

Mulching and Soil Depressions for Revegetation of Oil and Gas Wells in Arid Ecosystems



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U.S. Department of the Interior U.S. Geological Survey This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Today's talk

- 1. Brief origin of our research interests in oil and gas reclamation
- 2. "BLM Reclamation Review": findings about mulch & soil depressions
- 3. "WPRR": Collaborative field research project
 - Study design
 - Results comparing mulching and soil depressions
- 4. Research Conclusions



Energy & mineral development on arid Public land in the Intermountain West



	# Wells	Acres
Existing	69,000	275,000
In Progress	221,000	1.2 million
TOTAL	290,000	1.5 million





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Nauman, T. W., M. C. Duniway, M. L. Villarreal, and T. B. Poitras. 2017. Disturbance automated reference toolset (DART): Assessing patterns in ecological recovery from energy development on the Colorado Plateau. Science of The Total Environment **584–585:476-488**.

USGS Southwest Energy Development & Reclamation ("SWEDR") & BLM Support



<u>Goals</u>

- Understand past and current energy development impacts on the social-ecological systems of the Colorado Plateau
- Identify strategies to mitigate deleterious consequences of these activates now and into the future
- Create relevant technical resources for managers, practitioners, and scientists



EXAMPLES SERVICE AND ADDRESS FOR ADDRESS ADDR	
Oil and Gas Reclamation—Operations, Standards, and• DataMonitoring Methods• Pre-co• Reclamation• Reclamation	-driven benchmarks, standards levelopment planning amation BMPs
By Randi C. Lupardus, Janna Simoneen, Gordon Toeve, Barbara Sterling, Zachary H. Bowen, Zoe Davidson, Steven E. Hanser, Emily Kachergis, Alexander Laurence-Traynor, Nika Lepak, Rebecca K. Mann, Aleta Nafus, David S, Pilliod, and Michael C. Duniway	amation monitoring preting data
Welcome to the Science	Home Management Topics Related Publications About For Resource Managers Bibliography Search tool!
Annotated Bibliography of Scientific Research Relevant to Oil and Gas Reclamation Best Management Practices in the Western United Stat Published from 1969 through 2020 Bipthems Klunck Moral Monarch L Moor inst Minard C Darwey US Guadged Save Val Guadged Save	and get stored exploring the annotated bibliographies I provides easy actes to hundheds of summaries of published science and data products on topics for western land managers. products by management topic, location, year, and keywords to find information relevant to inns and decisions (see the Management Topic)'s tab abave for definitions). "Expurt to PDF button on the search results page to save citations, summaries, and search ters, as a slichtle document that can be appended to decision analyses.
	Standards, Methods, and Monitoring – Improving Reclamation Success on Western Public Lands
Cper-File Report XXXXXXXX U.S. Deartheart of the Interior U.S. Genetycal Barvey In Press	By Michael C. Durwey, 'Rebecca K. Mann, 'Moly Micoamick /Partick-Antenzon, 'Randi C. Lupandun, ' Self Mineso?
What do we already know? A Review of Current Reclamation Practices, Monitoring, & Standards 1. Assess scientific information on reclamation methods & their effectiveness 2. Analyze existing reclamation standards, monitoring, & practices	Acknowledgments This section to acknowledge partner agencies, funding cooperating agencies, or others external to the DS. Aussitures from USOS collwagows (If applicable) should appear in this section also but in a write prograph.
30 interviews at 25 offices across 6 states	"Reclamation Review" In Preparation

Reclamation Review:

Assess all accessible scientific information

Restoration Ecology

RESEARCH ARTICLE

The Use of Seedbed Modifications and Wood Chips to Accelerate Restoration of Well Pad Sites in Western Colorado, U.S.A.

Joshua D. Eldridge,^{1,2} Edward F. Redente,¹ and Mark Paschke¹

Abstract

Semiarid ecosystems of Western North America are experiencing a boom in natural gas development. However, these systems are slow to recover from the disturbances created. The purpose of this study was to develop improved restoration techniques on natural gas well nods in West. Dual-camera, high-resolution aerial assessment of pipeline revegetation

D. Terrance Booth - Samuel E. Cox

ublished online: 18 October 2008

DETERMINING RECLAMATION POTENTIAL FOR STEEP OIL AND GAS SITES IN THE POWDER RIVER BASIN, WYOMING¹

to completely restore cover on

although causes of salinity patch

gation. After removing the 55 sa

analyses, we found that wood chi

ment increased organic matter c

native species. Rough seedbed m

Brenda K. Schladweiler² and Dawn M. Gardner

Abstract. The collection of qualitative and quantitative data prior to any disturbance is an invaluable tool in the reclamation process, including the determination of future reclamation success of a given site. In conjunction with

any federal or state rules and regulations as collection and due diligence of companies, potential prior to disturbance can outline cons increase final reclamation success. Primary n prior to disturbance include vegetation and so disturbance and revertation computing a represent aerial monitoring costs. We recommend VLSA pipeline surveys as a means for facilitating required environmental monitoring and for addressing the monitoring backlog that has developed with increased energy-extraction activity.

