Siting Justification – Midyear Submission

NAU Hydropower Collegiate Competition

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1 Introduction

Converting a non-powered dam (NPD) into a hydroelectric facility requires in-depth research on the power potential, feasibility and risks associated with the site. The Siting Challenge required us to navigate numerous dams before we could finalize our selections: KR Lock and Dam #4 in Kentucky, the Mishawaka Fish Ladder in Indiana, and the Fish Barrier Dam in Washington. Our team, comprised of electrical and mechanical engineering students, focused on identifying key aspects and strategies for risk mitigation related to hydroelectric development. Despite our limited background in environmental and civil engineering theories, our team used our problem-solving skills to effectively research these areas to assess risks and needs. Ultimately, we utilized our industry expert resources and employed weighted risk matrices to refine our choices to the final three sites.

2 Site Selection Process

With the vast landscape of over 80,000 non-powered dams (NPDs) across the United States, our team initially focused our search within Arizona, leveraging proximity to our university to potentially simplify project logistics. Utilizing resources such as the *Oak Ridge National Laboratory's NPD Explorer* [3] and *ArcGIS Pro* [1] [2] [4] [6], we meticulously gathered critical data including high-resolution streamlines, hydraulic head heights, and hazard classifications. Our initial set of criteria directed us toward a group of dams in Arizona that were not suitable for development, and further investigation across the country was required to meet the competition's specified power generation range. The development of risk matrices was pivotal in distilling our options down to three viable sites, selected for their potential to meet the competition's requirements and align with our design objectives.

2.1 Selection Process and Criteria

The initial phase of our investigation, as depicted in the decision matrix of Arizona dams (<u>Table A1, Appendix A</u>), highlighted a critical water shortage in the region, casting doubt on the viability of hydroelectric projects within Arizona. As our expertise deepened, fueled by industry consultations and thorough research, we uncovered discrepancies in the data pertaining to Arizona's potential sites. Such findings necessitated a shift in our focus to types of dams less demanding in civil engineering modifications. Specifically, we targeted concrete and run-of-river dams, leading us to widen our search to states with more favorable hydrological conditions, such as California, Colorado, Washington, Oregon, Idaho, Kentucky, and Indiana. Our decision matrices, showcased in <u>Appendix A (Tables A3-A8)</u>, guided us through a consistent evaluation of various criteria, ensuring a uniform assessment across all potential sites.

To assist in the interpretation of these matrices, we established a legend, detailed in <u>Table A2 of Appendix A</u>, to provide clarity on our scoring approach. Our key criteria included:

- **<u>Potential Energy:</u>** Assessing an NPD's potential energy requires a more thorough understanding of the environment, existing structure, and flows. So, for preliminary estimate, we utilized the potential generation formula below to estimate the maximum potential [5]. This factor received a substantial weight of 25% in our decision matrices due to the competition's focus on generation capacity.

$$Potential\ Annual\ Generation = \frac{Q \times \Delta\mathrm{H} \times \eta}{11{,}800} \quad \mathrm{MW}$$

Where $\eta = 0.85$ assumed efficiency, Q is annual mean flow rate, and $\Delta\mathrm{H}$ is assumed head.

- **<u>Flow Rate:</u>** We established a baseline flow rate of 1000 cubic feet per second (cfs), deducing that at least 10 feet of head would be required to generate 1 MW. Sites with higher flow rates were preferred for their increased design flexibility and potential for higher energy output.
- **<u>Distance to Existing Power Infrastructure:</u>** Recognizing the limitations imposed by remote locations on small hydro projects, we set a cap of 10 miles from existing power infrastructure to preserve project viability, with closer sites deemed more favorable.

- **<u>Dam Ownership Type</u>** The likelihood of collaboration from dam owners was evaluated, with consideration given to the time and financial implications associated with obtaining project consent and initiating development.
- **<u>Potential Environmental Impact:</u>** Scores were derived from recent inspection data of dams, supplemented by additional research to ensure a comprehensive environmental assessment, such as endangered species within the area and current water quality.
- **<u>Dam Integrity:</u>** The integrity of dams was evaluated based on their construction year and the extent of recent refurbishments, ensuring that selected sites maintain structural soundness.
- **<u>Dam Type:</u>** Conversations with industry experts revealed that certain dam types, notably concrete, offer superior benefits in terms of conversion feasibility and risk mitigation, influencing our selection process.
- **<u>Accessibility:</u>** The feasibility of ongoing maintenance and operations was closely tied to each site's proximity to necessary infrastructure, with more accessible sites scoring higher.
- **<u>Local Community Need:</u>** Economic factors, including job availability and the financial health of local communities, were researched at promising sites to determine the potential socio-economic benefits of the project.

