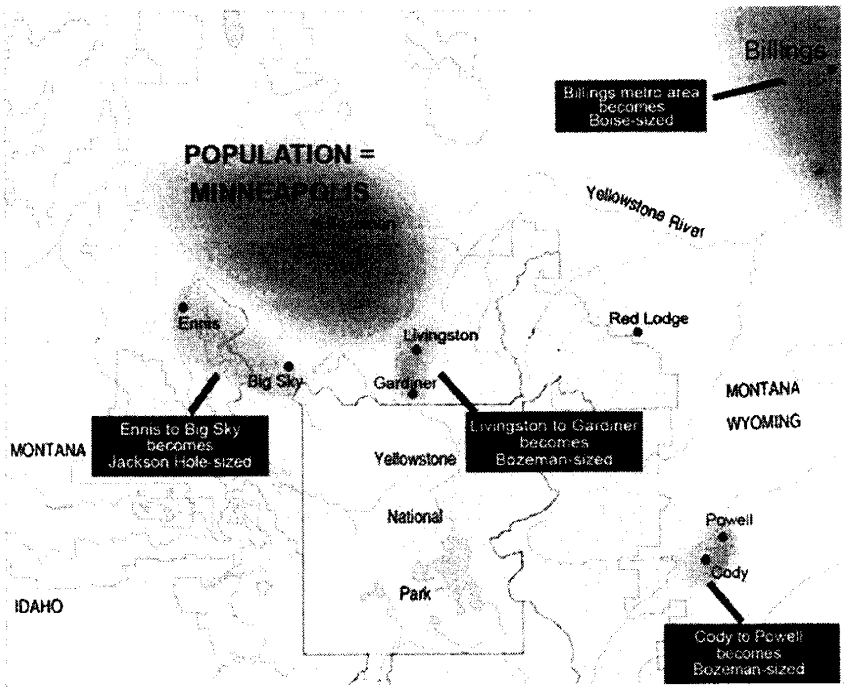


https://mountainjournal.org/the-wildest-ecosystem-in-america-faces-death-by-too-many-people

Climate Migration

From the same article: "And then you look at Houston and Hurricane Harvey and Florida and Hurricane Irma, and Phoenix broiling in 120-degree heat, the water shortages coming to cities in the desert Southwest, and the fires in southern California," Carpenter says from the slope of the Bridgers. "The current explosive growth in Greater Yellowstone is happening because the region is attracting a lot of people coming here with a lot of money wanting to live quieter lives closer to nature. They are the first big wave."

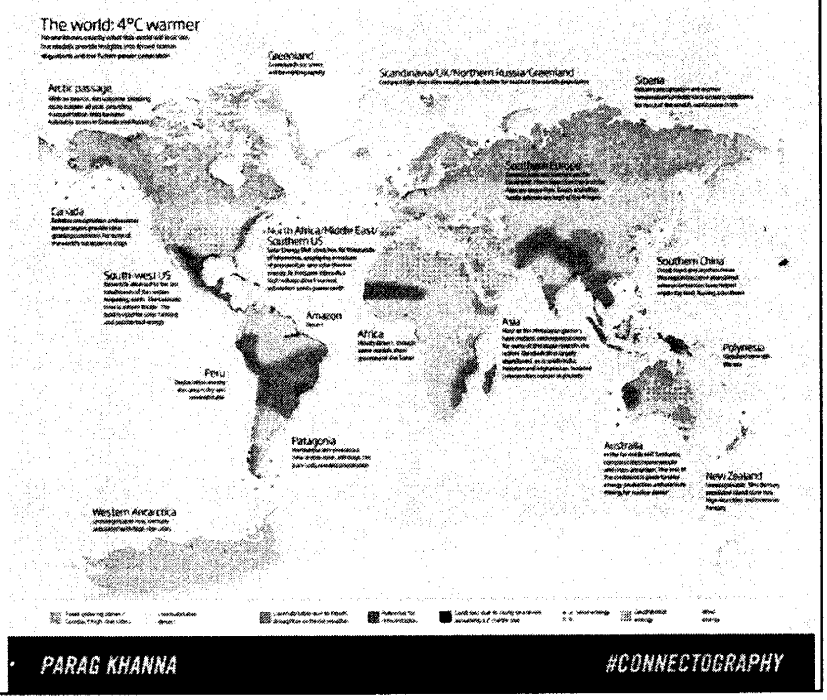
That alone, he says, is creating a nightmare of cascading growth-related issues, to which leadership in the Greater Yellowstone Ecosystem is either unable, unwilling or ill-equipped to confront.

"But how are the counties and towns going to handle a potential flood of climate refugees on top of the current inundation?" Carpenter asks. He doesn't even need to speak the answer.

The "flood" seems to have started at our southern border. See:
https://www.nytimes.com/2019/06/05/opinion/guatemala-migrants-climate-change.html

The world with a 7 degree rise in temperature

4 degrees centigrade is about 7 degrees Fahrenheit.

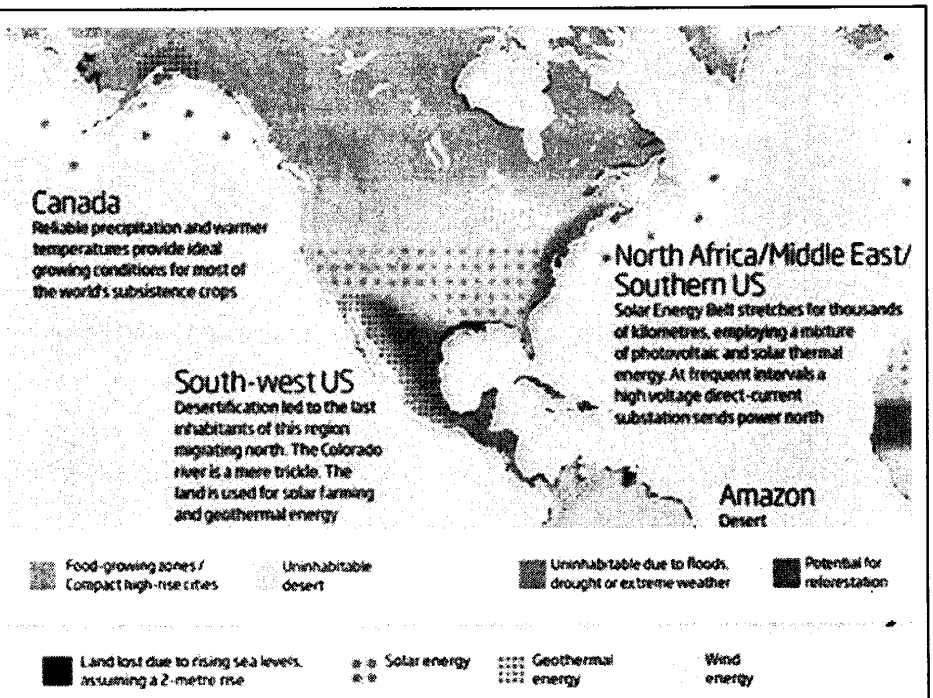


Imagine, for the purposes of this thought experiment, that we have 9 billion people to save — 2 billion more than live on the planet today.
A wholesale relocation of the world's population according to the geography of resources means abandoning huge tracts of the globe and moving people to where the water is. Most climate models agree that the far north and south of the planet will see an increase in precipitation. In the northern hemisphere this includes Canada, Siberia, Scandinavia and newly ice-free parts of Greenland; in the southern hemisphere, Patagonia, Tasmania and the far north of Australia, New Zealand and perhaps newly ice-free parts of the western Antarctic coast.

The citizens of the world's wealthiest and most populous nations will become climate refugees, which means things are going to get really, really ugly for everyone else.

North America with a 7 degree rise in temperature

The southern US will become a desert with the forced migration of tens of millions of people to the north. This will be somewhat mitigated by advances in technology.



The primary technology use will probably be desalinization. However this requires lots of energy, from where? But water conservation implementation through engineering and population education will also be important.

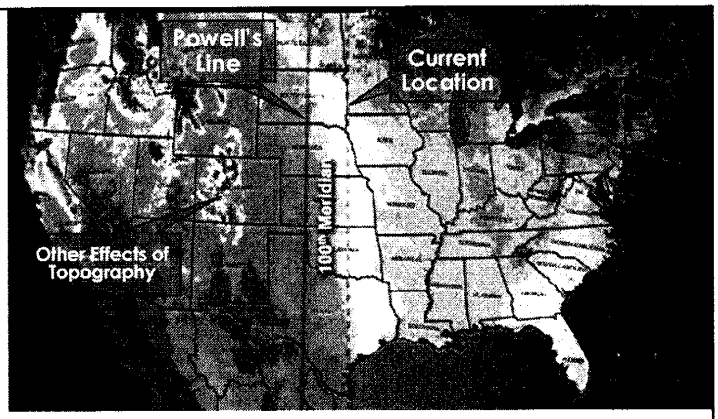
https://www.technologyreview.com/s/534996/megascale-desalination/
https://www.scientificamerican.com/article/israel-proves-the-desalination-era-is-here/

"The shortage of natural water is the worst that has been measured in about 100 years and is bringing water sources in the north to an unprecedented low point," Energy and Water Minister Yuval Steinitz said on April 9, 2018. Consequently, the water ministry announced a plan to build two more desalination plants to reinforce the five built along the Mediterranean coast over the past 13 years. It did not include their price, but similar facilities in Israel have cost about $400 million.

https://www.npr.org/sections/parallels/2015/06/14/413981435/israel-bringing-its-years-of-desalination-experience-to-California

Modifying Elements

Two previous slides are somewhat symbolic in that they show the general effect of temperature rise, but do not adequately show the effects of topography, weather patterns and other factors.



A striking example is shown in the migration of the 100th meridian which divides the arid west from the moister east. This line was first described in 1879 by a geologist, John Wesley Powell. It has recently been investigated with modern techniques and has been shown to have moved east about 140 miles, most probably due to the rise in average temperature. The line is caused by the "rain shadow" effect of the Rocky Mountains and by the change in moisture coming up out of the Gulf of Mexico.

Nearly a century and a half later, a Columbia University study published in the April issue of the journal *Earth Interactions* re-examined the boundary line—and presented two central findings: first, that the boundary is real, and second, that climate change is causing it to migrate east, expanding the dry part of the country.

Despite the fact that many farmers still don't acknowledge the link between human activity and climate change, only 18 states have climate mitigation plans in place, and the U.S. Environmental Protection Agency (EPA) has removed numerous climate-related documents from its own website, the resulting changes to agriculture will likely be hard to deny.

"There's no point in sticking your head into the sand—or into the tilled earth—about this: these changes are going to be happening," said climate scientist Dr. Richard Seager of Columbia's Lamont-Doherty Earth Observatory and the study's lead author.

"In any decision-making, it's worth thinking that conditions *are* going to change and it's going to require some adjustment in how the land is used agriculturally. What's the best thing to do that will minimize destruction and suffering that will occur?"

Though most contemporary Americans have probably never heard of the 100th Meridian, it's an environmental reality. In fact, Seager's team confirmed its existence by examining east-west differences in vegetation, precipitation, temperatures, and atmospheric circulation, as well as human approaches to settlement and agriculture.

But There Are Always Problems with Mitigation

One of the main water mitigating methods could be de-salinization. However:

Desalination brine:
The nearly 16,000 plants around the world that extract fresh water from the sea are discharging far greater amounts of toxic brine back into the ocean than previously thought, a new U.N. study reveals.
It says the salt-laden liquid is increasing the density of salinity where it is released, and poses a significant risk to marine life and ecosystems.
More than half of the 5 billion cubic feet of brine discharged each day worldwide comes from desalination plants operating in Saudi Arabia, the United Arab Emirates, Qatar and Kuwait.

Houston Chronicle, 20 January 2019

https://www.nytimes.com/aponline/2019/01/14/world/europe/ap-eu-united-nations-desalination.html

Too Much Brine? Study Highlights Growing Toxic Brine Problem
By The Associated Press
Jan. 14, 2019
BERLIN — The world's thirst for fresh water is causing a salty problem.
Desalination plants around the world are producing enough brine waste to swamp an area the size of Florida with a foot of salty water every year, according to a U.N.-backed report released Monday.
The study by researchers from Canada, the Netherlands and South Korea warned that much of the brine is being dumped untreated into the sea, and some is laden with toxic chemicals, causing harm to sea life.
The authors called for better brine management, particularly in countries that rely heavily on desalination for their water needs, such as Saudi Arabia, the United Arab Emirates, Kuwait and Qatar.
"We know that water scarcity is increasing in many regions across the world due to increased water demands, which are associated with population increase and economic growth," said one of the authors, Manzoor Qadir, assistant director of the United Nations University's Canada-based Institute for Water, Environment and Health.

At the same, climate change is making the availability of freshwater less predictable, such as by changing the amount of runoff snow in some regions, he said.

The authors examined 16,000 desalination plants worldwide and found they produce 142 million cubic meters (5,014 million cubic feet) of brine each day, or 51.8 billion cubic meters a year. That's about half more than previous studies had estimated, said Qadir.

The researchers called for better brine management, noting that studies have shown it can be used in aquacultures to boost yields of salt-tolerant species of fish, and the metals and salts contained in it — such as magnesium and lithium — could be mined.

Climate Migration and the Madison River

From the previous slides showing the world with a 7 degree rise in temperature, it appears the Madison River area could remain about the same in terms of rain and snow fall. However the temperature will be higher and the snow will melt earlier so that stream flows in summer will be lower. This combined with rising maximum temperatures may doom trout in our rivers unless there is some way to mitigate the lower river flows with higher water temperatures. Elk and other animals will also be affected adversely.

https://yellowstoneinsider.com/2018/03/04/yellowstone-expert-warns-climate-change-park/

Climate Warming and the Madison River

The following prediction was made in my September 2019 PPT:

"In the lower Madison, increasing temperatures will probably reduce or eliminate the trout population. This may lead to their replacement by more heat tolerant species of fish. Closure of this part of the river during the longer summer will be probable."

In October 2019 the Fish and Wildlife Commission enacted permanent hoot owl restrictions on the lower Madison. The lower Madison regulations already include the unlimited taking of Northern Pike which are probably affecting the trout population.

