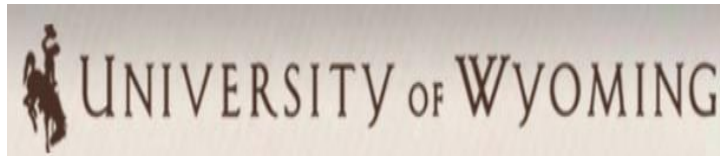


Defining Restoration Success in Wyoming's Natural Gas Fields: Suggestions for Selecting Reference Sites and Improving Ecological Site Descriptions

ASMR Conference
8 June 2015

Michael Curran, PhD Student, Program in Ecology
Dr. Peter Stahl



Restoration Success

- **Setting realistic and attainable goals for land reclamation and ecosystem restoration projects is considered to be an essential (and perhaps the most important) part for achieving restoration success** (e.g., Allen et al. 1997, Dickens and Suding 2013, Ehrenfeld 2000, Higgs 1997, Hobbs and Harris 2001, Hobbs and Norton 1996, March and Smith 2011, Parker 1997, Suding 2011, White and Walker 1997).
- **Undisturbed reference communities or pre-disturbance communities may provide good benchmarks for measuring restoration success** (e.g., Clewell 2009, Ruiz-Jaen and Aide 2005, SERI Primer 2004, Suding 2011).

What is Success?

What is Success?

success

[suh k-ses]


Spell Syllables

[Synonyms](#) [Examples](#) [Word Origin](#)

noun

1. the favorable or prosperous termination of attempts or endeavors; the accomplishment of one's goals.
2. the attainment of wealth, position, honors, or the like.
3. a performance or achievement that is marked by success, as by the attainment of honors:
The play was an instant success.
4. a person or thing that has had success, as measured by attainment of goals, wealth, etc.:
She was a great success on the talk show.
5. *Obsolete, outcome.*

Origin of success 

 Word of the Day

urbane 

 Difficulty index for success



All English speakers likely know this word


CITE





SERI Primer (2004) Attributes for Restoration Success

- 1) Similar diversity and community structure in comparison with reference sites
- 2) Presence of indigenous species
- 3) Presence of functional groups necessary for long-term stability
- 4) Capacity of physical environment to sustain reproducing populations
- 5) Normal functioning
- 6) Integration with the landscape
- 7) Elimination of potential threats
- 8) Resilience to natural disasters
- 9) Self-sustainability

Regulatory Standards for Restoration Success

| Field Office | Percent Cover | Erosion Control/Soil Stability ** | Weeds ** | Grass Richness+ * | Forb Richness | Forb Density Or Frequency | Shrub Richness | Shrub Density or frequency | Plant Vigor ** |
|-----------------------------------|---|--|--|--|---|--|---|---|--|
| Jonah Interagency Office | Greater than or equal to reference site | Site must be stable according to BLM Tech Note 346 | No noxious weeds or highly competitive Invasives | At least 2 bunch grass species and 3 total species | Equal or greater than reference | At least 75% of reference | Equal to or greater than reference | At least 50% of reference with no more than 10% rabbitbrush | Plants must be resilient as displayed by root system, flowers, and seed heads |
| Pinedale Anticline Project Office | Plant community sufficient to minimize visual impacts, provide habitat and forage, impede noxious weed invasion | Plant community must stabilize soils | No state or federally listed noxious weeds. Active treatment in place for weedy bromes | At least 2 bunch grass species and 3 total species | Equal to or greater than reference within 5 years | At least 75% of reference within 5 years | Equal to or greater than reference within 5 years | At least 50% of reference within 5 years | Plants must be resilient as above. Removal of external influences required for at least 1 year |
| Kemmerer BLM | Greater than or equal to 80% of reference site | Disturbed areas are immediately stabilized by mulching | Less than or equal to 10% of total vegetative cover | | | | | | |
| Rawlins BLM | Greater than or equal to 80% of reference site | Erosion features equal to or less than reference | No noxious weeds | | | | | | |
| WDEQ | Greater than or equal to 70% of reference | Grass must extend to any active roadway unless permanent anchor in place | | | | | | | |

Restoration Ecology and Succession

- Restoration has been called “assisted succession” or “the manipulation of succession”
- Common thinking in the past that this change was intended to reach a set endpoint

(Luken 1990, Cox and Anderson 2004, Walker et al. 2007).

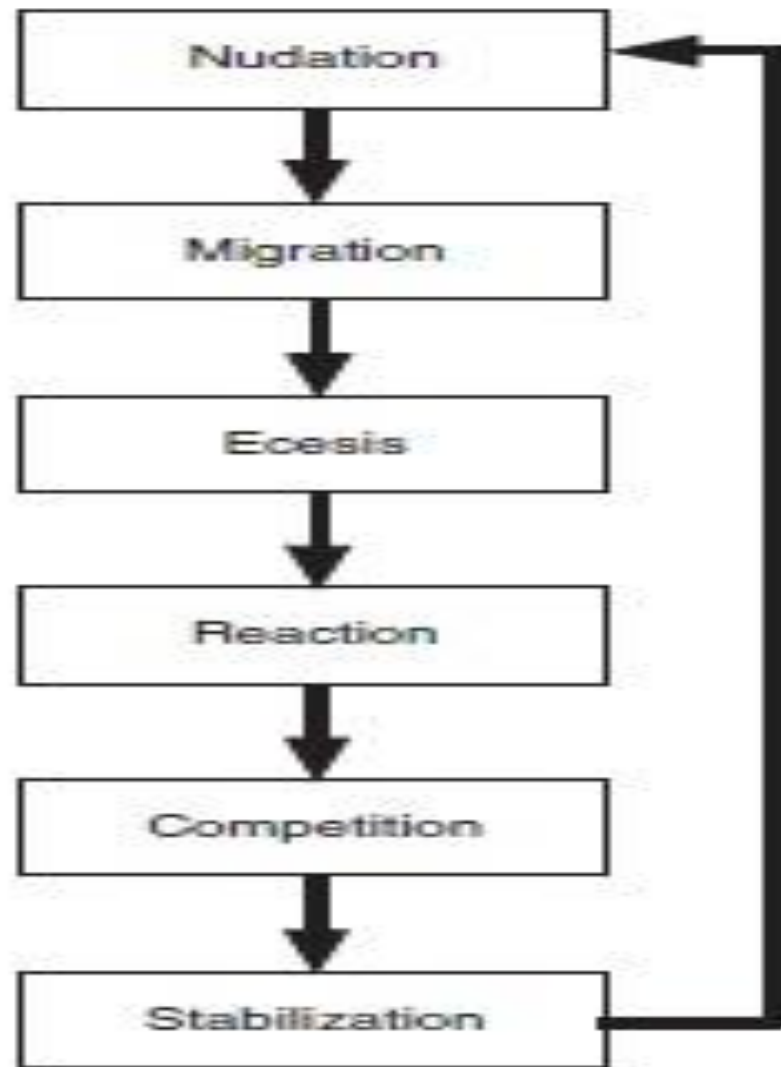


Fig. 1. The six causes of succession as identified by Clements (1916). In the contemporary view, stabilization is viewed as a net effect of the other causes, and not in itself a case of succession.



2014/07/26

W:109° 52' 47.85"
N:042° 46' 30.606"

Restoration Ecology and Succession

- Restoration ecology is a newer field and the main objectives of restoration are often focused on outcomes and overlook the processes taken to get to an endpoint (Walker et al. 2007).

What is Succession?

Succession and Ecology



succession



follow Dictionary.com

6. Also called **ecological succession**. *Ecology*. the progressive replacement of one community by another until a climax community is established.



Most English speakers likely know this word

Succession and Ecology – How did it get here?