RUNOFF AND EROSION FROM NATIVE AND RECLAIMED SITES: LARGE VERSUS SMALL PLOTS

M. Karl Wood¹, Bruce A. Buchanan¹, and Orlando J. Estrada²



Publication search

3,207 papers identified

692 papers Met quality & relevance criteria

387 papers Relevant to Oil & Gas Reclamation <u>Practices</u>

Mulching evaluated: 45 papers (12% of papers) Soil depressions evaluated: 15 papers (4% of papers)



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Runoff and erosion were compared using rainfall simulators



Science for a changing world

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Literature Review: **Mulching** *Drawbacks & Inconsistencies*



Drawbacks/Inconsistencies	#W (% of mul)	orks ch papers)
Suppressed plants or increased erosion	3	7%
No effects noted	10	22%
Species differences	6	13%
Metrics differed (e.g. germination ≠ survival ≠ biomass)	3	7%
Site mattered	3	7%
Mulch type mattered	2	4%
Mulch depth mattered	2	4%
Time since reclamation mattered	2	4%
Precipitation mattered	1	2%
Non-natives increased	1	2%



Literature Review: **Soil depressions** *Summary of articles' statements and findings*



Imprinting



Literature Review: **Soil depressions** *Drawbacks & Inconsistencies*



Drawbacks/Inconsistencies	#Wo % of "pi	rks & <i>t" papers</i>
Suppressed plants or increased erosion	4	27%
No effects noted	5	33%
Species differences	3	20%
Metrics differed (e.g. germination ≠ survival ≠ biomass)	1	7%
Site mattered	4	27%
Pitting type mattered	1	7%
Soil type mattered	1	7%
Time since reclamation mattered	2	13%
Precipitation mattered	3	20%
Non-natives increased	0	0%



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USGS Well Pad Reclamation and Research Project ("WPRR")





Collaborative Field Studies In areas of concentrated oil & gas development

> BLM Operators **USFWS** Contractors USGS

Goals

- Integrate & expand on current knowledge Collaborate with BLM and operators
- Understand factors limiting success Strategically test across years/sites
- Identify effective & affordable reclamation strategies For common plant communities and soils types For specific areas of interest

TAERUS

Use monitoring data to assess reclamation trajectories First vs. last year responses





USGS Well Pad Reclamation and Research Project ("WPRR") Key factors affecting disturbed arid landscapes

Reclamation Challenges

Severely Altered Biota

- Native Plants, Seed Bank
 Seedling Safe Sites
 Pollinators, Invertebrates
 Exotic Species
- Microorganisms
 Severely
 Nutrients, Organic Matter
 Altered
 Compaction, Crusting
 Destabilization, Erosion
 - **†** Salinization

Severely Altered Hydrology

Water Holding Capacity
 Runoff







USGS Well Pad Reclamation and Research Project ("WPRR") Key factors affecting disturbed arid landscapes

Runoff

Hydrology

Reclamation Challenges Reclamation Opportunities Tactic Comparisons Vative Plants, Seed Bank Seed Rates Severely Seedling Safe Sites Safe Sites Altered Pollinators, Invertebrates Seed Mix Diversity **Biota** Apply Weed Control **†** Exotic Species Microorganisms Microbial Inoculation ↓ Nutrients, Organic Matter Fertilizer/Compost Severely Altered **†** Compaction, Crusting Chiseling Soil **†** Destabilization, Erosion Tackifier, Mulch **†** Salinization Amendments Severely Water Holding Capacity Soil pitting Altered

Organic Matter



USGS Well Pad Reclamation and Research Project ("WPRR") Identification of study locations

Uintah Basin: Oil & Gas hot spot



6-9" Mean Annual Precipitation @ sites 14.6°C (58 °F) Mean Temperature @ sites 8 study sites, stratified by priority units





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USGS Well Pad Reclamation and Research Project ("WPRR")

Two-part study design





USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component







Treatments





<u>Seed mix</u>

Х

= Species with warm/dry distributions

= Species with cool/wet distributions

Randomized Layout





Monitoring

- Annual plant density counts
- 2 quadrats/plot
- Species data are summed by functional groups (e.g. seeded species)



USGS Well Pad Reclamation and Research Project ("WPRR")

Small-scale component



Site-specific randomization

Two Sites: Complete Randomized (4 replicates, 2 years data)



Two Sites: Randomized Block (4 blocks, 2 years data)

Block 1	Block 2	Block 3	Block 4
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Two Sites: Randomized Block (6 blocks, 1 year data)

Complete Randomized Sites Year 1 & 2 Data



<u>Model</u>

density~ *modifier*year* + (1|site) + (1|seedmix) Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(> z)
<u>Conditional Model:</u>				
(Intercept)	3.04049	0.54106	5.620	1.92e-08 ***
ConMods	0.02204	0.34765	0.063	0.949442
Mulch	1.17976	0.31448	3.751	0.000176 ***
Pits	1.45608	0.31205	4.666	3.07e-06 ***
Year	-1.18563	0.21007	-5.644	1.66e-08 ***
Year*ConMods	0.31637	0.26000	1.217	0.223667
Year*Mulch	-0.01529	0.23623	-0.065	0.948400
Year*Pits	-0.11396	0.23517	-0.485	0.627970
<u>Zero-inflation model:</u> No significant effects			R²(margina R²(condition	l) = 0.514 nal) = 0.877