Climate Warming and the Madison River

The Greater Yellowstone Ecosystem (GYE) is warming as noted by the National Park Service, "*Changes in Yellowstone Climate*", see notes:

"Researchers looking at annual average temperatures report an increase of 0.31°F/decade within the GYE, consistent with the continuing upward trend in global temperatures. Recent studies show mean annual minimum and maximum temperatures have been increasing at the same rate of 0.3°F/decade for the GYE. Conditions are becoming significantly drier at elevations below 6,500 ft. In fact, the rise in minimum temperatures in the last decade exceeds those of the 1930s Dust Bowl Era."

The increase in water temperatures over the past decades has been about 1.8 degrees Fahrenheit. This has apparently lead to the hoot owl restrictions noted in the previous slide. As noted by the NPS:

"Continued warming could have major implications to the management and preservation of the many aquatic resources we have today. Changes in volume and timing of spring runoff may disrupt native fish spawning and increase nonnative aquatic species expansion."

https://www.nps.gov/yell/learn/nature/climate-examine-evidence.htm
https://www.nps.gov/yell/learn/nature/climatechangeinfo.htm

Climate Warming and the Madison River

The effects of warming water temperatures were also noted by Gooseff (2005, see notes):

"In any event, all results here suggest that predicted climate change will have a warming impact on water temperatures in the Lower Madison River, and more importantly, the changes are likely to result in a negative impact on fish population health and mortality."

As the water temperatures increase in the River the need for hoot owl restrictions will move further upstream. In the future these restrictions will extend over the River below Quake Lake and eventually the whole river as well as all reivers in western Montana.

This warming will be the primary cause of a decline in the River's fishery.

This will have a major effect on the economy of the area and on river crowding. The crowding will be exacerbated by the increased number of residents in the valley caused by climate migration.

Gooseff, M. N., K. Strzepek and S. C. Chapra (2005)

Modeling the potential effects of climate change on water temperature downstream of a shallow reservoir, lower Madison River, MT; Climatic Change 68: 331–353.

Climate Migration and the Madison River

The major effect will come from increased migration of the population to the north. This will come because of the inundation of southern areas by desert conditions. These will include the drying up of the Colorado and Sacramento rivers. With no water, these populations will be forced to migrate to the northern US and Canada.

Migration will probably have a large effect on the lower Madison and the Three Forks area. This will probably be because the Bozeman-Gallatin area will not have enough water to sustain a population as large as shown above. The population will spill over into other areas with a better water supply.

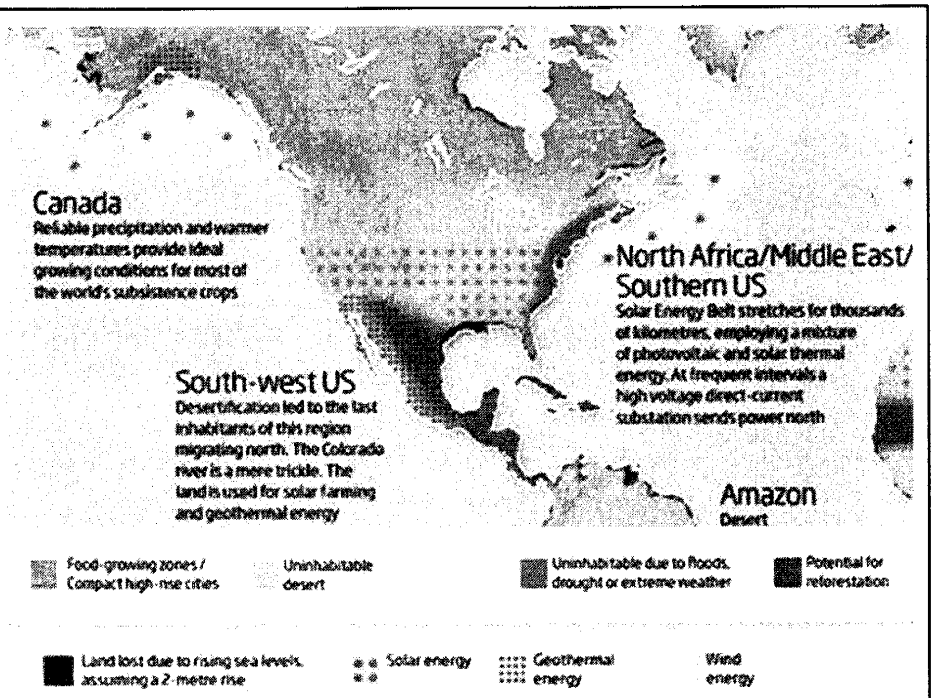
Climate migration is already occurring in the Madison Valley as seen by the "record?" number of new residences constructed during the past year.

https://yellowstoneinsider.com/2018/03/04/yellowstone-expert-warns-climate-change-park/

North America with a 7 degree rise in temperature

The main question is where will that yellow to green transition be?

Will it be further north or south as shown here?



Possible Mitigation of Lower Stream Flows and Higher Water Temperatures

- **The Madison River has one method to mitigate the rising temperatures and earlier snow melt. This is using the Hebgen reservoir.**
- **If a significant amount of water can be released during the summer this will raise stream flow and lower water temperatures.**
- **Then the reservoir can be refilled during the earlier spring runoff.**
- **However the lower water levels in the reservoir will affect businesses, residents and visitors to the area.**
- **There will be significant opposition to a plan like this.**
- **One unknown effect will be the withdrawal of ground water.**
- **MTFWP and the FW Commission must start considering methods of mitigation. Restricting commercial access has a minor effect.**

https://www.usbr.gov/gp/hydromet/hebr.html
Welcome to the Bureau of Reclamation, Great Plains Region
Hydromet System for Hebgen Lake, Madison River near West Yellowstone, Montana

Climate Migration and the Ennis Area

It is impossible to predict the exact expected population of the Madison Valley by the year 2050 and beyond, but it could easily be 100,000 plus.

The limiting factor will be our water resources. Areas such as the west bench aquifer being studied by the MBMG/GWIP/Montana Tech could be severely affected. Parts of this area could be without water from wells if the population becomes too large and the water table falls or disappears. There may not be enough water entering the system to sustain a large population in the Madison Valley.

These factors must be considered by the Town and Zoning Commissions of Ennis, by the County Commissioners, and the State and National Governments.

"It's good business," said Bruno Sarda, head of sustainability at NRG Energy. "All these questions ... are actually just good governance and good risk management.

(good business is planning for these changes, *MEO*)

Climate Migration and Affordable Housing

One aspect of climate migration is the financial side. Wealthier families will have the resources to migrate to areas with better climate. These families will generally be able to purchase homes at higher prices than current residents. This could mean there will be NO "affordable housing" in these areas.

In these areas the effect on the lower income peoples may be to increase the density of residents in sub-standard housing units. Will this result in "slums" in our valley?

What needs to be done NOW to mitigate this?

The citizens of the world's wealthiest and most populous nations will become climate refugees, which means things are going to get really, really ugly for everyone else.

Fund managers who have staked hundreds of millions of dollars want to know how climate change might affect those businesses, from supply chain disruptions to changing customer demand. Such disclosures, they say, would help investors better understand the long-term risks involved with a given company.

"Everyone had something in their 10-K [report] about carbon or climate," said Swami Venkataraman, a senior vice president at Moody's Investors Service, which now includes climate change risk in its ratings. "But their disclosures tend to be very inadequate. ... They simply say that carbon regulations are possible, and that's a risk facing the business. It doesn't really articulate the nature of that risk, the magnitude of that risk, the kind of exposure the company faces."

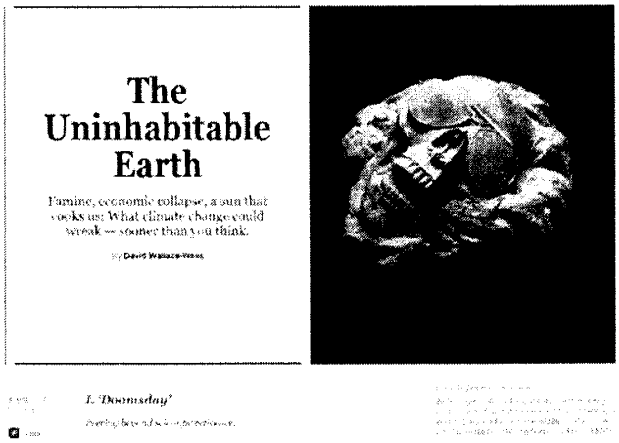
NRG Energy, which owns Houston-based Reliant Energy, is one of more than 200 major companies that have adopted a new climate change disclosure framework that emerged from the G20, a group of 19 of the world's wealthiest nations plus the European Union. Chaired by billionaire and former New York City Mayor Michael Bloomberg, the Task Force on Climate-Related Financial Disclosures has the support of Dow Chemical, Dupont, Royal

Dutch Shell, Statoil, Bank of America and other global behemoths.
"It's good business," said Bruno Sarda, head of sustainability at NRG Energy. "All these questions ... are actually just good governance and good risk management."

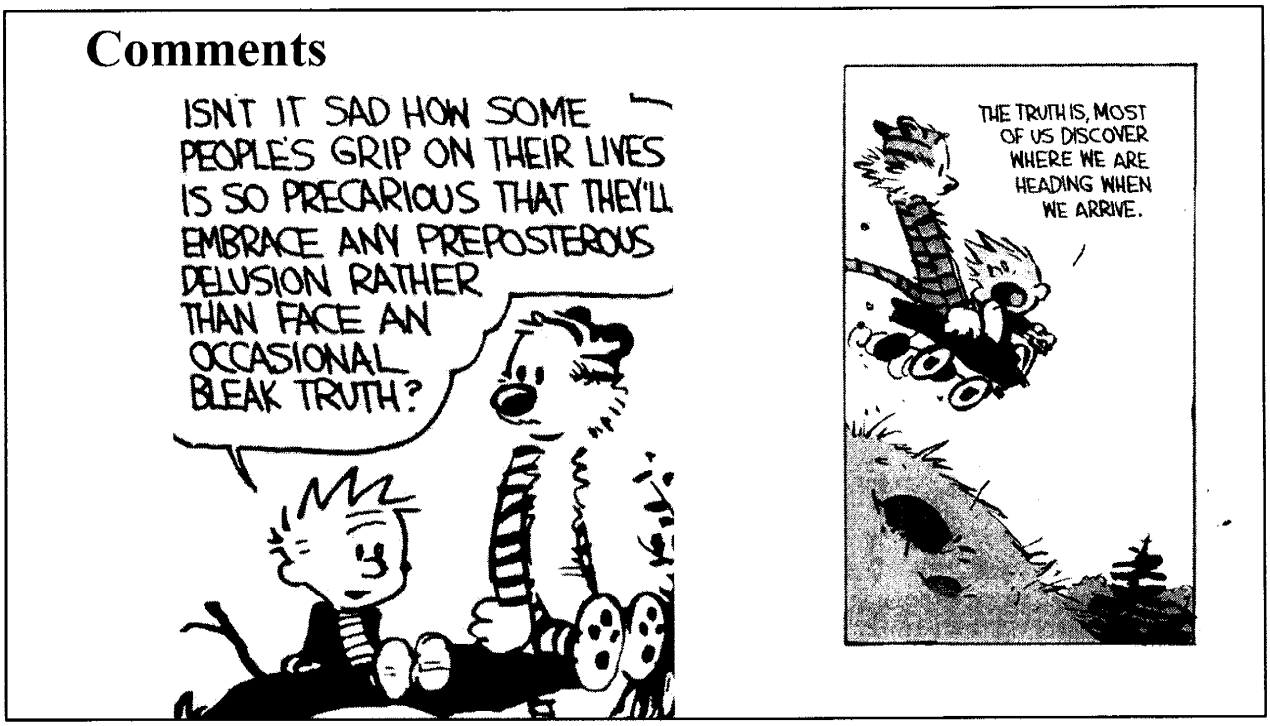
Comments

Most of the above slides were done before I heard about this book on climate change. This book has similar conclusions, but they are even more disastrous:

https://www.amazon.com/Uninhabitable-Earth-Life-After-Warming/dp/0525576703/ref=sr_1_1?ie=UTF8&qid=1550785789&sr=8-1&keywords=the+uninhabitable+earth



Comments



Unfortunately

Primary Sources

Climate Change, Migration, and Population Growth (2010) Population Action International, 1300 19th Street, NW Suite 200, Washington, DC 20036-1624 USA

The Ennis Groundwater Investigation (2018) Andrew Bobst and Mary Sutherland; *Ground Water Investigation Program (GWIP),* MONTANA BUREAU OF MINES AND GEOLOGY, 1300 West Park Street, Butte, MT 59701-8997 USA

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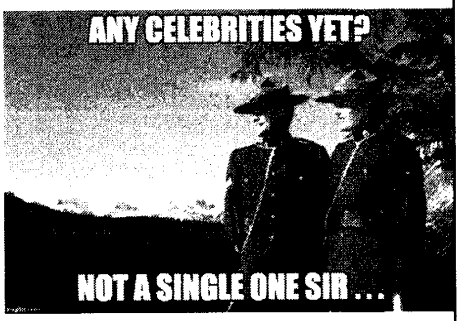
Disclaimer!

These projections are based on my reading and interpretation of currently available reports and the scientific literature.

They do not reflect in any way the policies of local, county, state or federal governments with which I might be associated. They are purely my product and has been supported solely by my finances.

***Mark E. Odegard*; Grizzly Geosciences**



But we must not forget:

"We're so busy watching out for what's just ahead of us that we don't take time to enjoy where we are."
- Calvin & Hobbes

COVID-19 Response

Following guidance from the White House, Centers for Disease Control and Prevention, and state and local public health authorities, we are increasing access and services in a phased approach across all units of the National Park System. Before visiting a park, please check the **park website** to determine its operating status. Updates about the overall NPS response to COVID-19, including safety information, are posted on **www.nps.gov/coronavirus.**

National Park Service

Yellowstone

National Park
ID, MT, WY

Changes in Yellowstone Climate

Scientists with the National Park Service and other organizations closely monitor variables that may reflect a changing climate. In Yellowstone, these include whitebark pine, snowpack, the greening of plants, and wildlife.

NPS / Jim Peaco

The Greater Yellowstone Ecosystem is a complex region, encompassing approximately 58,000 square miles and 14 mountain ranges. Weather varies greatly across steep elevational changes, bringing snowfall to some areas, and warm, dry conditions to others. This dynamic system has provoked the curiosity of researchers for a long time.