- 1825 -- Adolphe Dureau de la Malle (French naturalist) “Memoir on alternation or on alternative succession in the reproduction of plant species living in a community - is it a general law of nature?”
- 1859 – Henry David Thoreau (American author, poet, philosopher, abolitionist, naturalist, tax resister, development critic, surveyor, and historian) “The Succession of Forest Trees”
- 1899 – Henry Chandler (H.C.) Cowles (American Botanist and Ecology Pioneer) “The Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan”
- 1916 & 1920 – Frederic Edward Clements (American plant ecologist and pioneer in vegetation succession) – “Plant Succession” and “Plant Indicators”

Cowles' Succession

- 1899 -- “The Ecological Relations of the Vegetation of the Sand Dunes of Lake Michigan” Cowles suggested that a ‘dune-complex... is a restless maze, advancing as a whole in one direction, but with individual portions advancing in all directions.’
- 1911 -- Cowles suggests that different vegetation zones in North America are ultimately driven by the moisture supply throughout the region, and that original plant communities develop in a ‘somewhat definite fashion to those that come after, a phenomenon that has been termed as succession.’

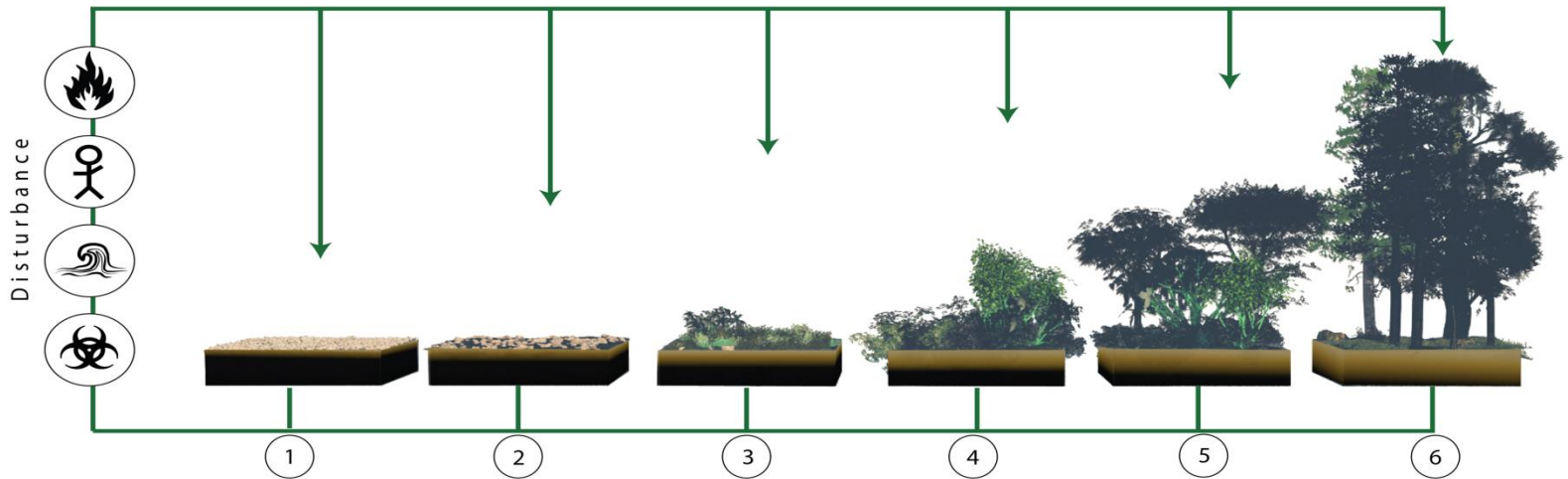
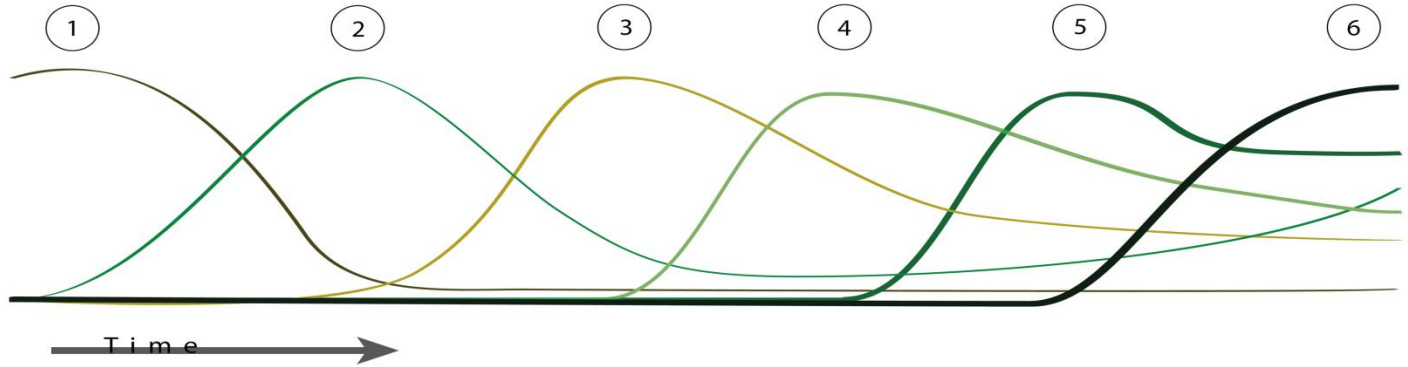
Clementsian Succession

- 1916 -- Clements began his studies in grasslands (more stable than Cowles' dunes)
- “The treatment of the plant community as a ‘complex organism’ undergoing a life cycle and evolutionary history analogous to the individual organism’ (Real and Brown 1991).
- Clements suggested that succession must be progressive, but acknowledged that disturbance could lead to ‘retrogression’, or a movement away from ‘climax’ conditions.

Clementsian Succession

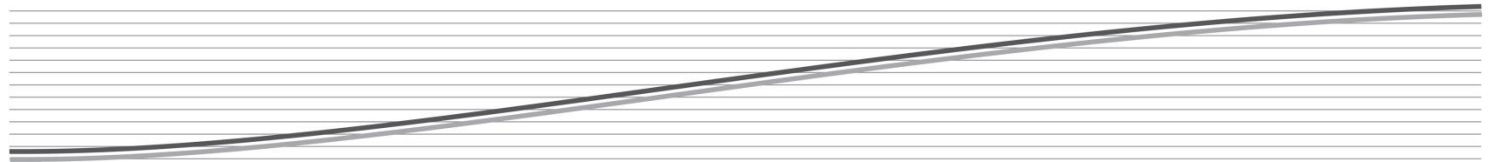
Forest Succession Over Time In Six Stages

- 1 Bare Rock
- 2 Mosses Grasses
- 3 Grasses Perennials
- 4 Woody Pioneers
- 5 Fast Growing Trees
- 6 Climax Forest



Increase over Time

Biodiversity
Biomass
Soil Layer



Succession and Ecology



succession



follow Dictionary.com

6. Also called **ecological succession**. *Ecology*. the progressive replacement of one community by another until a climax community is established.



Most English speakers likely know this word

Climax – Definition



climax

[klayh-maks]

[Spell](#) [Syllables](#)

[Synonyms](#) [Examples](#) [Word Origin](#)

noun

1. the highest or most intense point in the development or resolution of something; culmination;
His career reached its climax when he was elected president.
2. (in a dramatic or literary work) a decisive moment that is of maximum intensity or is a major turning point in a plot.
3. *Rhetoric.*
 - a. a figure consisting of a series of related ideas so arranged that each surpasses the preceding in force or intensity.
 - b. the last term or member of this figure.
4. an orgasm.
5. *Ecology.* the stable and self-perpetuating end stage in the ecological succession or evolution of a plant and animal community.

verb (used with object), verb (used without object)

6. to bring to or reach a climax.

Origin of climax

Word of the Day

urbane

Difficulty index for climax



Most English speakers likely know this word

Word Value for climax

17 20

Climax – Word Origin



Word Origin and History for climax

n.

1580s, in the rhetorical sense (a chain of reasoning in graduating steps from weaker to stronger), from Late Latin *climax* (genitive *climacis*), from Greek *klimax* "propositions rising in effectiveness," literally "ladder," from root of *klinein* "to slope," from PIE root **klei-* "to lean" (see *lean* (v.)).