Preliminary Results

- Years differed from one another
- Significant treatment effects:

Pits (more likely to affect plants) > Mulch > ConMod = No Treatment

Randomized Block Sites Year 1 & 2 Data



<u>Model</u>

density~ *modifier*year* + (1/site/block) + (1/seedmix) Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(> z)
Conditional Model:				
(Intercept)	-0.55611	1.36046	-0.409	0.683
ConMods	0.45973	1.91596	0.240	0.810
Mulch	1.13849	1.41203	0.806	0.420
Pits	0.75976	1.45412	0.522	0.601
Year	0.26813	0.74287	0.361	0.718
Year*ConMods	0.40064	1.01877	0.393	0.694
Year*Mulch	0.08169	0.79705	0.102	0.918
Year*Pits	0.18933	0.81899	0.231	0.817
Zero-inflation model:			R²(marai	nal) = 0.473

No significant effects

Preliminary Results

- No significant effects.
- Low precipitation following seeding -> <u>Very little plant growth overall</u>
- Establishment increased yr 2 but not enough to see treatment effects

Randomized Block Sites Year 1 Data



<u>Model</u>

density~ *modifier*year* + (1/site/block) + (1/seedmix) Zero-inflated hurdle model using a Poisson distribution

	Estimate	Std. Error	z value	Pr(> z)
<u>Conditional Model:</u>				
(Intercept)	1.06372	0.20516	5.185	2.16e-07 ***
ConMods	0.08508	0.25656	0.332	0.7402
Mulch	0.74703	0.19200	3.891	9.99e-05 ***
Pits	0.52513	0.21982	2.389	0.0169 *
Zero-inflation model:				
(Intercept)	-0.2480	1.1246	-0.220	0.8255
ConMods	-0.9996	1.0022	-0.997	0.3186
Mulch	-2.0970	0.8918	-2.352	0.0187 *
Pits	0.4595	0.7665	0.599	0.5489
			R ² (marginal	') = 0.281
Preliminary Results				

• Mulch increases likelihood of a plant being present

• If plants are present

Mulch (more likely to affect plants) > Pits > ConMod = No Treatment

USGS Well Pad Reclamation and Research Project ("WPRR")

Large-scale component













Flatten surface and Drill-seed

Monitoring

- Annual plant density counts
- 10 quadrats/plot
- Species data are summed by functional groups (*e.g. seeded species*)







Model

Sqrt(density) ~ treatment*seed method + (1/site/block) Linear mixed effects model with a square root transformation

	Chisq	Df	Pr(>Chisq)
Mulch	28.8221	1	7.934e-08 ***
Seed Method	6.1854	1	0.01288 *
Seed Method*Mulch	3.2234	1	0.07259.

R-sq (marginal)	0.08296
R-sq (conditional)	0.92870

Preliminary Results

- Most variance explained by site
- Significant treatment effects
 Mulch > no mulch
 Broadcast + rough surface > Drill-seed + flat

Four sites, installed 2019-2021



<u>Model</u>

Sqrt(density) ~ treatment*seed method + (1/site/block) Linear mixed effects model with a square root transformation

	Chisq	Df	Pr(>Chisq)
Mulch	3.5465	1	0.05967.
Seed Method	21.2112	1	4.114e-06 ***
Seed Method*Mulch	0.0939	1	0.75933

R-sq (marginal)	0.27484
R-sq (conditional)	0.65186

Preliminary Results

- High seedling mortality
- Significant treatment effects
 Mulch (marginally) > no mulch however:
 Strong lasting effect of broadcast + rough surface

Collaborative Reclamation Research

Reclamation Literature Review

- Mulch, soil depressions studied, used for reclamation Only 14% & 4% of studies respectively, but on the rise
- Mulch & depressions can benefit plants Through water retention, microclimate modification, improving OM/structure/chemistry
- Neither treatment is consistent 22% of mulch & 33% of depression papers found <u>no effect</u> mixed results due to treatment factors, sites, species, year







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 22% of mulch & 33% of depression papers found <u>no effect</u> mixed results due to treatment factors, sites, species, year

Small Scale Study (plot-level)

- Early results: Mulch or Pits? Site/year dependent
- No effects when precipitation is exceptionally low

Large Scale study (landscape-scale)

- Mulch > no mulch
- Rough surface/broadcast seeding: lasting effects
- Cost-effective solutions needed









Additional Collaborators

Zack Bowen **Travis Poitras Travis Nauman** Steve Hanser **Rita Reisor** Patrick Ahrnsbrak Patrick Anderson Natalie Stone Molly McCormick Marty Appawoo **Kevin Sadlier** Josh Wager Jan Nelson **David Pilliod** David Baird **Christine** Cimiluca **Casey McKee**

Thank You!







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Talented Technicians

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