Across Space and Time

Space and time are critical to the evaluation of real-world data, and every study defines their parameters differently. This can make it difficult to get a sense of what is actually occurring. Climate summaries over longer periods of time and across larger areas tend to mask local extremes. Conversely, a continuously changing set of short-term reference averages (weather "normals") could unintentionally obscure the long-term magnitude of change. It is important to look at climate information across many scales and to use available data and models to arrive at reasonable answers to our questions about how climate has changed, how those changes will affect the park, and what impacts we may be able to anticipate in the future.

Analyzing smaller areas within the Greater Yellowstone Ecosystem (GYE), say in Yellowstone National Park or on the Northern Range, poses specific challenges. Small regions have fewer actual monitoring stations to feed data to computer models and gridded weather data is often used to fill in the gaps. As a consequence, small-area analyses may not be as accurate. Local field observations from stream gauge and weather stations can be used to verify some of the observed trends, and to describe local conditions to which the ecological system may be responding. This "ground-truthing" allows researchers to arrive at reasonable conclusions about ecological activity.

Temperature and Precipitation

Global temperature is the master force affecting climate. Everything else that climate affects—sea level rise, growing season, drought, glacial melt, extreme storms—is driven by changes in temperature. Weather stations have been maintained within the GYE since 1894, resulting in some of the longest running records of temperature and precipitation anywhere in the United States. These days, increasingly sophisticated satellite technology as well as data sets yielded by the science of climate modeling, also help climate experts and park managers assess the current situation in the GYE across several scales.

There is evidence that climate has changed in the past century and will continue to change in the future. Researchers looking at annual average temperatures report an increase of 0.31°F/decade within the GYE, consistent with the continuing upward trend in global temperatures. Recent studies show mean annual minimum and maximum temperatures have been increasing at the same rate of 0.3°F/decade for the GYE. Conditions are becoming significantly drier at elevations below 6,500 ft. In fact, the rise in minimum temperatures in the last decade exceeds those of the 1930s Dust Bowl Era.

Future Temperature and Precipitation

All global climate models predict that temperatures in the GYE will continue to increase. Projections of future precipitation vary based on differing scenarios that account for future levels of greenhouse gas emissions, which depend upon economic, policy, and institutional improvements, or lack thereof. Any potential increases in precipitation that may or may not occur will be overwhelmed by temperature increases. Considering the most recent trends in which warmer temperatures have been exacerbating drought conditions during the summers, a warmer, drier future for the GYE appears likely in the coming decades. By the latter part of the 21st century, the hot, dry conditions that led to the fires of 1988 will likely be the norm, representing a significant shift from past norms in the GYE toward the type of climate conditions we currently see in the southwestern United States.

Snowpack and Snow Cover

Snowmelt in the alpine areas of the Rocky Mountains is critical to both the quality and quantity of water throughout the region, providing 60–80 percent of streamflow in the West. Throughout the GYE, snow often lingers into early summer at high elevations. Each year, a large spike in water flow occurs when snow starts to melt at lower elevations, usually in late February and early March. Peak flow is reached when the deep snow fields at mid and high elevations begin to melt more quickly, typically in June. Minimum flow occurs during winter when all the previous year's snow has melted, temperatures have dropped, and precipitation comes down as snow instead of rain so only water flowing from underground sources can supply the streams. By contrast, the proportion of stream flow due to rain storms is significantly lower than the contributions of snow melt.

Changes in the area covered by snow are especially important because snow reflects solar radiation and tends to keep land cool.

NPS / Neal Herbert

Climate change is expected to affect both snow accumulation and rate of spring melt. In some places, warmer temperatures will mean more moisture falling as rain during the cooler months and the snowpack melting earlier in the year. The reduction in snowpack is most pronounced in spring and summer, with an overall continued decline in snowfallprojected for Yellowstone over the coming decades. The Yellowstone, Snake, and Green rivers all have their headwaters in Yellowstone. As major tributaries for the Missouri, Columbia, and Colorado rivers, they are important sources of water for drinking, agriculture, recreation, and energy production throughout the region. A decrease in Yellowstone's snow will affect millions of people beyond the boundaries of the GYE who depend this critical source of water.

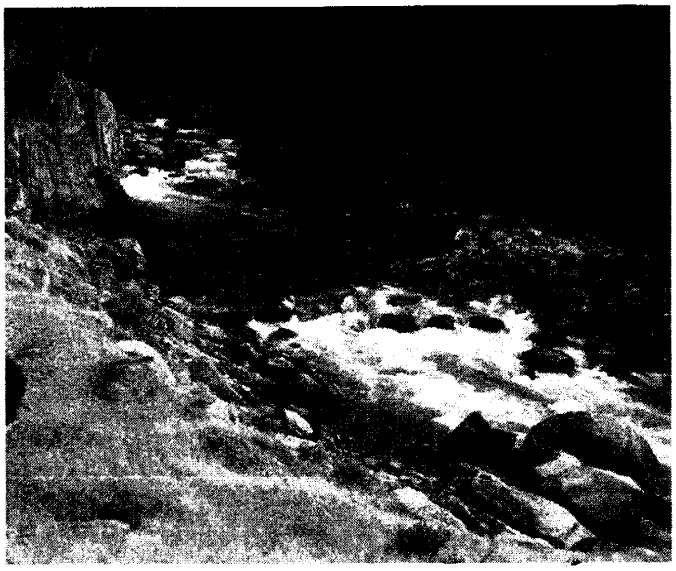
Future Snowpack and Snow Cover

The interaction between snowpack, temperature, and precipitation involves a complex interchange between heat and light. Warming temperatures increase evaporation; increased moisture in the air could lead to more snowfall and cloud cover. The increased cloud cover could block additional heat from reaching the surface of the earth resulting in cooler temperatures below. However, increased temperature could possibly limit snowfall instead—by converting it to rain or by melting snow rapidly once it falls, thereby driving snowlines further up the mountains. Recently modeling work indicates that snowpack will almost certainly decline in the long-term.

Changes in the area covered by snow are especially important as snow reflects more solar radiation out to space (albedo) than bare ground and tends to keep the surface cool. When land is exposed, sunlight is absorbed by the surface of the earth. This raises the overall surface temperature, which leads to more melting and less snowcover.

Stream Flow and Water Temperature

Glaciers, snowpack, and rainfall produce water that flows through streams, lakes and rivers, and these waterways are critical to life. Analyses of streams during 1950–2010 in the Central Rocky Mountains, including those in the GYE, show an 89% decline in stream discharge. Reduced flows were most pronounced during the summer months, especially in the Yellowstone River. In addition, stream temperatures have changed across the range of the Yellowstone, with a warming of 1.8°F (-16.8°C) over the past century. Continued warming could have major implications to the management and preservation of the many aquatic resources we have today. Changes in volume and timing of spring runoff may disrupt native fish spawning and increase nonnative aquatic species expansion.



Climate change will affect streams differently, but increased variability is expected along with a shift in the timing of peak flows.

NPS / Jim Peaco

Growing Season

The Intergovernmental Panel on Climate Change (IPCC) predicts that overall forest growth in North America will likely increase 10–20% as a result of extended growing seasons and elevated CO2 during the next century but with important spatial and temporal variations. Forests in the Rocky Mountain/Columbia Basin region are expected to have less snow on the ground, a shorter snow season, a longer growing season due to an earlier spring start, earlier peak snowmelt, and about two months of additional drought. Despite a longer growing season, Yellowstone forests will likely be less dense, more patchy, and have more diverse age structure. In fact, experts project less tree cover in much of the park as well as potential migration of new species like Ponderosa pine. Complicating matters, increased drought stress and higher temperatures may increase the likelihood of widespread die-offs of some vegetation.

The integrated runoff response from the Yellowstone River has been toward earlier spring runoff peaks, which suggests that the majority of the park is experiencing shorter winters and longer summers as a result of snowpack changes. Changes in these seasonal patterns will likely disrupt vegetation growth and development, causing plants to bud, flower, fruit and die at different times of the year than they do now. Those changes, in turn, would alter or seriously disrupt wildlife migrations, one of the key resources for which Yellowstone National Park is globally treasured.

Extreme Events: Insect Activity

Although outbreak dynamics differ among species and various forests, climate change appears to be driving current insect outbreaks. Western spruce budworm outbreaks were more widespread and lasted longer in the 20th century than in the 19th century primarily because of fire suppression and increasing fir populations. However, patterns of spruce budworm outbreaks have been tied to climate nationwide.

Summer and spring precipitation are positively correlated with increased frequency of outbreaks over regional scales and long time frames, but experimental evidence suggests that drought may promote infestations. Although bark beetle infestations are a force of natural change in forested ecosystems, several concurrent outbreaks across western North America are the largest and most severe in recorded history. From 2004 to 2008, the area of mountain pine beetle outbreaks increased across Wyoming from 1,000 to 100,000 acres. At the end of 2016, 26% of whitebark pine trees in the GYE had been killed as a result of mountain pine beetle, whitepine blister rust, wildland fire, and other factors. Since 1999, an eruption of mountain pine beetle events has been observed that exceed the frequencies, impacts, and ranges documented during the last 125 years. Aerial assessment of whitebark pine species populations within the GYE has indicated a 79% mortality rate of mature trees. These changes may be early indicators of how GYE vegetation communities will shift due to climate change.

These outbreaks of bark beetles in the West have coincided with increased temperatures and changes in precipitation patterns, suggesting a response to a changing climate. Warming temperatures and the loss of extreme cold days reduce winter overkills of insects, speed up life cycles, modify damage rates, and lead to range expansions, particularly in the north.

Future Insect Activity

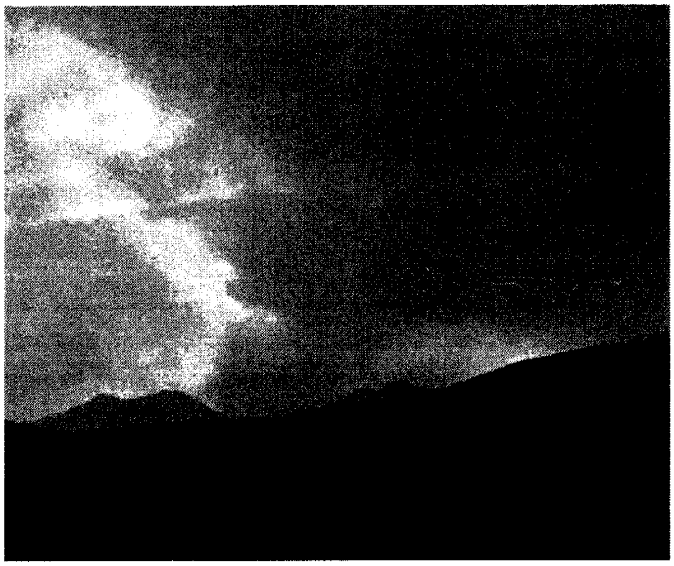
Climate change, and particularly warming, will have a dramatic impact on pest insects, and the recent trends of increasing outbreaks are expected to worsen. The greatest increase in mountain pine beetle outbreaks is expected to occur at high elevations, where models predict warmer temperatures will increase winter survival. At low elevations, however, mountain pine beetle populations may decrease as warmer temperatures disrupt the insects' seasonality. Climate change will also alter host susceptibility to infestation. Over the short-term, trees will likely increase in susceptibility to pests due to stress from fires, drought, and high temperatures; over the long-term, these stresses will cause tree ranges and distributions to change. Moreover, climate change and changes in CO2 and ozone may alter the conifers' defensive mechanisms and susceptibility to beetles through their effects on the production of plant secondary compounds.

Insect infestations are damaging millions of acres of western forests and there is clear evidence that damage is increasing. Nonetheless, future predictions of the extent of infestations remain uncertain because our understanding of insect infestations is incomplete. Key uncertainties include the influence of drought and precipitation changes, how altered forest/host composition will alter outbreaks, the biochemical response of trees and evolution of defensive mechanisms, regional differences, and the interactive effects of fire, plant disease, and insect outbreaks.

Extreme Events: Fire Activity

The increasing frequency of warm spring and summer temperatures, reduced winter precipitation, and earlier snowmelt in the West during the last 20 years has led to an increase in the frequency of very large wildfires and total acres burned annually. The relative influence of climate on fire behavior varies regionally and by ecosystem type, but generally current-year drought, low winter precipitation, wind conditions, and high summer temperature are determining factors for area burned in the Rockies.

Fire dynamics have been altered by climate indirectly through its effects on insect infestations and forest health. By changing the forest environment, bark beetles can influence the probability, extent, and behavior of fire events, but despite the widely held belief that bark beetle outbreaks set the stage for severe wildfires, few scientifically and statistically sound studies have been published on this topic. That fire promotes beetle infestations is clearer; the fire-caused injury changes conifers' volatile emissions, increasing their susceptibility to bark beetles.



Rapid climate and associated ecosystem transitions in the Rocky Mountains have occurred in the past and will likely occur in the future. Projections include a higher frequency of large fires, longer fire seasons, and an increased area of the western US burned by fire.

NPS / Jim Peaco

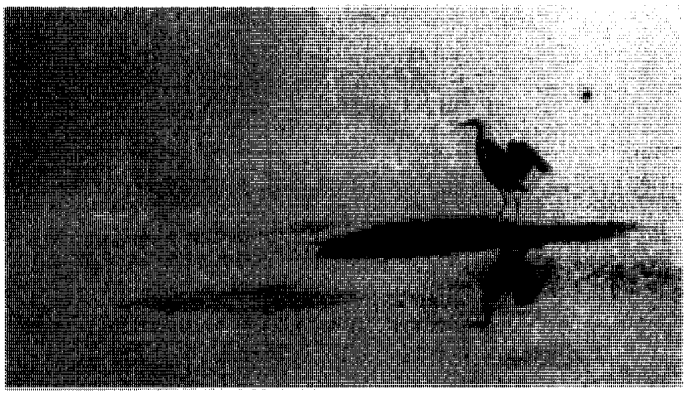
Future Fires

Most evidence suggests that climate change will bring increases in the frequency, intensity, severity, and average annual extent of wildland fires. Models project that numerous aspects of fire behavior will change, including longer fire seasons, more days with high fire danger, increased natural ignition frequency and fire severity, more frequent large fires, and more episodes of extreme fire behavior. The best evidence is for increases in the average annual area burned. However, the charcoal in lake sediment cores is telling a different story in Yellowstone. These records extend back 17,000 years, and were taken from Cygnet Lake on the Central Plateau. Charcoal from 8,000 years ago, when temperature increases equal what we are now experiencing, shows more frequent but smaller fires than today.