The rhetorical meaning evolved in English through "series of steps by which a goal is achieved," to "escalating steps," to (1789) "high point of intensity or development," a usage credited by the OED to "popular ignorance." The meaning "sexual orgasm" is recorded by 1880 (also in terms such as *climax of orgasm*), said to have been promoted from c.1900 by birth-control pioneer Marie Stopes (1880-1958) and others as a more accessible word than *orgasm* (n.).

v.

1835, "to reach the highest point," from *climax* (n.). Related: *Climaxed* ; *climaxing*.

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Twitter
g+

Nearby words for climax

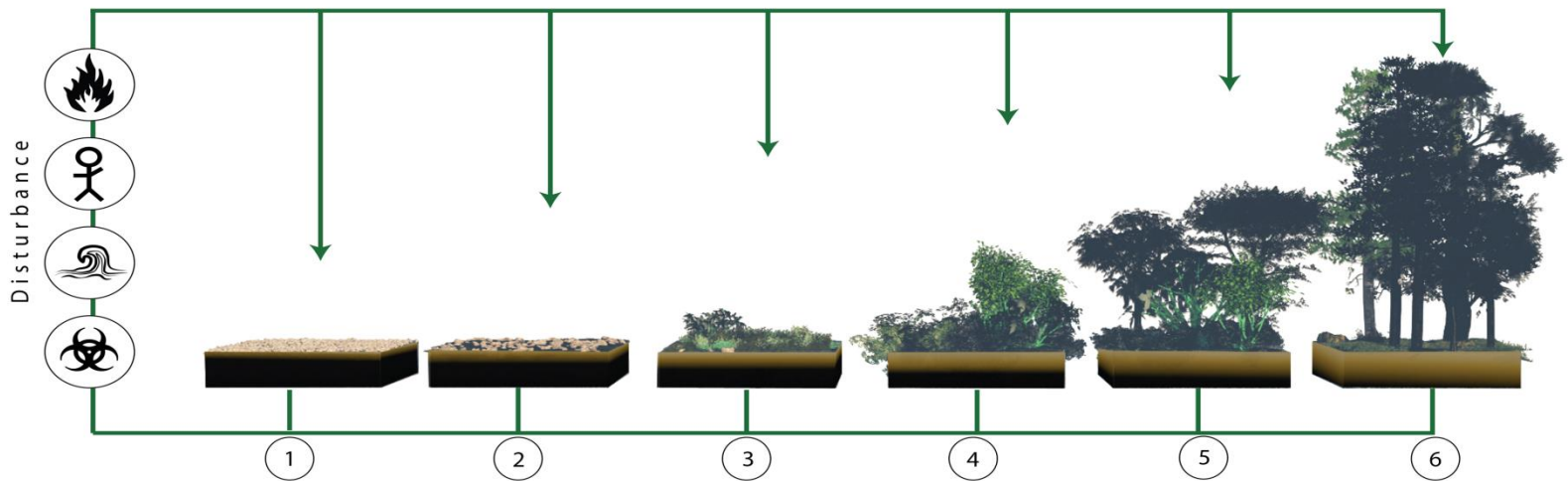
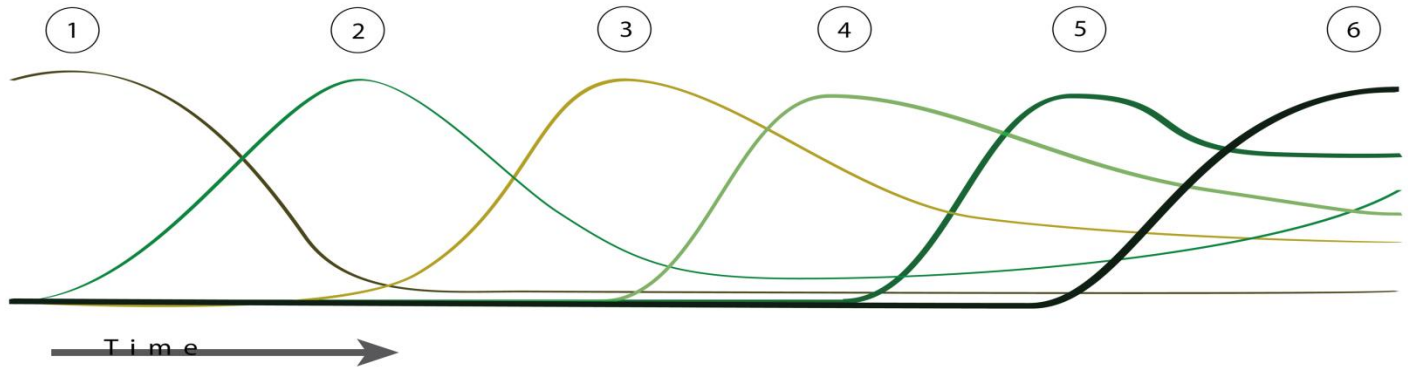
climatizing
climatography
climatological
climatologist
climatology

climax

How do we view Climax? -- Ecology

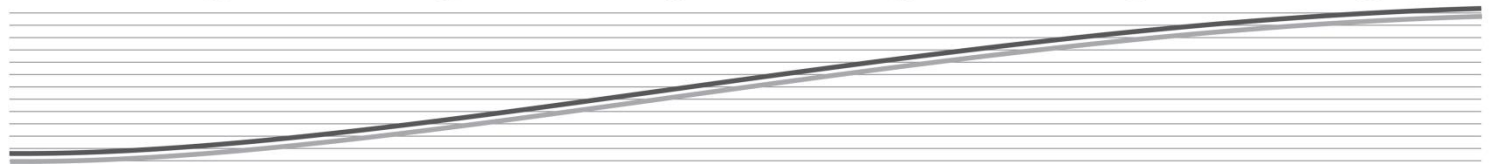
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- 4 Woody Pioneers
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- 6 Climax Forest




Increase over Time

Biodiversity
Biomass
Soil Layer



How do we view Climax? -- Ecology



The image shows a screenshot of the Dictionary.com website. At the top left is the Dictionary.com logo. In the center is a search bar with the word "climax" entered. To the right of the search bar are social media icons for Facebook, Twitter, and Google+, and the text "follow Dictionary.com". Below the search bar, the first definition is highlighted in a light blue box. To the right of the definition is a horizontal bar chart with vertical lines of varying heights, representing the frequency of the word's use. Below the bar chart is the text "Most English speakers likely know this word".

Dictionary.com

climax

follow Dictionary.com

5. *Ecology*, the stable and self-perpetuating end stage in the ecological succession or evolution of a plant and animal community.

Most English speakers likely know this word

Does Climax fit into all areas of ecology?

- 1926 – Henry Gleason argues idea of complex organism, suggests no fixed end point ('climax community') for any group of plant species. Sir
- 1935 – Sir Arthur Tansley was also highly critical of Clements and some of the ideas behind succession. **Simply not true that vegetation everywhere, all the time, is making progress towards a climax community**

Robert Harding Whittaker and Succession

- 1948 – Graduated with PhD from University of Illinois
- 1956 – First to provide empirical evidence to challenge Clements' ideas on succession
- 1970 and 1972 – Whittaker's ideas began to bring Gleason and Tansley's ways of thinking back into popularity

Rangeland Management and E.J. Dyksterhuis

- 1949 – “Condition and Management of Rangeland Based on Quantitative Ecology”
- Proposed ‘rangeland condition’ or ‘successional stage’ model be used to guide rangeland management.
- Primary concerns in rangeland health at time were grazing and drought
- Disturbance due to grazing or drought could cause retrogression to a rangeland and the removal of disturbance would result in a linear progression of a plant community to reach a ‘climax’ community that would have been found prior to disturbance (Dyksterhuis 1949, Westoby et al. 1989, Borman and Pyke 1994).