Following our research, we engaged in critical discussions about factors that could disqualify certain sites, such as ecological concerns, cultural significance, and regulatory statuses (such as pending or current FERC licenses). These factors were crucial in helping us reduce the number of viable locations to the final three, which were the Kentucky River Lock and Dam #4, the Mishawaka Fish Ladder in Indiana, and the Fish Barrier Dam in Washington. These locations were chosen based on their operational viability and potential for seamless integration.

2.2 Final Selected Sites and Next Steps

Our final sites came down to KR Lock and Dam #4 in Kentucky, Mishawaka Fish Ladder in Indiana, and the Fish Barrier Dam in Washinton due to their feasibility and the positive impact they could have on their respective communities. Unlike Arizona, where water scarcity posed a significant challenge, these regions offer more reliable water sources essential for hydroelectric power generation. With our focus narrowed to these three prospects, our forthcoming actions will delve into a comprehensive feasibility study for each. This will encompass a further evaluation of environmental impacts, construction and operational logistics, amount of watershed, and other site-specific risks. By collating data and consulting with local experts, we will determine the most suitable site for the competition's requirements and proceed to refine our conceptual design.

Our envisioned co-development strategies are carefully designed to augment the unique attributes of each finalist site. At Kentucky's KR Lock and Dam #4, we're exploring a partnership with the nearby Buffalo Trace Distillery to supply renewable energy, complemented by a battery storage system for peak demands, showcasing sustainable industry support. The Fish Barrier Dam in Washington presents an opportunity for pumped hydro storage, leveraging its proximity to the Mayfield Dam to boost efficiency. In Indiana, the Mishawaka site, with its existing fish ladder, inspires us to integrate StreamDiver units, enhancing the natural landscape. This initiative could align with municipal development goals, offering a blend of tourism and education on renewable energy, thus fostering community engagement and environmental awareness.

3 Risk Identification

In addressing the risks associated with this project, our team placed significant emphasis on early risk analysis to guide our decision-making process. Our objective is to develop a project that not only promises feasible returns to attract investors but also ensures long-term sustainability and supports environmental rehabilitation efforts. To this end, we devised matrices to systematically evaluate and balance these considerations, ensuring the identification of the safest and most cost-effective solutions (refer to Table B1 in Appendix B).

3.1 Approach to Minimizing Risk

Throughout the siting challenge, we diligently updated our research and remained vigilant for potential critical risks, including public protests and government initiatives for river rewilding. Construction and maintenance accessibility was a priority, steering us away from extremely remote locations. Our risk assessment incorporated a comprehensive review of all risk factors, derived from industry interviews and extensive research, to identify viable sites for hydroelectric conversion.

In preparing for future risk evaluations, we delved into the predominant hydroelectric risks at our three chosen sites. Detailed matrices outlining these risks are available in Tables B.2-B.4 in Appendix B. Common challenges across our sites include the management of heavy rainfall, flooding, and natural disasters, necessitating robust emergency planning. Environmental assessments will be conducted to evaluate the impact on protected and invasive species, ensuring the project's harmony with local ecosystems. Moreover, there's potential to employ predictive models to anticipate climatic variations due to global warming, ensuring the resilience of our operations. Proactive strategies will be implemented to manage river debris and trash accumulation, and we will establish safety protocols and maintenance schedules to guarantee consistent power generation. Future design and siting efforts will incorporate these risk mitigation measures to affirm the project's viability.

4 Conclusion

The process of converting a non-powered dam into a hydropower one is an endeavor that demands meticulous research, effective communication, and proficient project management. Our team approached the task with diligence, leveraging various software tools and industry interviews to identify potential sites and assess associated risks. Our next steps involve detailed feasibility studies, incorporating risk assessments and co-development strategies that align with local community and environmental goals. As we refine our designs and engage with stakeholders, our focus remains on ensuring the viability, sustainability, and community integration of our hydroelectric conversion project, poised to contribute to the clean energy landscape.

5 References

[1] "ArcGIS Web Application," *ornl.maps.arcgis.com*. https://ornl.maps.arcgis.com/apps/webappviewer/index.html?id=4756decebce4408ba4bc0a0c3dc23a5f (accessed Jan. 27, 2024).

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[3] Carly H. Hansen, Christopher R. DeRolph, Forest D. Carter, Scott T. DeNeale. 2022. U.S. Non-Powered Dam Characteristics Inventory. HydroSource, Oak Ridge National Laboratory, Oak Ridge, TN. DOI: https://www.doi.org/10.21951/US_NPD_Characteristics/1860464

[4] G. H. Nelson, "Maps to estimate average streamflow and headwater limits for streams in U.S. Army Corps of Engineers, Mobile District, Alabama and adjacent states," U.S. Department of the Interior, U.S. Geological Survey, Mobile, Alabama, 1984.