Projecting the influences of climate change on future patterns of fire is extremely difficult. Fuels, along with fire weather, determine fire size and severity: the stand-replacing fires of today open up the forests where stands have been burned, limiting fuels for the next fire. As a result, areas with frequent fires also tend to have small fires. Other factors, such as increases in non-native, annual grass invasions, may alter fire dynamics, making predictions based on climate alone difficult.

Climate Change

Yellowstone's climate is changing. A continued rise in temperature will fundamentally alter the ecosystem.

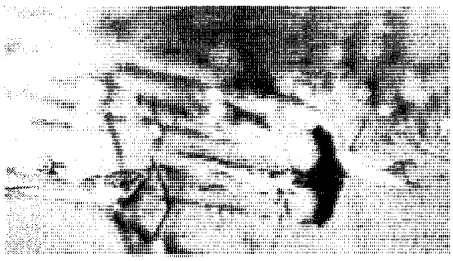


Examining the Evidence

Climate change is predicted to cause birds to shift their range, migratory patterns and timing, and interfere with reproduction.

Climate Change Explorer

The Climate Change Explorer is a tool that compares past averages to future predictions for variables in the Greater Yellowstone Area.



Greater Yellowstone Network

The Greater Yellowstone Network is one of 32 National Park Service Inventory and Monitoring networks that operate across the nation.

GLORIA

Global Observation Research Initiative In Alpine Environments (GLORIA) is a world-wide long-term monitoring network with sites in the park.

Last updated: December 5, 2017

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COVID-19 Response

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Examining the Evidence: Climate Change

Whitebark pine trees, living on the edge in high elevations, are vulnerable to climate change.

NPS / Diane Renkin

Insights from Paleoecology

As we think about and prepare for the future, it is important to learn what we can from past episodes of climate change. The study of paleoecology has provided insight into prehistoric changes in the ecosystem, including evidence of ancient plant and animal movements that have been preserved in fossil records. Studies conducted in the last 20 years have provided critical insights into past climate change and its ecological consequences in the GYE.

During the transition from glacial to Holocene conditions (ca. 14,000–9,000 years ago), temperatures rose at least 9°F–12°F (-13°C–11°C). As a result of rising temperatures, plant species expanded their ranges into newly available habitats forming new plant communities. Throughout the Holocene, climate variation of a lesser magnitude continued to occur, resulting in smaller shifts in species distributions and increased fire frequency during hotter and drier periods.

Though the changes documented in the paleo record occurred over longer periods of time, drawing from the past of this region can help to gauge the potential for future changes. If future climate change is of similar magnitude to the changes that occurred in the past 9,000 years, it is likely that Yellowstone's ecosystems will change to some extent, but probably not to any great degree. However, if the magnitude of future change is comparable to that of the glacial to Holocene transition, then enormous changes are possible—even likely.

Heeding the Signs of Change

Aspen

Findings from research focusing on aspen forests indicate a possible shift in the distribution of this important species may already be underway. By comparing documentation of aspen regeneration before and after the 1988 fires, experts found evidence suggesting that the sexual reproduction of aspen in the Rocky Mountains occurs primarily after large severe fires. Prior to 1988, aspen regeneration was understood to occur primarily via vegetative root sprouting. Aspen seedlings, rarely documented prior to the fires, were observed in 1988 burn areas, including areas where aspen had not been present before the fires, often many kilometers from pre-fire aspen stands. Aspen seedlings have persisted in many areas, and in some instances expanded into higher elevations since 1988. Meanwhile, aspen forests at the lowest elevations and on the driest sites have declined throughout much of the western U.S. in response to severe drought in the early 2000s. Research is ongoing to fully understand the processes at work, but the pattern is consistent with expectations of shifts in species ranges from a warming climate.

Whitebark Pine

Five-needle pine trees are foundational species in high-elevation ecosystems across the West. For the sub-alpine species whitebark pine (Pinus albicaulis), warming temperatures may indirectly result in loss of suitable habitat, reducing its distribution within its historic range over the next century. Whitebark pine is associated with lower summer maximum temperatures and adequate springtime snowpack for survival.

Modeling of whitebark pine habitat in the greater Yellowstone area predicts that suitable habitat will decrease over time and the species may only be able to survive at the highest elevations, although it is likely that there will remain microrefugia (small areas with suitable climates) of whitebark pine throughout the region.

Given the ecological importance of whitebark pine, and that 98% of the species occurs on public lands, an interagency whitebark pine monitoring group, including the National Park Service, US Forest Service, Bureau of Land Management, and US Geological Survey, has been monitoring the status and trend of whitebark pine stands since 2004.

Sagebrush Steppe

Sagebrush steppe is one of the most altered ecosystems in the intermountain West. Substantial sagebrush areas have been converted to agriculture, heavily grazed, and degraded through altered fire regimes and the invasion of nonnative plants. Changes in climate are expected to further alter fire regimes and increase invasive species in sagebrush steppe and low-elevation woodlands. Yellowstone National Park also has upland vegetation data that may be useful in addressing climate change responses in sagebrush-steppe and grassland systems and initiated a long-term monitoring program of sagebrush steppe habitats across the park in 2015.

Alpine Vegetation and Soils

The cold and relatively little-studied alpine ecosystems, are among those where climate change impacts are expected to be pronounced and detectable early on. The Greater Yellowstone and Rocky Mountain networks collaborated to implement alpine vegetation and soils monitoring in high elevation parks. National parks including Glacier, Yellowstone, Rocky Mountain, and Great Sand Dunes are now participants in the Global Observation Research Initiative in Alpine Environments (GLORIA) monitoring network. Monitoring includes sampling of vascular plants, soil temperature, air, and temperature at a set of four alpine summits along an elevation gradient. This set of sites span alpine environments from northwest Montana to southern Colorado. Information is available through the GLORIA website at **http://www.gloria.ac.at/**.

Wetlands

Wetlands in Yellowstone are few and far between, and include small lakes and kettle ponds, which are already drying up. Scientists don't know how much ground-water recharge they will need to recover. However, precipitation and snowpack will likely continue to decrease, which will continue to decrease surface and ground water—and thus the lakes and ponds may not recover. Recognizing that many of these small water basins are already drying, the park began to monitor groundwater hydrology in 2012 to understand the drivers and variability in groundwater flow patterns. The baseline information obtained from these select sites further informs the anticipated consequences under changing climatic conditions. As wetlands diminish, sedges, rushes, and other mesic (water-loving) plants will likely decline. In turn, amphibians and some birds will also lose habitat.

Annual monitoring data suggest chronic repetition of dry, warm years, could lead to a decline in upwards of 40% of the region's wetlands. This decline could ultimately reduce the distribution and abundance of wetland-dependent species, including boreal chorus frogs.

Chorus frogs prefer shallow, ephemeral wetland habitats, making them especially vulnerable to climate change. Boreal chorus frog breeding habitat responded negatively to dry, warm years. Some sites where breeding was documented dried up prior to completion of amphibian metamorphosis, which can cause reproductive failure. The strong relationship between annual runoff, wetland inundation, and chorus frog breeding occurrence suggests increasingly difficult conditions for amphibians if projected drought increases occur.

Declines in water levels and drying conditions could affect other species which are dependent on inundated wetlands for survival like, moose, beaver, trumpeter swans, and sandhill cranes. In addition, wetland loss is expected to reduce plant productivity, which in turn impacts the carbon sequestration potential of landscapes, affects hydrologic flow paths and water storage within floodplains and uplands, alters

GLORIA

Global Observation Research Initiative In Alpine Environments (GLORIA) is a world-wide long-term monitoring network with sites in the park.

soundscapes, affects wildlife viewing opportunities, and potentially removing natural fire breaks important for managing low to moderate intensity wildfires.

In the past several decades, Yellowstone staff have noticed drops in pond water levels on the northern range. Alterations in water availability and forage could have huge implications for wildlife, especially waterfowl and amphibians.

Jennifer Whipple

Understanding how climate change will influence wildlife requires a comprehensive understanding of the park's climate system and how it interacts with both plants and animals. Clear predictions are difficult to make, but many current and potential impacts have been identified.

- Wolverines require deep snow to build the dens in which they breed and raise their young. Decrease in annual snowpack may cause a decline in wolverine populations.
- Wolves take advantage of deep snow to prey upon long-legged, small footed ungulates who are less agile in extreme winter conditions. Decrease in annual snowpack may decrease wolf hunting success.
- Elk and pronghorn migration is triggered by a number of factors including hours of daylight—a factor unaffected by climate change. However, early spring green-up could leave them migrating after their forage has lost much of its initial nutritional value, or earlier peak stream water flow could force them to change their migration routes.
- The tiny pika tolerates a very narrow habitat range. As the climate zone they live in shifts to higher elevation, pika must move with it.
- Due to extended warm temperatures in fall, male grizzly bears are tending to den later, which exposes them to risks associated with hunting of elk outside of the park boundary.
- Foxes have to adapt to harder snow surfaces. Harder snow surfaces decrease access to rodents but increase access to carcasses.
- Increased water levels over extended periods on Yellowstone Lake have interfered with pelican reproduction. Extended periods of high water caused by snowmelt in early summer not only flood existing nests, but prevent pelicans from re-nesting. High lake levels also reduce foraging success.

Climate change is predicted to cause birds to shift their range, migratory patterns and timing, and interfere with reproduction.

NPS / Neal Herbert

Climate change is anticipated to cause changes in the distribution and abundance of many species in Yellowstone. Thanks to the growing library of field studies and the availability of increasingly fine-tuned global climate models, ecologists are in a good position to deepen our understanding of how plants, animals, ecosystems, and whole landscapes respond to climate change, and consequently, to think about how the GYE is likely to change in the coming century.

Changes in Yellowstone Climate

Scientists with the National Park Service and other organizations closely monitor variables that may reflect a changing climate.

Climate Change

Yellowstone's climate is changing. A continued rise in temperature will fundamentally alter the ecosystem.

Management and Monitoring

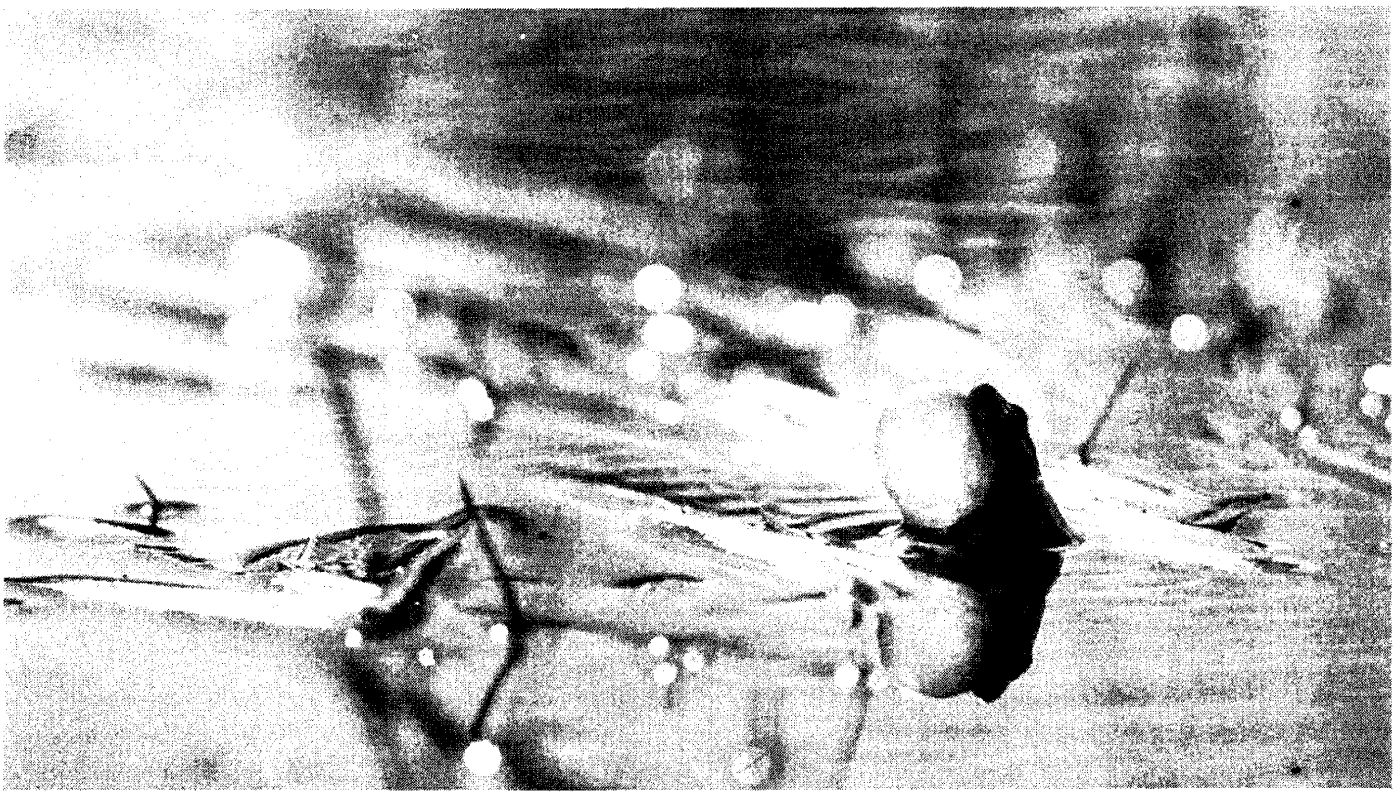
Many national parks and other protected areas were set up to safeguard a wide range of plant and animal life assuming a certain set of climate conditions. As the climate drivers change, the natural ecosystem and human use of that landscape are bound to change. Even subtle shifts in climate can create substantial changes—nature will begin to rearrange itself, and our ability to protect and manage national parks will be challenged.

In 2010, the National Park Service released its Climate Change Response Strategy. The Climate Change Response Strategy provides direction to our agency and employees to address the impacts of climate change. It describes goals and objectives to guide our actions under four integrated components:

Science

> Park scientists conduct research to help us understand the effects of climate change on national parks. The National Park Service also collaborates with other scientific agencies and institutions to discover the best available climate science. This information is then applied to address the specific needs of park managers and park partners as they confront the challenges of climate change.