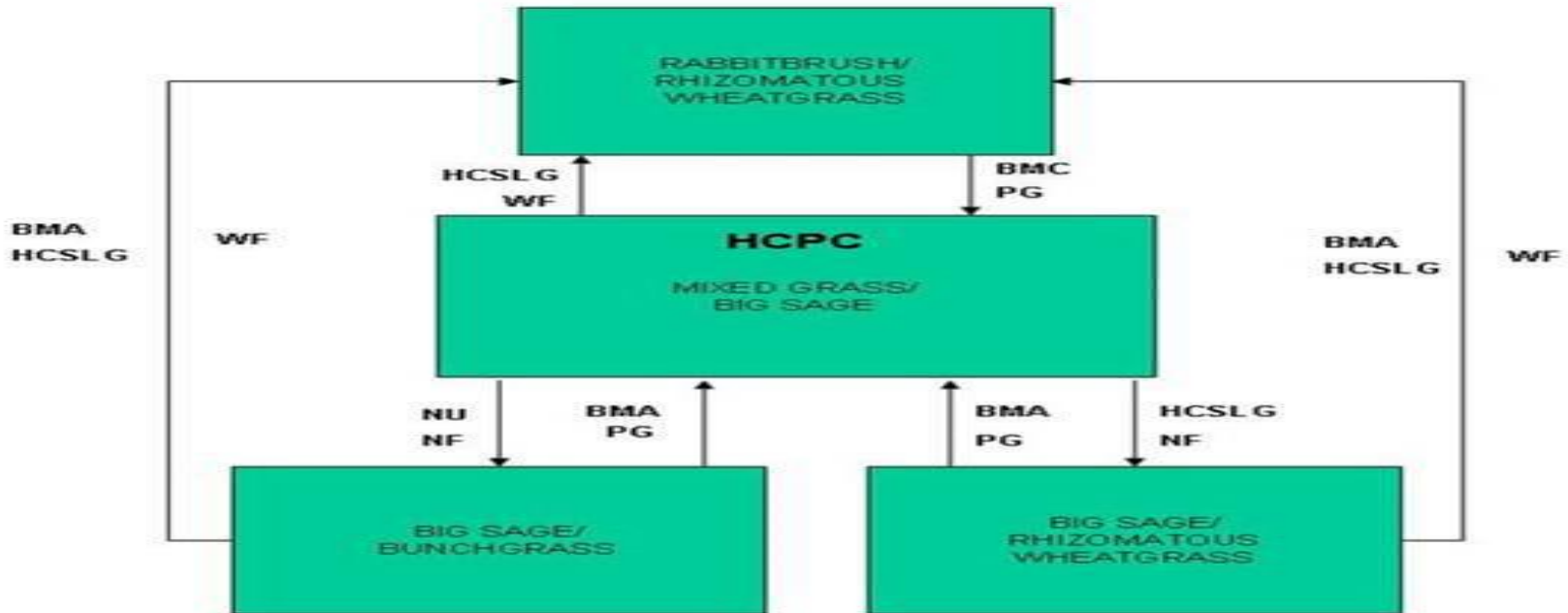
Rangeland Management and E.J. Dyksterhuis

- Rangeland condition is measured by comparing disturbed communities to adjacent undisturbed communities (considered to be 'climax communities').
- The disturbed community is then ranked based on a point on a linear trajectory between a heavily disturbed community and a climax, or undisturbed, community
- 4 Possible Conditions
 - Excellent, Good, Fair, Poor

Ecological Site Descriptions

Site Type: Rangeland
MLRA: 34A-Cool Central Desertic Basins and Plateaus

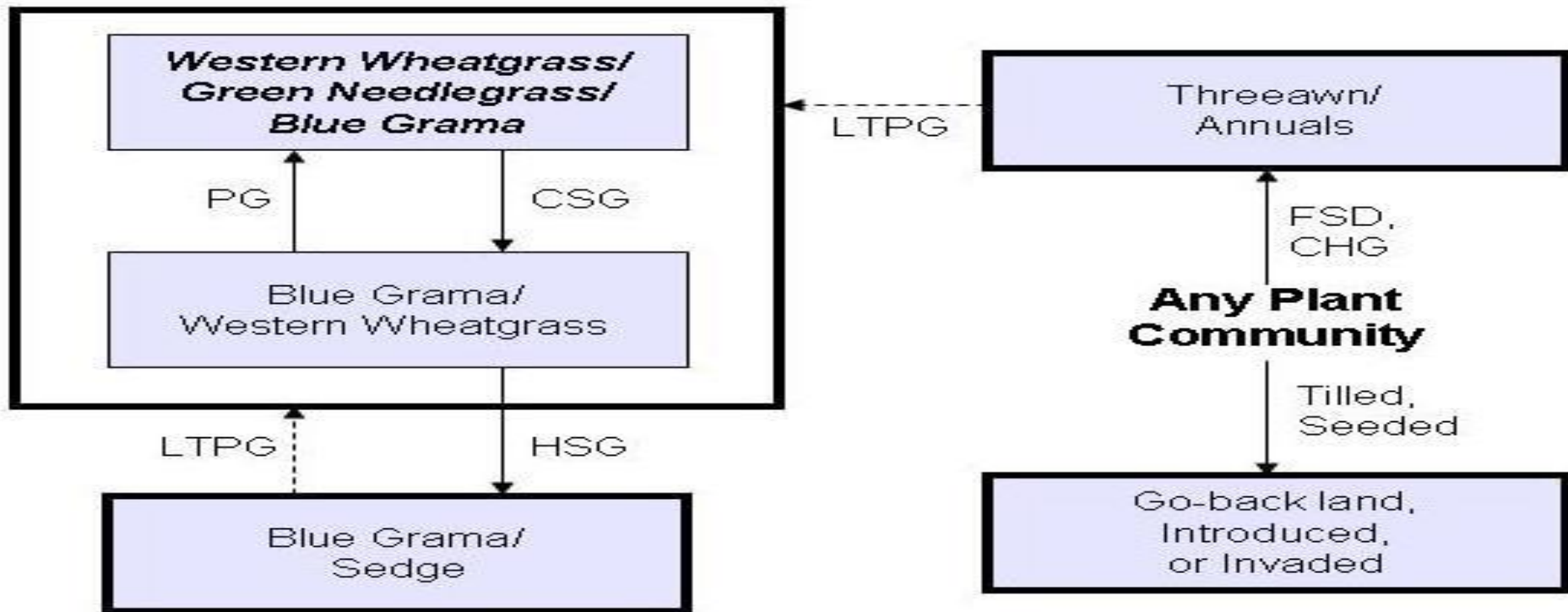
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BMA – Brush Management (all methods)
BMC – Brush Management (chemical)
BMF – Brush Management (fire)
BMM – Brush Management (mechanical)
CSP – Chemical Seedbed Preparation
CSLG – Continuous Season-long Grazing
DR – Drainage
CSG – Continuous Spring Grazing
HB – Heavy Browse
HCSLG – Heavy Continuous Season-long Grazing
HI – Heavy Inundation
LPG – Long-term Prescribed Grazing
MT – Mechanical Treatment (chiseling, ripping, pitting)

NF – No Fire
NS – Natural Succession
NWC – Noxious Weed Control
NWI – Noxious Weed Invasion
NU – Nonuse
P&C – Plow & Crop (including hay)
PG – Prescribed Grazing
RPT – Re-plant Trees
RS – Re-seed
SGD – Severe Ground Disturbance
SHC – Severe Hoof Compaction
WD – Wildlife Damage (Beaver)
WF – Wildfire

Ecological Site Descriptions



CHG – Continuous heavy grazing; **CSG** – Continuous seasonal grazing; **FSD** – Frequent and severe defoliation; **HSG** – Heavy seasonal grazing; **LTPG** – Long-term prescribed grazing; **PG** – Prescribed grazing.

Interagency Ecological Site



Handbook for Rangelands

January 2013



"Helping People Help the Land"

Ecological Site Descriptions

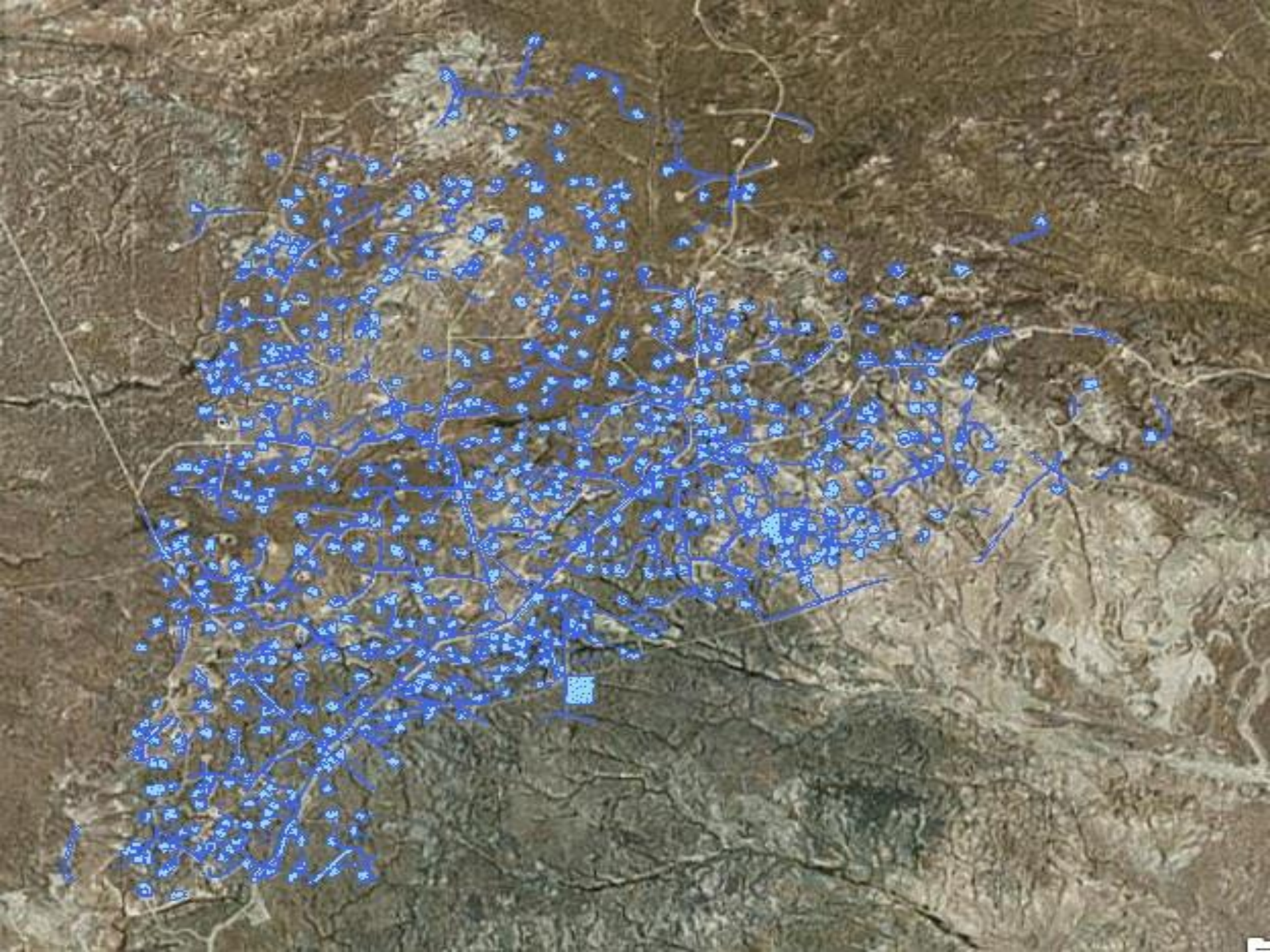
- "The BLM, USFS, and NRCS have a common objective of utilizing science-based technical processes to sustain and enhance natural resources and the environment. They have used different methods to stratify landscapes into units for planning, analysis, and decision making. Their jurisdictions are intermingled throughout much of the United States, including both private and public lands; therefore, a standardized method to define, delineate, and describe terrestrial ecological sites is more efficient than each agency having their own method." – Interagency Handbook
- "ESDs provide land managers the information needed for evaluating suitability of the land for various land-use activities, the capability to respond to mgmt. activities or disturbance processes, and the ability to sustain productivity over the long term." –Interagency handbook

Ecological Sites

- “An ecological site is a distinctive kind of land with specific physical characteristics that differs from others kinds of land in its ability to produce a distinctive kind and amount of vegetation.” –National Range and Pasture Handbook
- “Ecological Sites provide a general ecological foundation for management” – Moseley et al. 2010
- “Where changes in **soils, aspect, topography, or moisture conditions** are abrupt, the boundaries of the ecological site conditions will be obvious. Where soils and plant communities change gradually along broad environmental gradients in areas of fairly uniform topography, ecological site distinctions are more difficult to specify...” – Moseley et al. 2010

Jonah Infill Natural Gas Field







Regulatory Standards for Restoration Success

| Field Office | Percent Cover | Erosion Control/Soil Stability ** | Weeds ** | Grass Richness ⁺ | Forb Richness | Forb Density Or Frequency | Shrub Richness | Shrub Density or frequency | Plant Vigor ** |
|-----------------------------------|---|--|--|--|---|--|---|---|--|
| Jonah Interagency Office | Greater than or equal to reference site | Site must be stable according to BLM Tech Note 346 | No noxious weeds or highly competitive invasives | At least 2 bunch grass species and 3 total species | Equal or greater than reference | At least 75% of reference | Equal to or greater than reference | At least 50% of reference with no more than 10% rabbitbrush | Plants must be resilient as displayed by root system, flowers, and seed heads |
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| Rawlins BLM | Greater than or equal to 80% of reference site | Erosion features equal to or less than reference | No noxious weeds | | | | | | |
| WDEQ | Greater than or equal to 70% of reference | Grass must extend to any active roadway unless permanent anchor in place | | | | | | | |

| Map Unit Symbol | API | No forbs present undisturbed | No forbs present disturbed |
|-----------------|--------------|------------------------------|----------------------------|
| 5203 | 49-035-21391 | 1 | 2 |
| 5203 | 49-035-21509 | 7 | 2 |
| 5203 | 49-035-21558 | 5 | 2 |
| 5203 | 49-035-21844 | 7 | 2 |
| 5203 | 49-035-21899 | 5 | 4 |
| 5203 | 49-035-21918 | 2 | 3 |
| 5203 | 49-035-21923 | 3 | 2 |
| 5203 | 49-035-21991 | 4 | 3 |
| 5203 | 49-035-22066 | 7 | 5 |
| 5203 | 49-035-22234 | 1 | 2 |

Sampling Vegetation Attributes (BLM Tech. Ref. 1734-4)