The Greater Yellowstone Network (GRYN) conducts high-quality natural resource monitoring and collects robust inventory data to track changes in resources as they occur. In support of this reporting the interactive web site **www.climateanalyzer.org** provides climate data for many locations across the country. GRYN is part of the National Park Service High Elevation Climate Change Response Monitoring Program, along with the Rocky Mountain Network and the Upper Columbia Basin Network, created to measure changes in resources as a result of climate change.



Greater Yellowstone Network

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Mitigation

> The most effective way to lessen the long-term effects of climate change is to reduce greenhouse gas emissions. The National Park Service aims to be a leader in reducing its carbon footprint through energy efficient practices and integrating climate-friendly practices into administration, planning, and workforce culture.

The *Green Parks Plan* defines a collective vision and a strategic plan for sustainable operations in the National Park Service. The plan is framed around nine categories and sets ambitious goals to make the National Park Service a worldwide leader in sustainability:

- Continuously Improve Environmental Performance
- Be Climate Friendly and Climate Ready
- Be Energy Smart
- Be Water Wise
- Green Our Rides
- Buy Green and Reduce, Reuse, Recycle
- Preserve Outdoor Values
- Adopt Best Practices
- Foster Sustainability Beyond Our Boundaries

The *Climate Friendly Parks (CFP) Program*, of which Yellowstone is a member, is one component of the NPS Green Parks Plan. The program supports parks in developing an integrated approach to address climate change through implementing sustainable practices

throughout their operations. Since 2003, the program has assisted parks with:

- Measuring park-based greenhouse gas (GHG) emissions
- Educating staff, partners, stakeholders, and the public about climate change and demonstrate ways individuals and groups can take action to address the issue
- Developing strategies and specific actions to address sustainability challenges, reduce GHG emissions, and anticipate the impacts of climate change on park resources.

The CFP Program includes over 120 member parks dedicated to reducing resource consumption, decreasing GHG emissions, and educating park staff and the public about climate change and sustainable initiatives taking place across the agency.

Adaptation

Climate change will alter park ecosystems in fundamental ways. The National Park Service must remain flexible amidst this changing landscape and uncertain future. In some cases we must take bold and immediate actions, while in others we may be methodical and cautious. Many techniques will be utilized, evaluated, and refined as new science becomes available and the future of climate change unfolds.

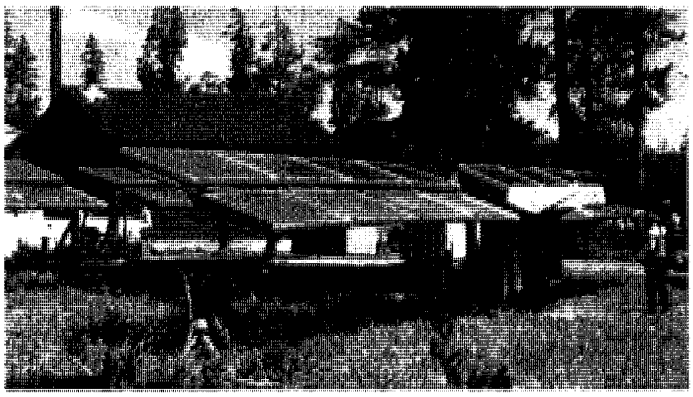
Communication

National parks are visible examples of how climate change can affect natural and cultural resources. Park rangers engage visitors about climate change by sharing information concerning the impacts to parks and steps the agency is taking to preserve our heritage.

Outlook

The complexity of the global climate system means that there is no one, "best" model for predicting the future climate everywhere on the earth. Instead, scientists use a group of different models that are all good at predicting some part of the answer. Usually, the greatest differences among predictions are not caused by the mathematical methods used to model the climate system. Most uncertainty is due to the difficulty in predicting what people will do. If climate scientists knew what choices humans were going to make about limiting greenhouse gas emissions, then their predictions about climate change would be much more certain.

Climate change is generally not an easy or pleasant conversation piece. However, it is a conversation that we need to have, and a process we must continue to study. Humans will need to adapt, as will wildlife and ecosystems. Through better understanding, we may arrive at more informed decisions to help conserve and adapt to our changing environment.



Conservation Measures

The solar panels at Bechler Ranger Station are one of many energy

Sustainability

We strive to demonstrate and promote sound environmental

conservation projects parkwide. stewardship.

☑ **Climate Change and The Greater Yellowstone Ecosystem**

The Issue

The global climate is changing, and is already affecting the Greater Yellowstone Ecosystem.

- Average temperatures in the park are higher now than they were 50 years ago, especially during springtime. Nighttime temperatures seem to be increasing more rapidly than daytime temperatures.
- In the last 50 years, the growing season (the time between the last freeze of spring and the first freeze of fall) has increased by roughly 30 days in some areas of the park.
- At the northeast entrance, there are now 80 more days per year above freezing than there were in the 1960s.
- There are approximately 30 fewer days per year with snow on the ground than there were in the 1960s.

Climate change impacts are detected by studying

- Vegetation
- Snowpack
- Phenology (timing of significant biological events like the budding of trees or arrival of migratory birds in the spring)
- Alpine habitats
- Wildlife movement patterns
- Water
- Fire
- Insect infestations
- Wetlands

The continued rise in temperature will fundamentally alter Yellowstone's ecosystem:

- Likely affecting the composition of plants and animals throughout the park.
- Altering the amount and timing of spring snowmelt, which affects water levels, vegetation growth, and the movement of wildlife from migrating bison to spawning trout to the arrival of pollinators. As headwaters to significant water basins, any change in the rivers flowing out of Yellowstone affects downstream users like ranchers, farmers, towns, and cities.
- Fire frequency and season length could increase.

Last updated: April 24, 2018

CONTACT THE PARK

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TO: Montana Fish and Wildlife Commission

FROM: Mark E. Odegard; GrizGeo, LLC; Ennis, MT meo@grizgeo.com

Commissioners:

General Comments from Mark E. Odegard a member of the now defunct

"MADISON RIVER NEGOTIATED RULEMAKING COMMITTEE"

During our meetings it became clearer to me that there was not enough evidence that the rather harsh rules that were suggested in the 19 April 2018 "DRAFT RECREATION MANAGEMENT PLAN - ENVIRONMENTAL ASSESSMENT" needed to be implemented. This was also brought out during our evaluation of the various alternatives. Most of the alternative "consequences" used in the evaluation were related to the effect on users of the River. The "Status Quo" scored in the same range as the best alternative as shown in Figure 1. **This says that doing nothing at this time is as good as anything else.**

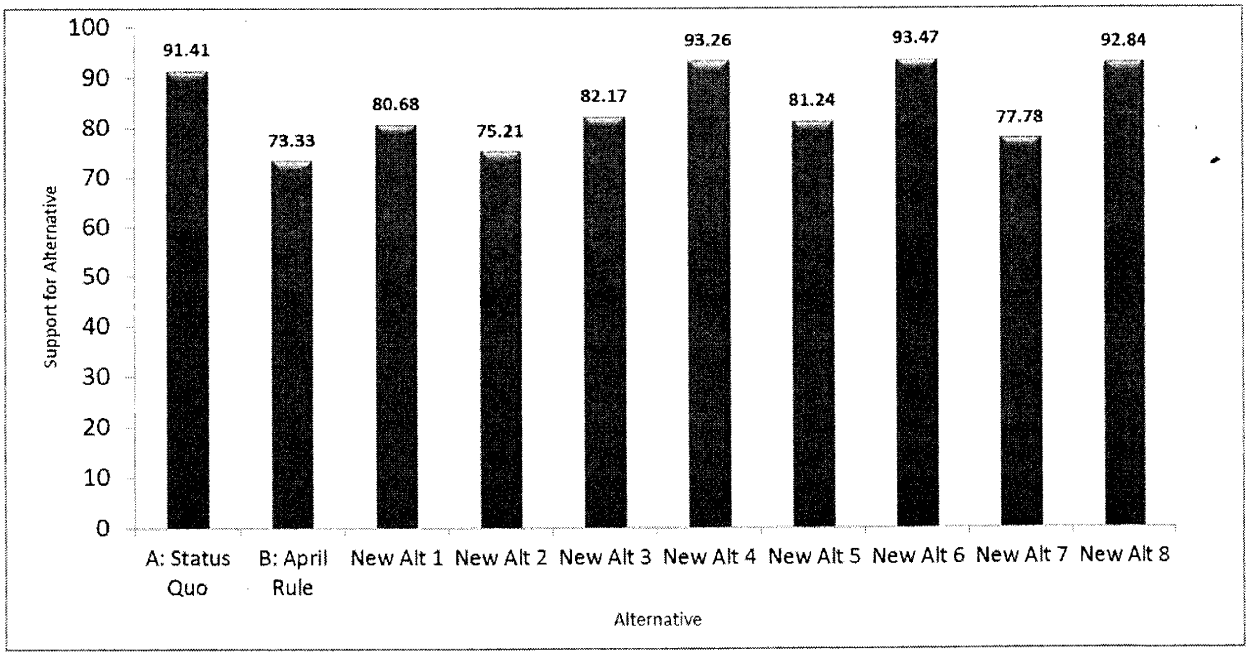

Figure 1: Scores of the various alternatives based on the consequences estimated by the group, the SDM decision analysis resulted in the following rankings of support for the alternatives. Higher scores indicate the alternative is predicted to do a better job at achieving objectives

Fishery

In addition, the Administrative Rule of Montana (ARM) 12.11.410 (1), shown below, states that the primary concerns for management of the River are basically the preservation of naturally occurring resources, with the highest priority that of the quality of the fishery. **From the data that we were given the fishery appears to be in good shape and does not indicate degradation at this time.** Items (2) and (3) offer some, non-quantitative guidelines, but the need does not seem necessary. **This is because the current quantity of recreational use has not affected the fishery or other factors as yet.**

12.11.410 RIVER RECREATION MANAGEMENT PLANS AND RULES GENERALLY
(1) The highest priority of a management plan is providing protection for the following resources:
(a) the quality of the fisheries;
(b) wildlife;
(c) water;
(d) riparian habitat; and
(e) other natural resources in or along the river.
(2) Management plans or rules must not allow unlimited recreation to compromise long-term conservation.
(3) Management plans and rules must maintain a balance between quality of experience and unlimited quantity of experience.

Experience

We were also presented the "Angler Satisfaction, Demographic, and Creel Surveys-Upper Madison River, 2015 – 2017" data showing some significant dissatisfaction primarily with the resident float fishermen and primarily in the mail survey. In my experience, having fished many of the western rivers, and having some experience with surveys, I make these comments:

(1) Mail surveys are typically a problem in that dissatisfied people are more disposed to returning the surveys since they are dissatisfied. People with a satisfied or neutral experience do not have as much incentive to return a survey. There are some methods to mitigate these differences, but I don't know if any were employed.

(2) Having experienced near "Shoulder to Shoulder" fishing on rivers such as the Columbia and the Klamath in California, the limited crowding I see on the Madison is minimal in comparison. I too would like the number of fishermen to be at the same level as I fished with in the 1950's but that is impossible. **I think the Madison fishing experience should be extended to as many as possible. I am not a "I've got mine, you can't have yours" person.**

One thing I pointed out during the presentation on this is that anglers were only classified as "resident" or "non-resident". Many people who live in the Ennis area and fish the River own land and dwellings but are part-time residents. These people, and land owners also have a vested interest in the health of the River. We have found in our Zoning Commission meetings that they make contributions, sometimes more than full-time residents. **This distinction should be included in future surveys.**

Economics and Business Development

As was pointed out in many comments at the end of our meetings, the management of the River will have a significant effect on towns and businesses along the River, and on those nearby as well. In reading the environmental assessment, no quantitative data were presented. There were statements that "FWP predicts", but no details on how the predictions were determined, or on how any "prediction" was arrived at.

The main conclusion was that any management plan would not affect the overall economy of the State. **To me this says that the effect on local economies of Ennis, West Yellowstone, Three Forks, and all the small businesses along the River is not important to FWP and the Commission.**

The big problem with implementing a management plan quickly is the effect on current business planning in the River area. Developments are proceeding that assume there will be continued economic growth. These developments have already committed significant time and money. Any short-term implementation of a management plan would have severe consequences. **Any plan should be announced well ahead of implementation and/or phased in over a significant period of time.**

Commercial Float Fishing

The path favored by the MRCAC, FWP and the Commission to manage use of the River was to limit the number of guided, commercial float trips. I just do not understand the logic in this. The only effects will be a **small** limitation on the total number of angler days and the number recreational user days. It will not limit growth in the number of non-commercial float trips. And it will not limit the total number of anglers and recreational River users.

From my experience with other rivers, the only way to limit the total number of user days is with a permit plan. This, of course, is politically a problem, but will become necessary with time. **Any limitations should affect all user groups. I have great reservations about any plan that would target a single group simply because that is the easiest thing to do.**

Areas of Interest

I have included below, comments on two of the reaches of the River. These utilize an integrated ArcGIS project that I developed to help me understand the River system. It's the kind of work I do professionally for the oil, mining and environmental industries. In doing this I have found, as usual, inconsistencies in available data. There are also new questions that have come up. **I will probably keep on working on this as my schedule allows including doing some survey QA/QC.**

Comments on the Future of the Madison River

The two main and existential threats to the health of the River are (1) increase population in area of the Madison River, (2) a warming of the river, and (3) early, rapid melting of the snow-pack which will reduce summer and early fall flows to a dangerous level.

The second two threats are a result of global warming/climate change. The first threat is already occurring and will be exacerbated by climate change. Eventually normal population growth will be overwhelmed by climate migration, which is already beginning to occur.

I have included a PowerPoint presentation on global warming which I originally developed for use by the Ennis Zoning Commission because of the effects of population growth. I have modified parts of it dealing with the Madison River.

My, and others, main conclusion is that global warming to a temperature far above what we had hoped to limit it is now inevitable and will have a severe environmental impact.

I have been worrying about and following global warming, which is part of Earth sciences, since the late 60's. Much of what we know was known or suspected by then and in the 70's. Modeling has been developed which has led to quantitative predictability. I have carried these predictions a little further than most investigators who are generally afraid that the consequences will be to horrific and will not be believed. This could lead to loss of tenure in an academic setting or to the problems that the EPA has been subjected to. I am not constrained by these problems. My scientific reputation is secure.