| | |
|---|-----|
| IV. ATTRIBUTES | 23 |
| A. Frequency | 23 |
| B. Cover | 25 |
| C. Density | 26 |
| D. Production | 27 |
| E. Structure | 28 |
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| K. Harvest Method | 112 |
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| M. Visual Obstruction Method - Robel Pole | 123 |
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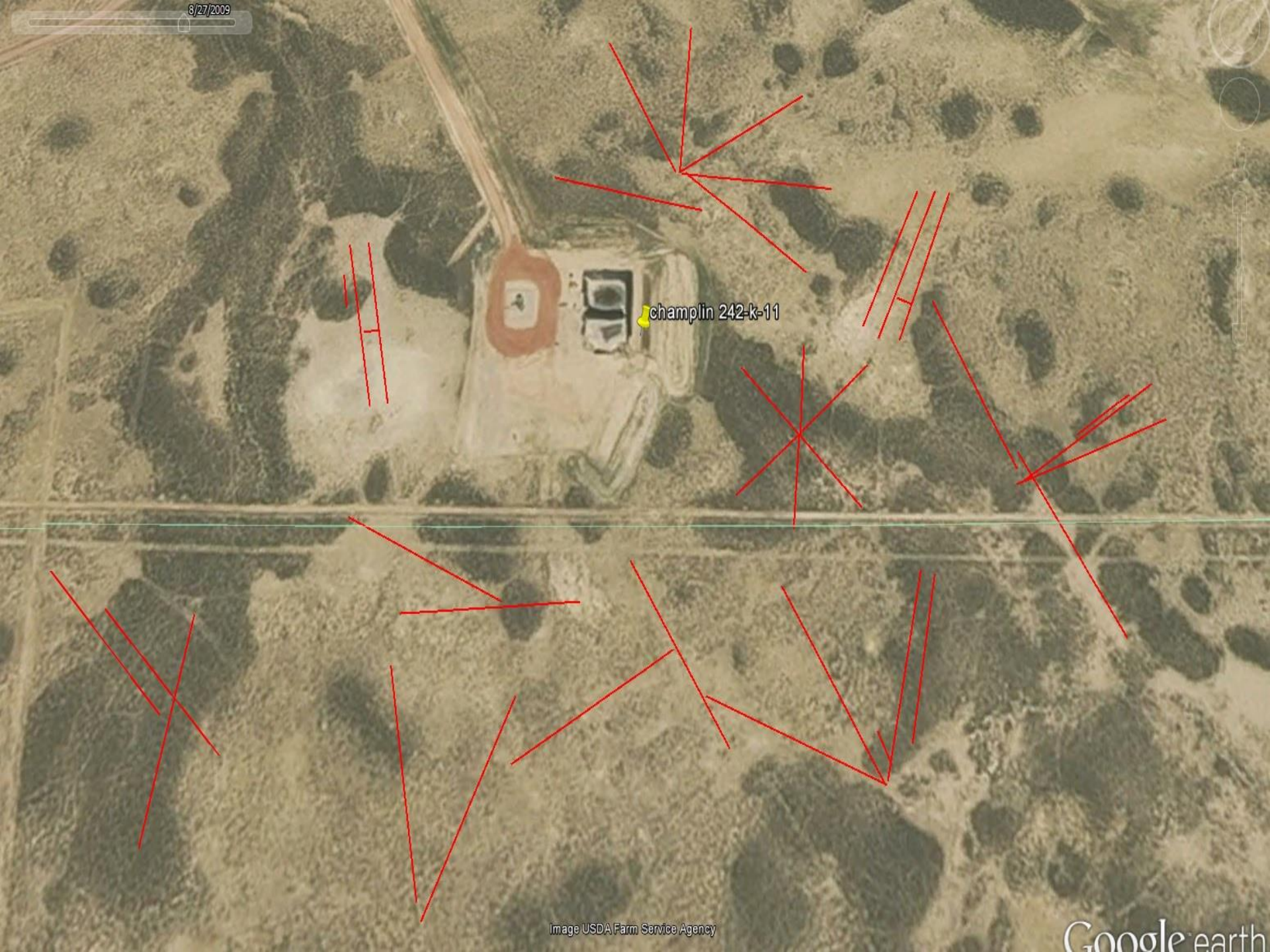
Monitoring in Jonah Infill

- 2006 – CSR randomly placed five 1 m² frames on well pads and adjacent reference areas for vegetation measurements (most between June 5 and June 8)
- 2007 – CSR randomly placed five 1 m² frames on well pad and adjacent reference areas for vegetation measurements (all between July 11 and July 19)
- 2008 – CSR placed a 1 m² frame 10 times along a 50 m transect on well pads and adjacent reference areas for vegetation measurements (in accordance with BLM tech. notice 1734-4) (most between June 11 and June 14)
- 2009 – CSR placed a 1 m² frame 10 times over a 50 m transect on well pads and adjacent reference areas for vegetation measurements (in accordance with BLM tech. notice 1734-4) (most between July 13 and July 17)
- 2010 – CSR used either one 100 m or two 50 m transects and recorded basal ground cover at 200 points (in accordance with BLM tech. notice 1734-4) (all between June 1 and June 7)
- 2011 – CSR used either one 100 m or two 50 m transects and recorded basal ground cover at 200 points (in accordance with BLM tech. notice 1734-4) (all between July 6 and July 10)

- **There is no evidence that the same locations on pads or reference sites were monitored between years when the same method was used.



champlin 242-k-11



champlin 242-k-11

Search

ex: 37,407229, -122.107162
Get Directions History

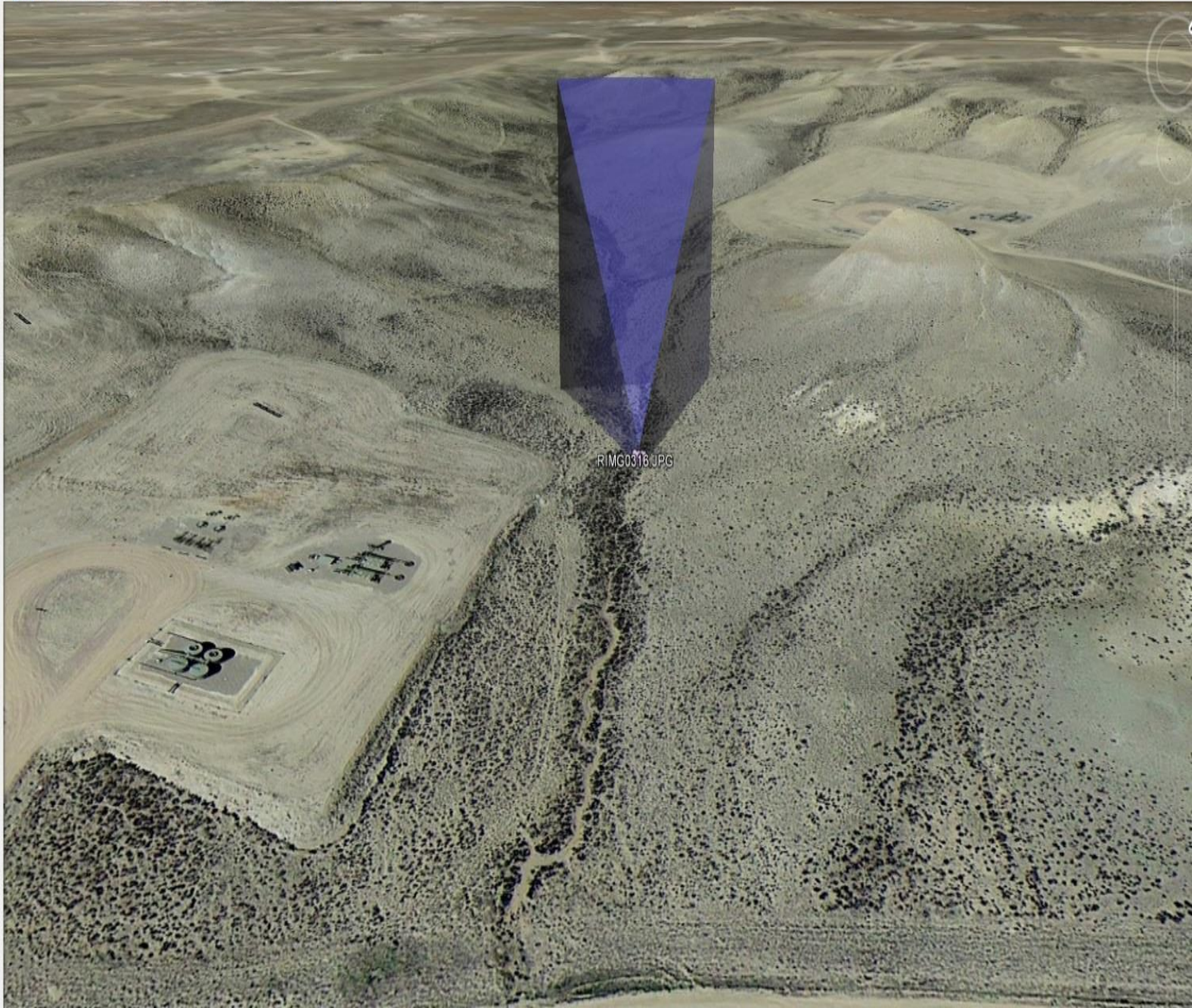
▼ Places

- Photos
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 - RIMG0095.JPG
 - RIMG0120.JPG
 - RIMG0143.JPG
 - RIMG0166.JPG
 - RIMG0268.JPG
 - RIMG0292.JPG
 - RIMG0316.JPG
 - RIMG0338.JPG
 - RIMG0360.JPG
- Field of View
 - RIMG0049.JPG
 - RIMG0095.JPG
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 - RIMG0316.JPG
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▼ Layers Earth Gallery >>

- Primary Database
- Borders and Labels
- Places
- Photos
- Roads
- 3D Buildings
- Ocean
- Weather
- Gallery
- Global Awareness
- More



▼ Search

Search

Search

ex: 37.407229, -122.107162

Get Directions History

▼ Places

- Photos
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 - RIMG0360.JPG

▼ Layers

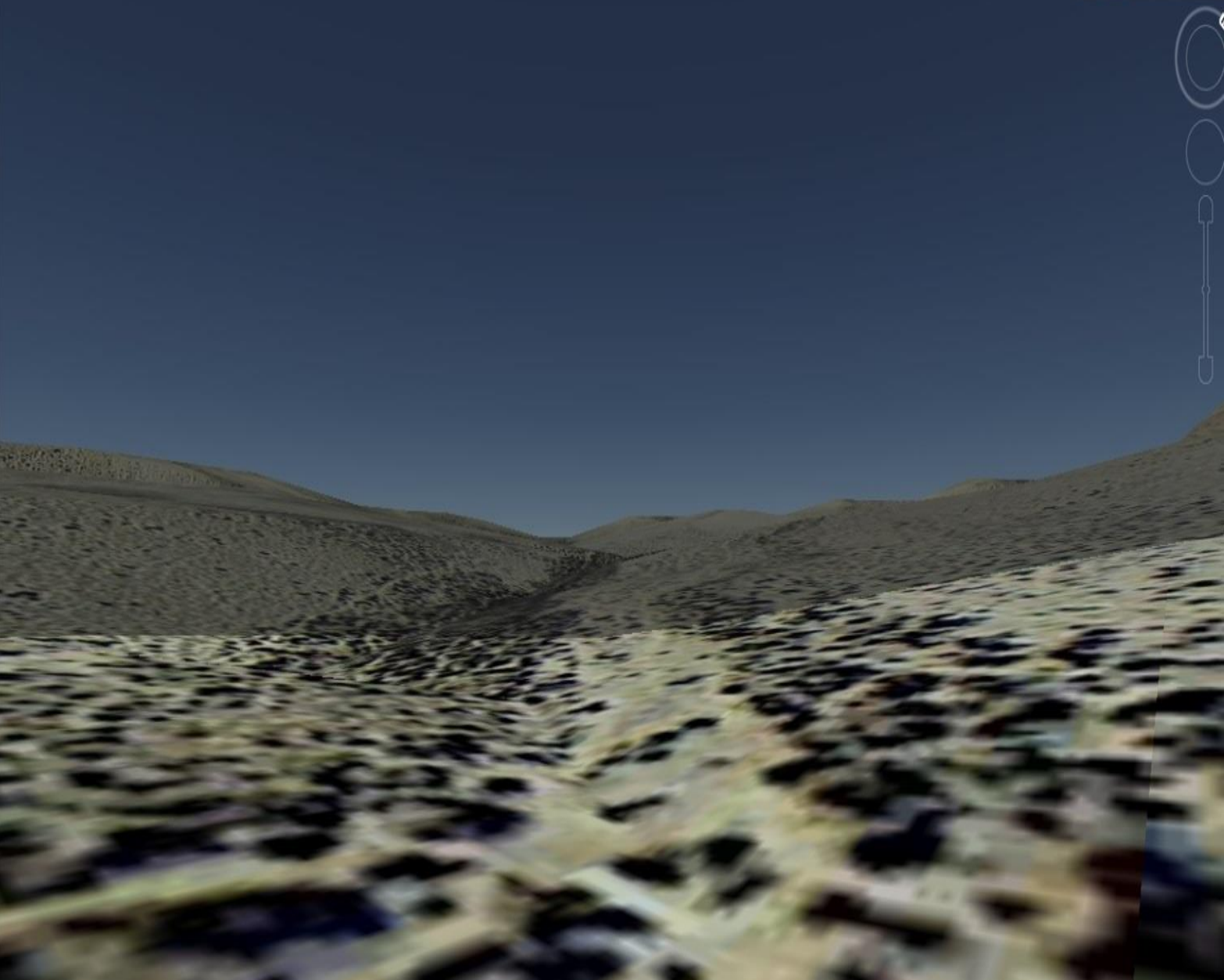
Earth Gallery >>

- Primary Database
 - Borders and Labels
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 - Photos
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 - Ocean
 - Weather
 - Gallery
 - Global Awareness
 - More



Sign in

Exit ground-level view



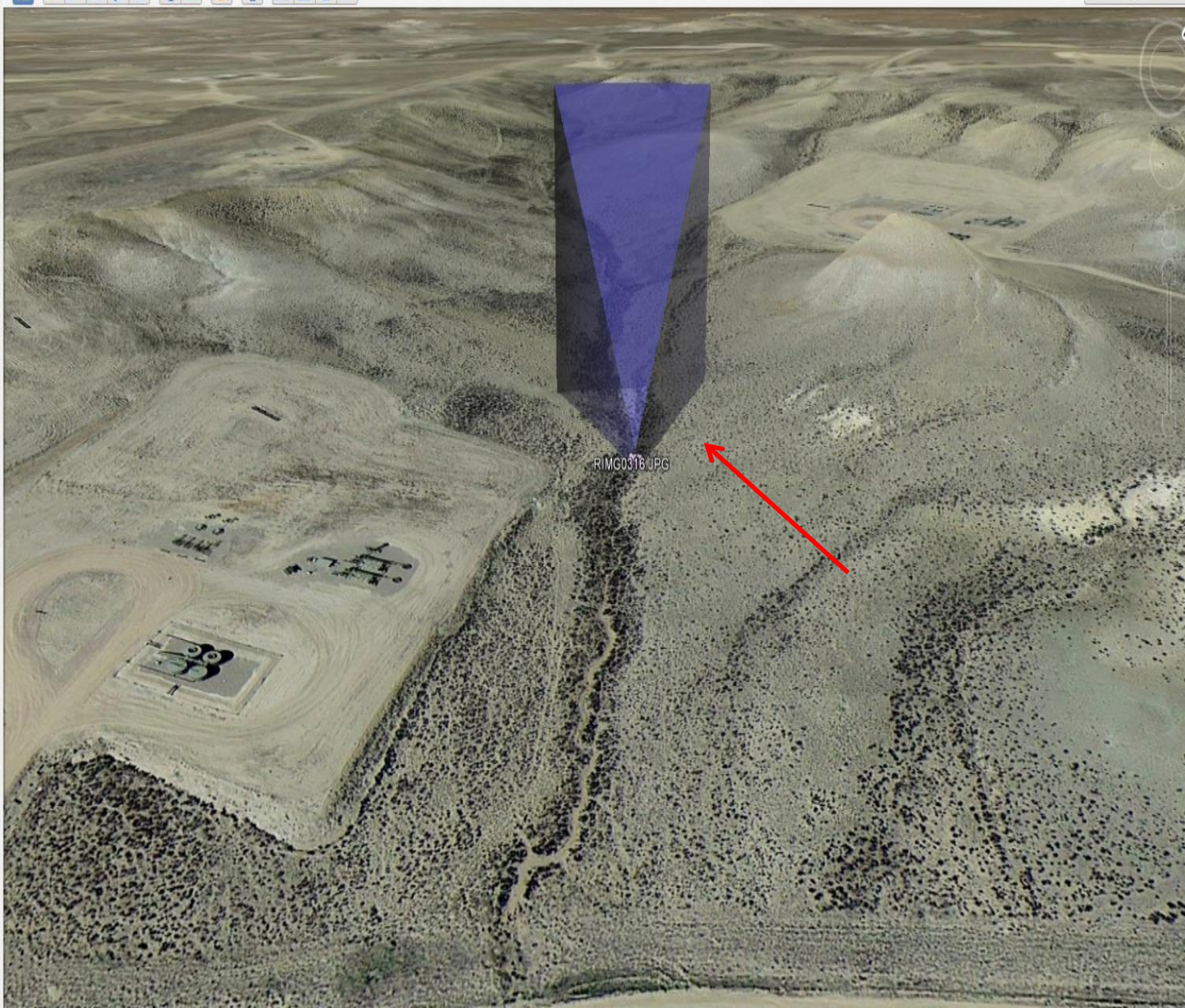


2014/06/09

W:109° 39' 00.534"
N:042° 27' 22.776"