At the end of these comments is also a non-color print out of the PPT with added comments. These comments include references of interest.

What to DO?

A plan should be developed for the management of the Madison River that takes account of all factors. This should include the identification of "tipping points" that trigger new initiatives (i.e. restrictions, permitting, etc.) This will be difficult.

Mark E. Odegard
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TO: Montana Fish and Wildlife Commission

FROM: Mark E. Odegard; GrizGeo, LLC; Ennis, MT meo@grizgeo.com

Commissioners:

Comments on the Ennis FAS to Ennis Lake Section

The following figures are from the ArcGIS project I developed and from Google Earth. Note that the colors on entities controlling the land parcel are RED – FWP; Yellow – other State of Montana; Green – US Forest Service; Redish-Brown – BLM, USDA; and Pink – unknown or public, but probably all public lands. Background is the State of Montana's NAIP Arial Photographs from the State Library.

My experience

This has been my primary fishing area on the Madison since I was about 10 years old. My experience is that fishing success has been similar over that period. I was fishing Salmon and Steel Head in the Columbia River Basin during the "whirling disease" so I did not experience that period.

Access

Figure 1 is from the Ennis FAS to the Valley Garden FAS. Access is generally unrestricted in this area. Figure 2 is from the Valley Garden FAS to Ennis Lake. Figure 3 shows a Global Earth image of the location of a fence down to the river's edge with a FWP sign saying there is no access to the private land behind the sign. This effectively limits access down river from this sign during a lot of the year. This leads to overcrowding in the accessible section.

There is potentially acces to the river above the lake through the BLM land on the south-east side of the lake to the river through the land inside the pink. I have not tried this and do not know if the footing is OK or if there are fences.

What this means is that for much of the year a little over one-third of this part of the river is only accessable using a personal water-craft for wade fisher-people. And if one is used it would need to be taken out at one of the FAS's or the BLM sites, which would require a shuttle. I can't afford a shuttle.

In the 19 April 2018 "DRAFT RECREATION MANAGEMENT PLAN - ENVIRONMENTAL ASSESSMENT" it states: "Conversely, the upper and lower wade-only reaches offer great access and opportunity for wading anglers." As I have shown, the is not exactly the case.

I would propose that this remain as a Wade-Only sections. Also that float access be allowed in wade-only sections but no float-fishing. Float access is importan for the young, the old and the disabled. I do not know what should be done with the other wade only section as I have not fished it in a long time.

Due to the warming climate this sections will probably have hoot-owl restrictions imposed on it in the near future. I understand from the FWP that the temperatures are already reaching this limit. I would propose moving the wade-only section up-river when this occures.

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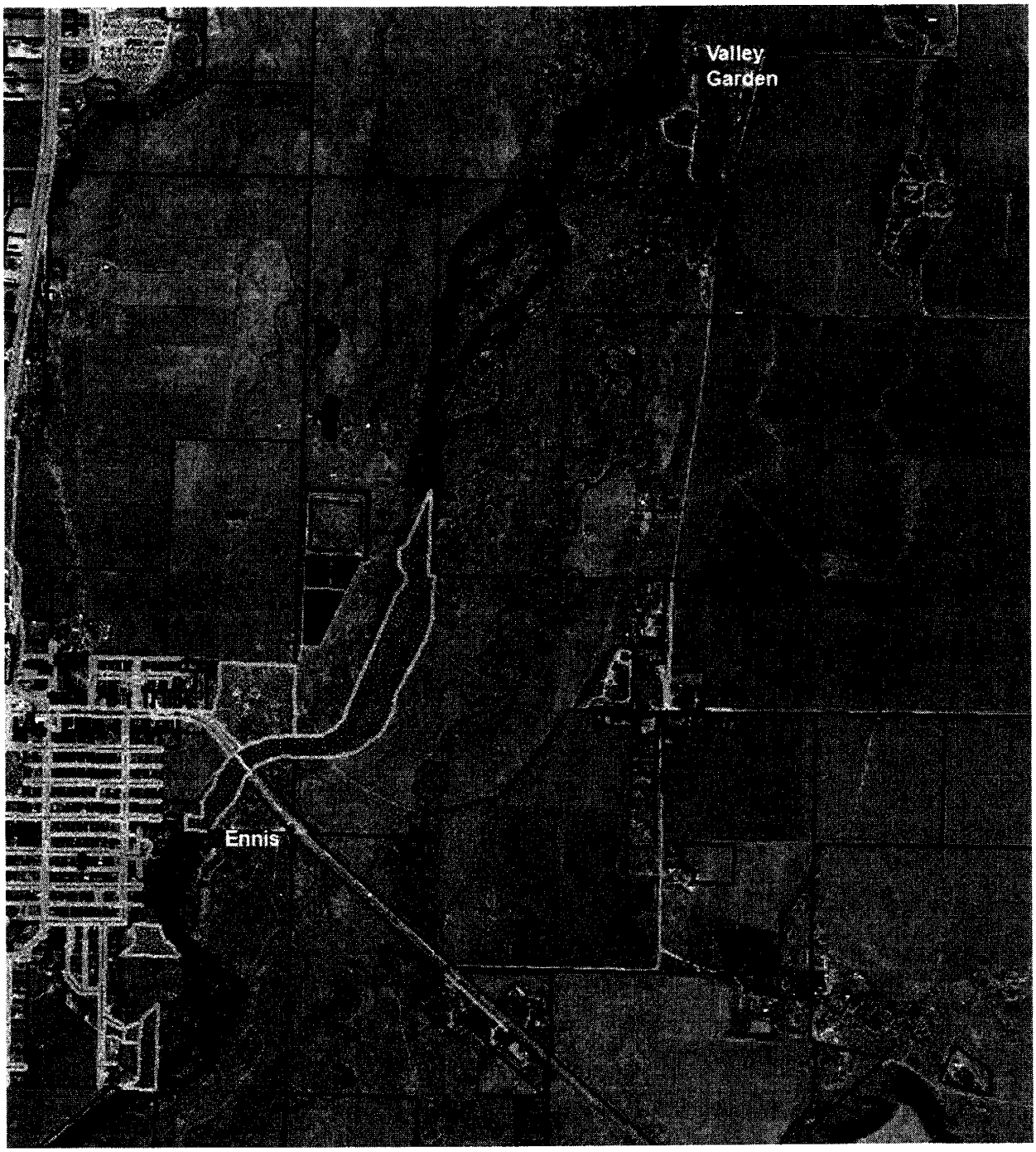

Figure 1: Ennis FAS to the Valley Garden FAS. I understand that the FWP land has been extended to the other side of highway 287 to possibly link with a trail on the moved Varney Bridge over the river from the park in Ennis.

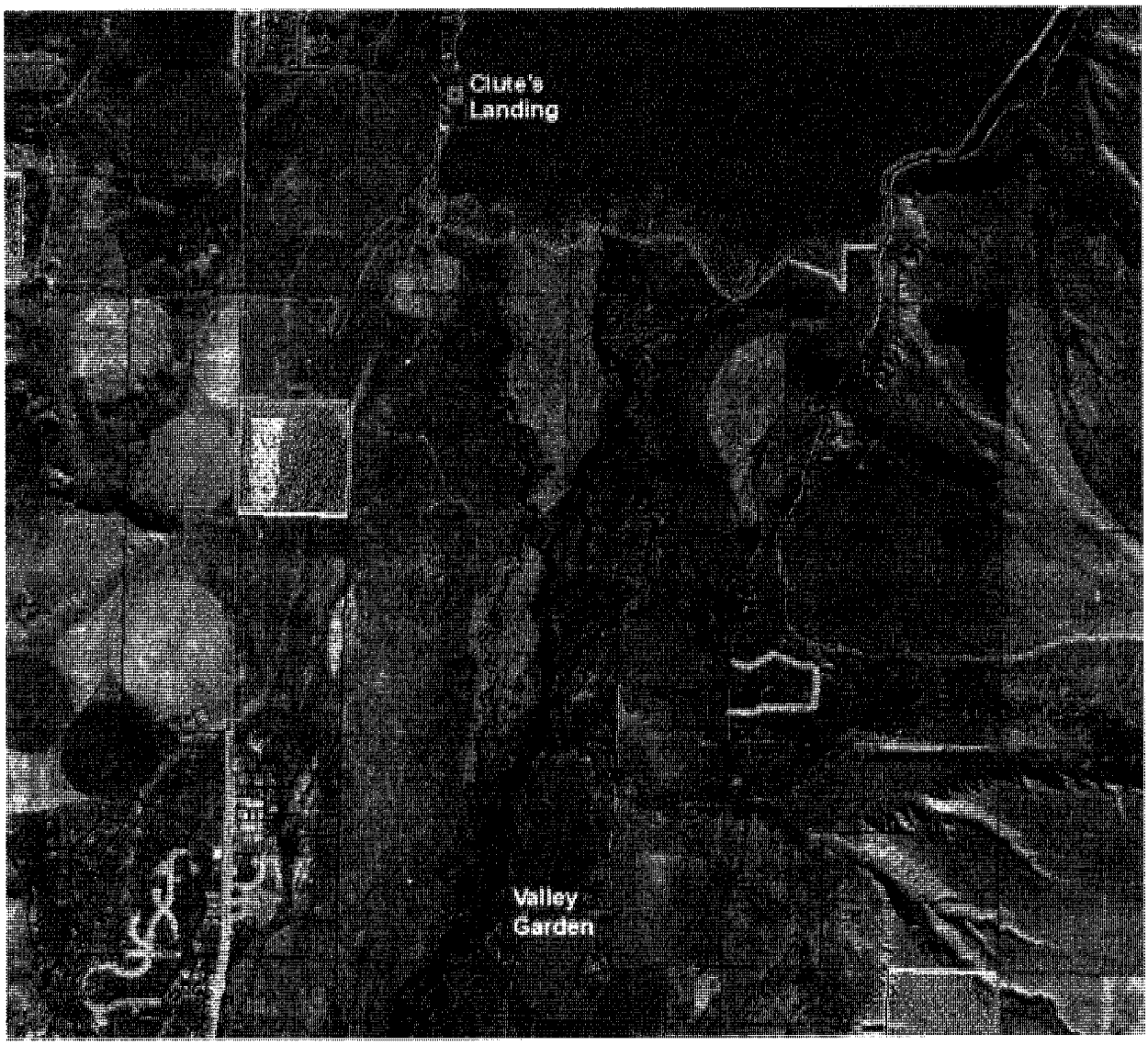

Figure 2: Valley Garden FAS to Ennis Lake. The BLM land is in the northeast corner of the image.

Figure 3: Google Earth image of the location of a fence down to the river's edge with a FWP sign (arrow) saying there is no access to the private land behind the sign. The river course has changed since this image was made and now limits access to wading in the river or by watercraft. If the river is high, wading is dangerous. The bank is very steep in this area. This is the NE limit of the Valley Garden FAS.

TO: Montana Fish and Wildlife Commission

FROM: Mark E. Odegard; GrizGeo, LLC; Ennis, MT meo@grizgeo.com

Commissioners:

Comments on the Madison River below Black's Ford FAS.

The following figures are from the ArcGIS project I developed and from Google Earth. Note that the colors on entities controlling the land parcel are RED – FWP; Yellow – other State of Montana; Green – US Forest Service; Reddish-Brown – BLM & USDA; and Pink – unknown and public, but probably all public lands.

My experience

I have only fished part of this section, mainly just down from Black's Ford. I did not realize that there was as much access as there is.

Access

Figure 1 is from the Black's Ford FAS to the Greycliff FAS, FWP land. Access is generally unrestricted in this area. Figure 2 and 3 show the other parts of the river in this area. The backgrounds are the State of Montana's NAIP Arial Photographs from the State Library.

Figures 4 to 6 show the same areas but with the higher resolution Google Earth images.

In the 19 April 2018 "DRAFT RECREATION MANAGEMENT PLAN - ENVIRONMENTAL ASSESSMENT" it continually states: "The 18.9-mile reach of the lower Madison River between Greycliff FAS and the confluence with the Jefferson River is one of the most scenic and least developed reaches of the river." I would disagree with some of this statement. The area currently has minimal development, but outside of the FWP, State and public lands the area can have significant commercial and non-commercial development. I would also contend that the area is not particularly scenic as shown in Figures 9 and 10. The area will probably also see rapid development as soon as the water resources around Bozeman become totally used. (See my submitted climate change PPT and PDF.)

Figures 7 to 9 show the area around the Climbing Arrow Bridge. This area contains some public land at the bridge site. This could be used for fishing access. There are also roads along irrigation ditches near the river.

Because the land along about half of this section of the river (almost all below the Cobblestone area) is private there is limited access in these areas to wade fishermen. I would propose making access possible at the Climbing Arrow Bridge site. The reason use of this part of the river is limited is because the access is limited. I am sure the private landowners like this. **These owners can develop up to the rivers high-water limit, which will make the scenic designation totally irrelevant.**

For the same reasons I cannot understand why the Commission would want to limit the currently, very light commercial use on the river, other than to satisfy private landowners.

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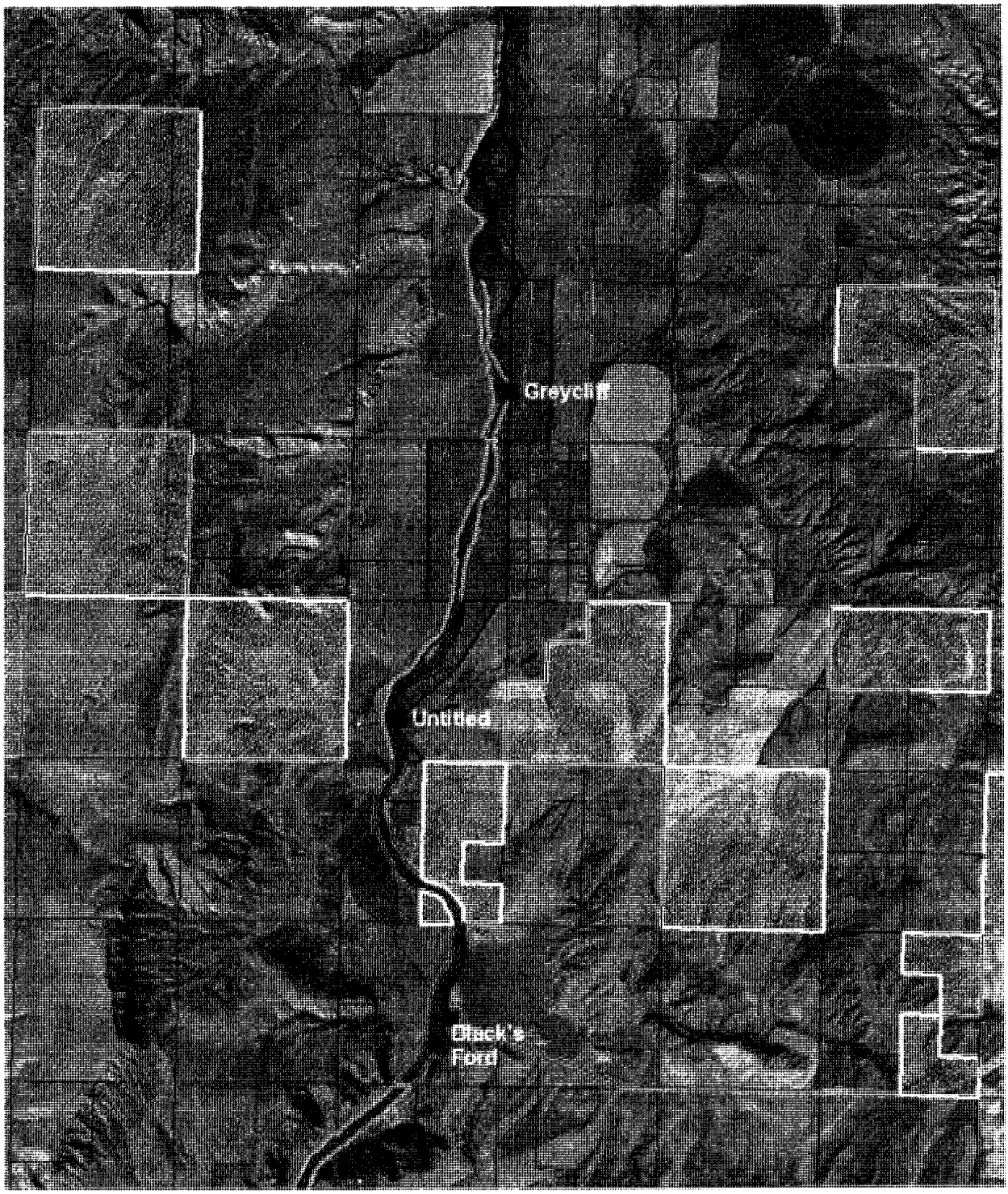

Figure 1: Black's Ford FAS to Greycliff FAS. Most of this section of the river is public land with private land outside the boundaries. Note that the "Untitled" FAS is not in the FWP GIS data base or in the FAS pamphlet. I don't think there is any document showing the location of public lands along this section of the river.

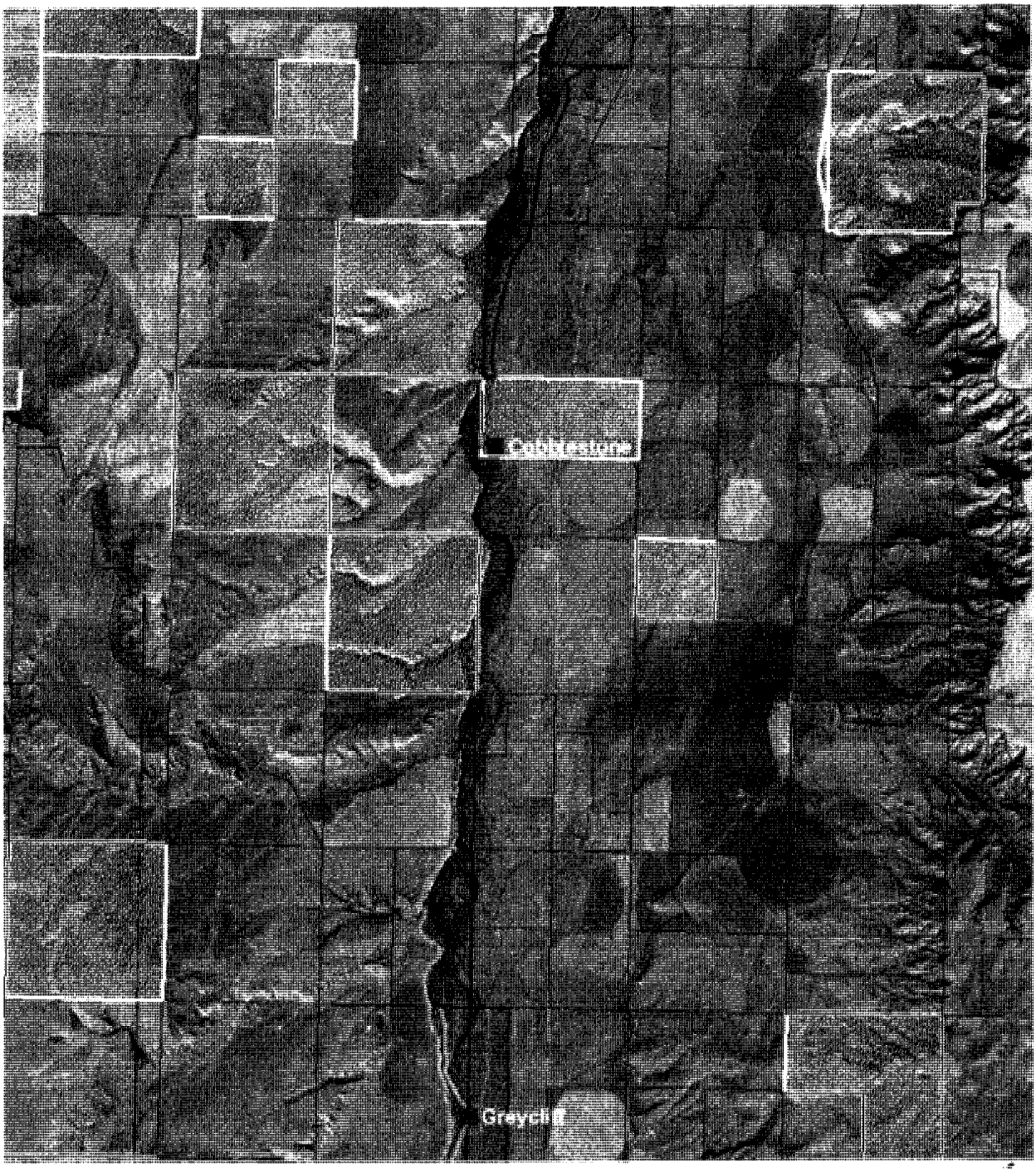

Figure 2: Greycliff FAS to Cobblestone FAS. About half the land along the river is private.

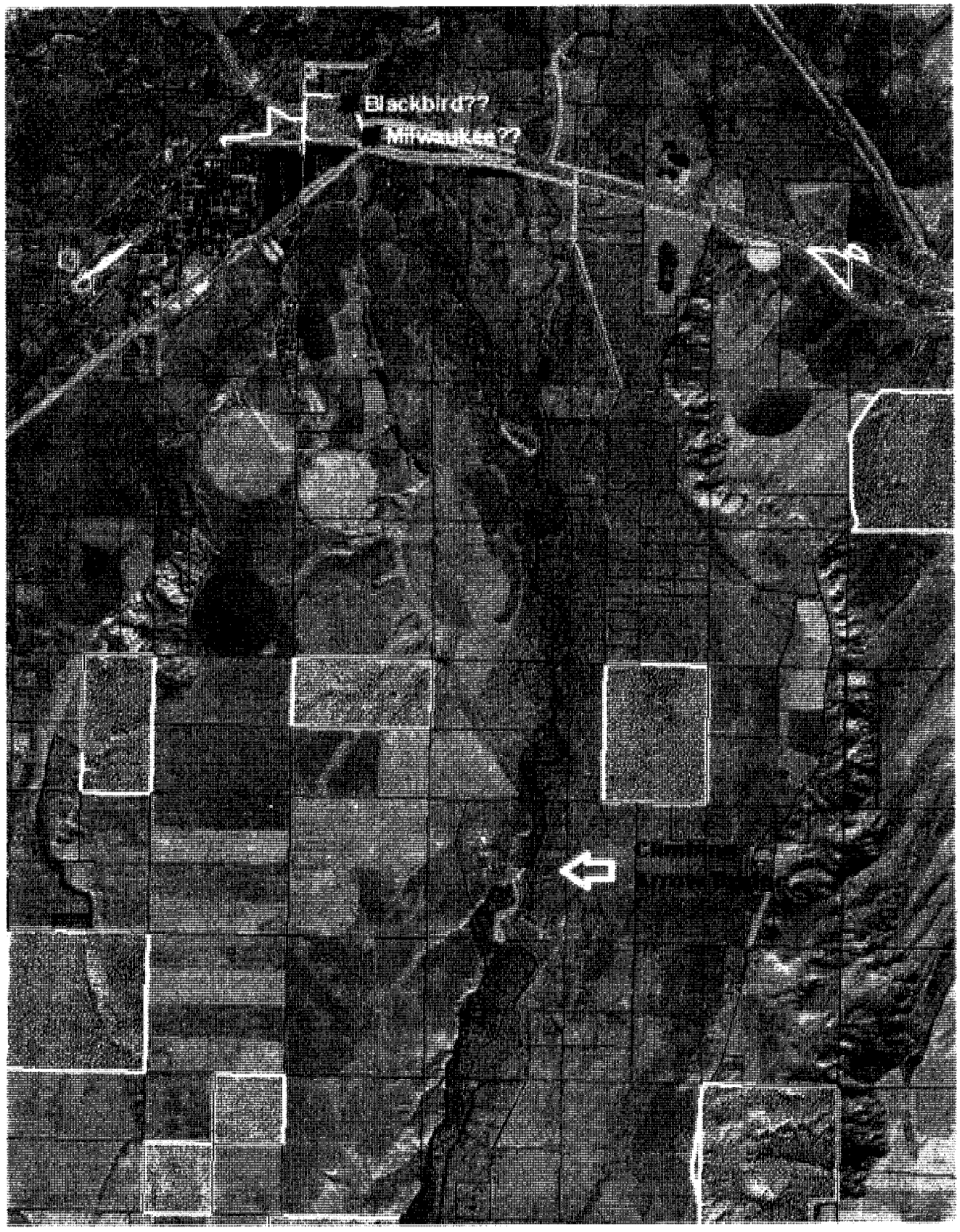

Figure 3: Shows the area of the river from the FWP land north of the Cobbelstone FAS to the confluence with the Jefferson River. Most of the river banks are in private hands. Note the Climbing Arrow Bridge location.

Figure 4: Google Earth image from Black's Ford to just down river from the Greycliff FAS.

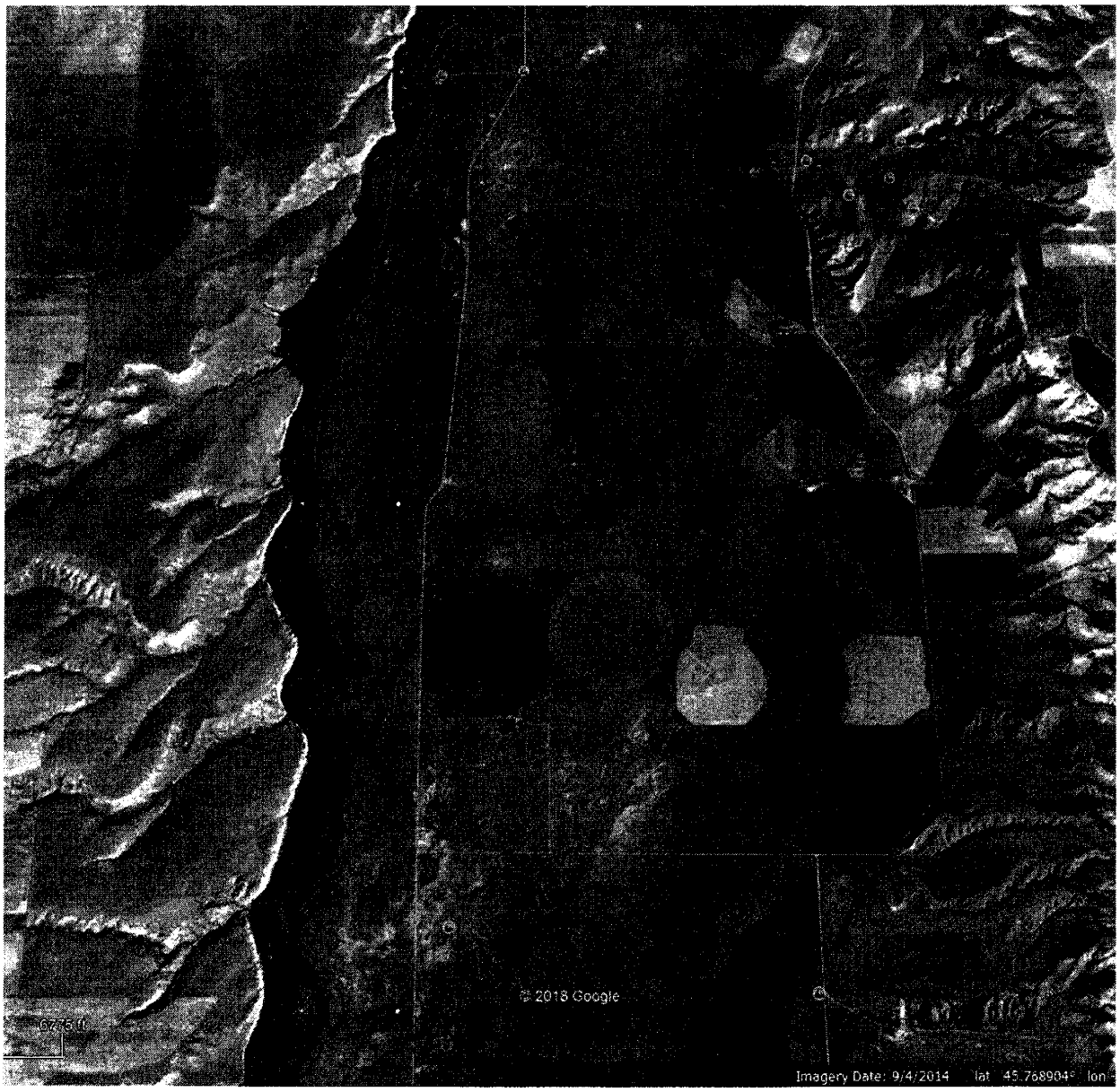

Figure 5: Google Earth image from just down river of the Greycliff FAS to the Cobblestone FAS.