- Photos
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 - RIMG0095.JPG
 - RIMG0120.JPG
 - RIMG0143.JPG
 - RIMG0166.JPG
 - RIMG0268.JPG
 - RIMG0292.JPG
 - RIMG0316.JPG
 - RIMG0338.JPG
 - RIMG0360.JPG
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 - RIMG0360.JPG

- Primary Database
 - Borders and Labels
 - Places
 - Photos
 - Roads
 - 3D Buildings
 - Ocean
 - Weather
 - Gallery
 - Global Awareness
 - More





2014/06/09

N:189° 38' 57.138"
N:842° 27' 24.848"

Spatially Well-balanced Sampling

- A sample that is well-spread over the population with few nearby units is said to be spatially balanced or called a spatially well-balanced sample....if the response has spatial trend, estimation can be greatly improved by selecting a spatially balanced sample.”
(Robertson et al. 2013)

Spatially Well-balanced Sampling

Create Random Points

Left: 0.000000 Top: 250.000000
Right: 250.000000 Bottom: 0.000000

Clear

Number of Points [value or field] (optional)
 Long: 100
 Field

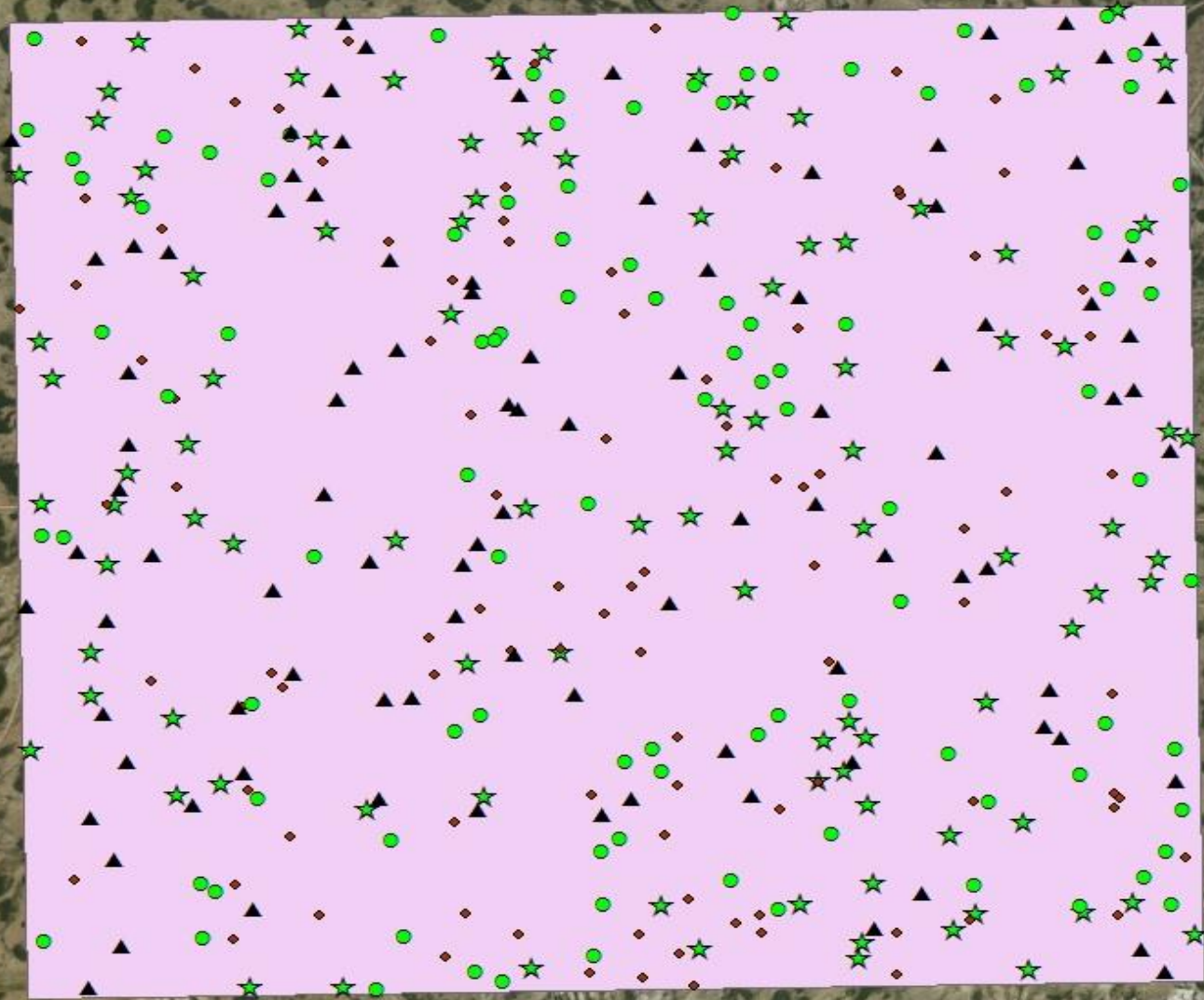
Minimum Allowed Distance [value or field] (optional)
 Linear unit: 15 Meters
 Field

Create Multipoint Output (optional)

OK Cancel Environments... << Hide Help Tool Help

Minimum Allowed Distance [value or field] (optional)

The shortest distance allowed between any two randomly placed points. If a value of 1 Meter is specified, all random points will be farther than 1 meter away from the closest point.







2014/08/09

N:109° 39' 01.150"
N:042° 21' 33.046"



2014-06-09

N: 109° 38' 52.702"
E: 042° 27' 23.705"








2014/07/26

W:109° 52' 47.85"
N:042° 46' 30.606"



RIMG0339.JPG
RIMG0294.JPG

RIMG0164.JPG RIMG0212.JPG
RIMG0156.JPG

RIMG0137.JPG RIMG0085.JPG

RIMG0217.JPG
RIMG0276.JPG





2014/07/28

N:109° 53' 19.197"
E:062° 44' 54.594"



2014/07/26

W: 109° 52' 37.278"
N: 042° 44' 53.124"

Insect Diversity

- On Rocky Mountain Bee Plant dominated well pad
 - Coleoptera – 14
 - Diptera – 5
 - Hemiptera – 5
 - Homoptera – 17
 - Hymenoptera – 2
- In undisturbed reference area
 - Diptera – 4
 - Hemiptera – 7
 - Homoptera – 6



2014/07/26

N: 109° 51' 33.936"
E: 042° 46' 06.09"



2014/07/26

W:109° 51' 55.904"
N:042° 46' 56.96"

Insect Diversity

- On-site with low grass diversity:
 - Coleoptera - 1
- Off-site with low grass diversity:
 - Coleoptera - 1

Conclusions

- Using Ecological Site Descriptions to group well pads together to aim towards a range of values within a population may save money and make setting goals for success easier
- Sampling reference areas better with better methodologies than we currently have may improve Ecological Site Descriptions or allow them to be created in areas where they do not exist
- In instances where reference communities have been improperly managed, they may not be what we want to aim at for success
- In cases where pad construction has yet to occur, pre-disturbance inventory may be advantageous

Conclusions

- In arid systems, land reclamation and ecosystem restoration to pre-disturbance condition or a reference area may take a long time
- If land reclamation is aimed at ecosystem restoration instead of specifically land restoration, there may be benefits in rejuvenating surrounding areas
- In arid systems, succession may not be linear, especially on drastically disturbed lands
- In a changing climate, ESDs will most likely need to be consistently updated
- Regulatory success standards may benefit ecosystems by including more of SERI's primer restoration success standards
- In an era of Restoration Ecology, Rangeland Health may need to be reevaluated

Thank you!

- Questions? Comments?