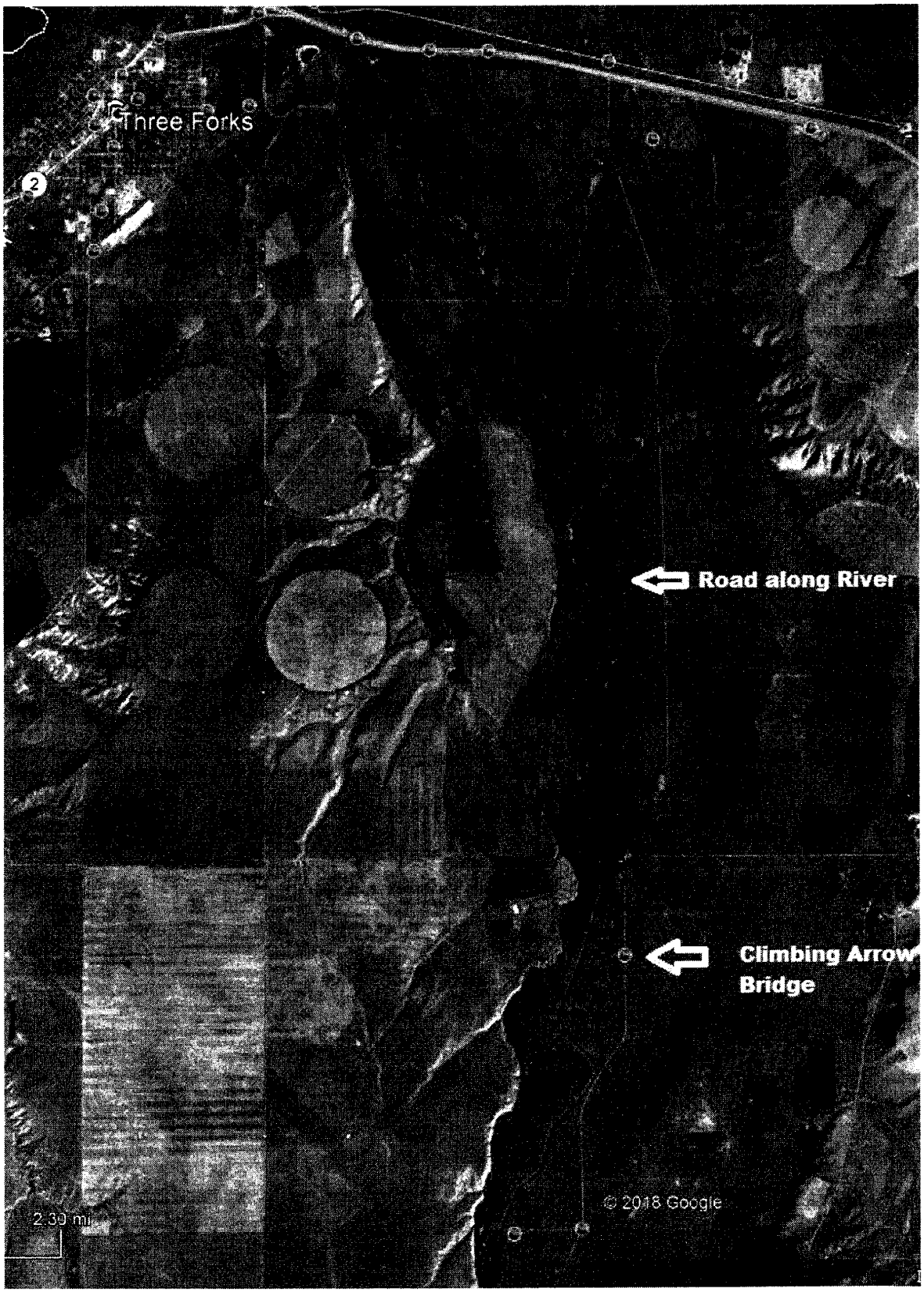

Figure 6: Google Earth image from Cobblestone FAS to I90. Note road and bridge.

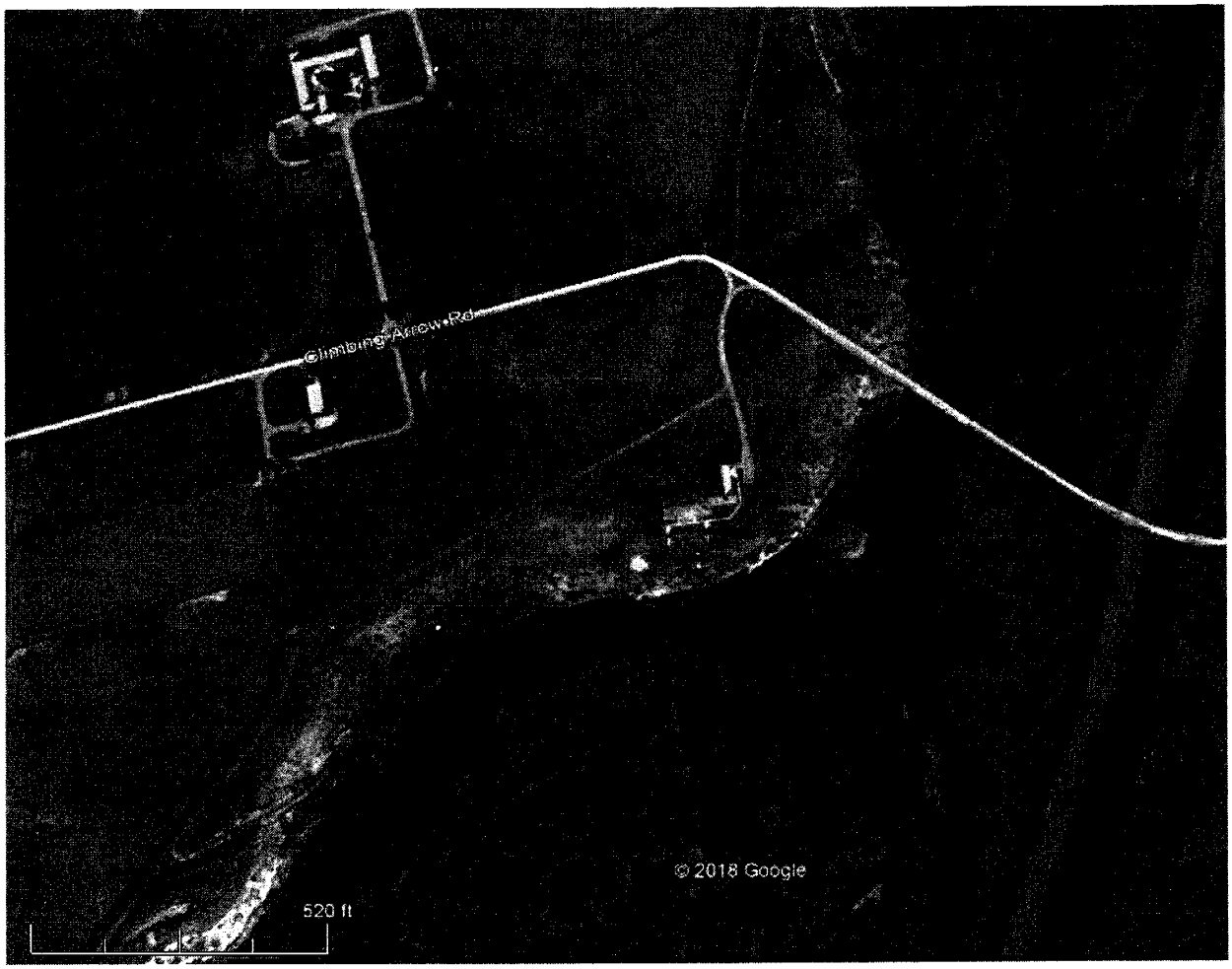

Figure 7: Google Earth image of the Climbing Arrow bridge area. The road along the river is on the left of the image.

Figure 8. ArcGIS image of the Climbing Arrow Bridge area. There appears to be public land around the bridge and up and down River, but no FAS. The road in this area is also along an irrigation ditch. Not sure if the road has an easement.

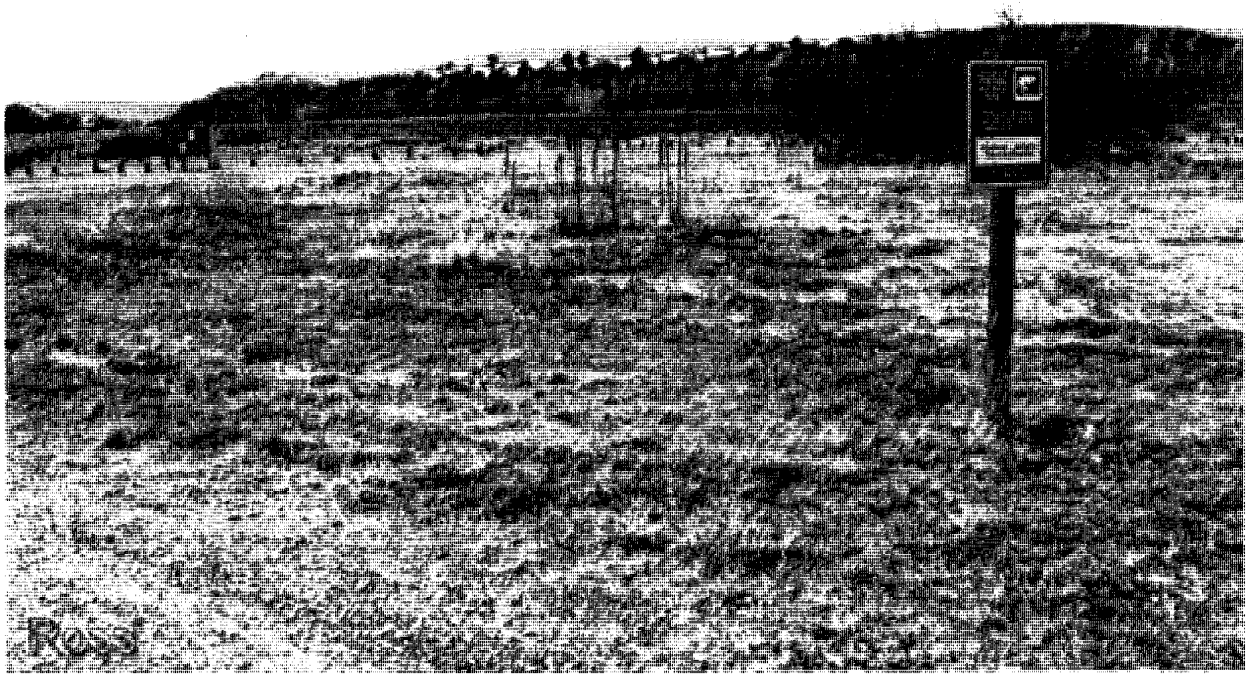

Figure 9. Area around the Cobblestone FAS.

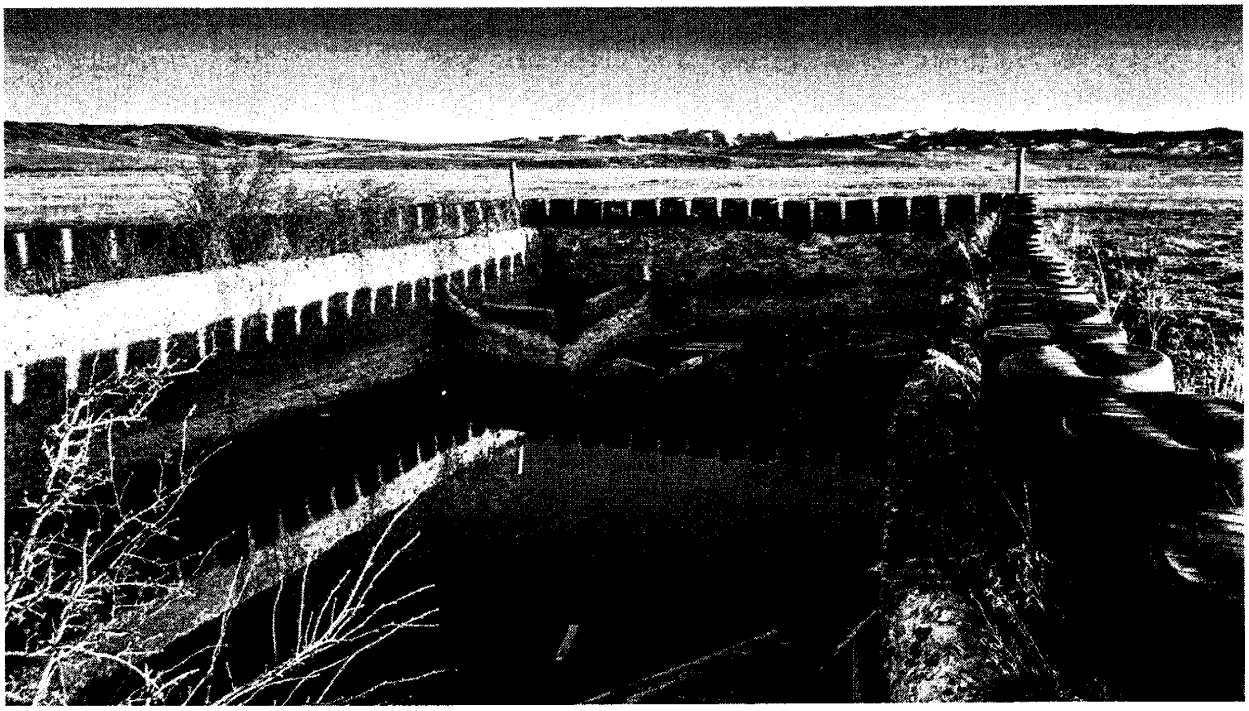

Figure 10. Some conditions that exist near the lower Madison below the Greycliff FAS, and the somewhat non-scenic view.