[5] Potential hydroelectric development at existing Federal Facilities. [Online]. Available: https://www.usbr.gov/power/data/1834/Sec1834_EPA.pdf [Accessed Oct. 28, 2023].

[6] The U.S. Department of Energy, "An Assessment of Energy Potential at Non-Powered Dams in the United States", Oak Ridge National Laboratory, April 2012. [online]. Available: https://www.energy.gov/eere/water/articles/assessment-energy-potential-non-powered-dams-united-states. [Accessed: 25/Oct/2023].

Appendix A

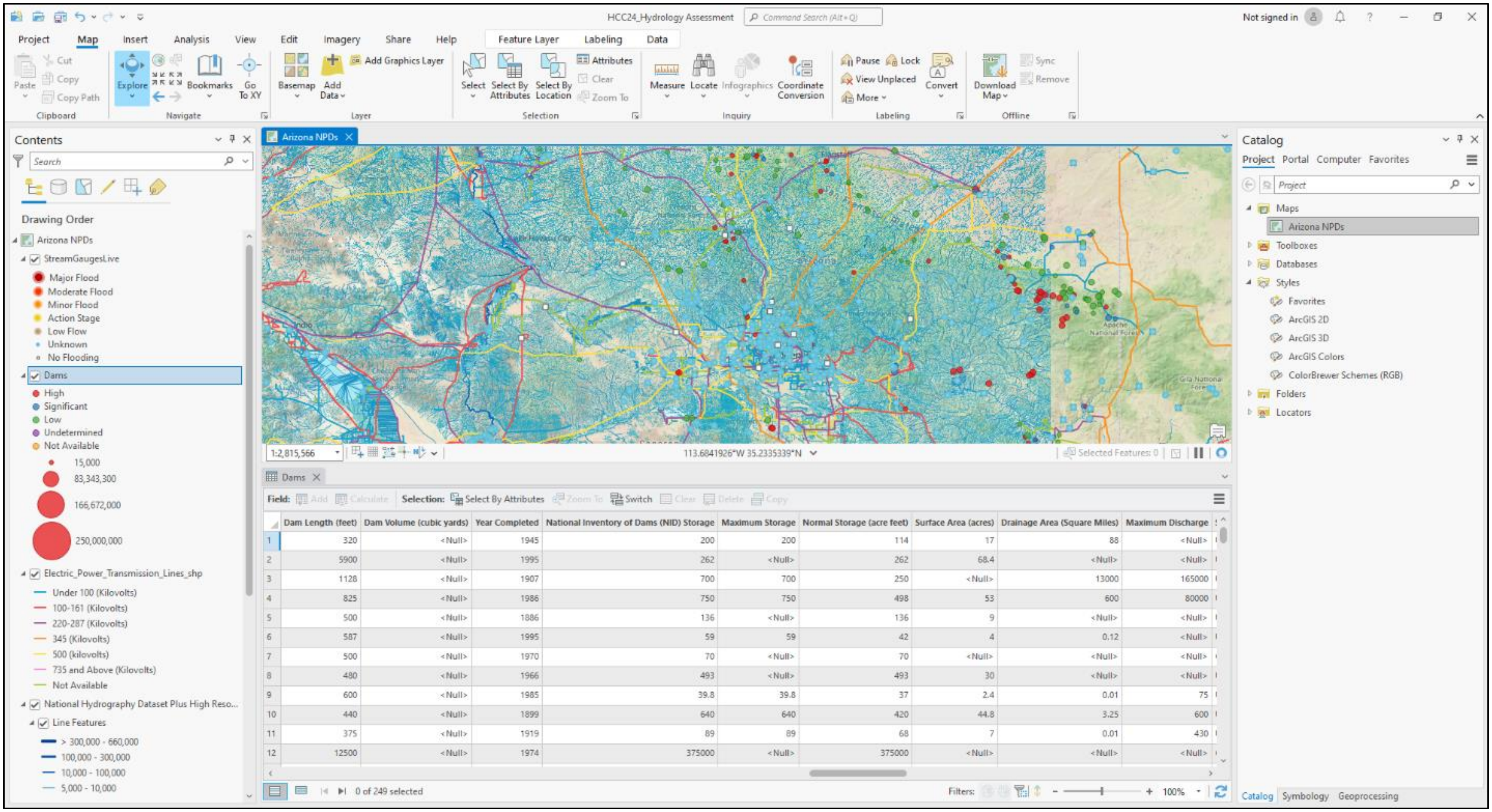

Figure A1: ArcGIS software used for data analysis and geographical data.

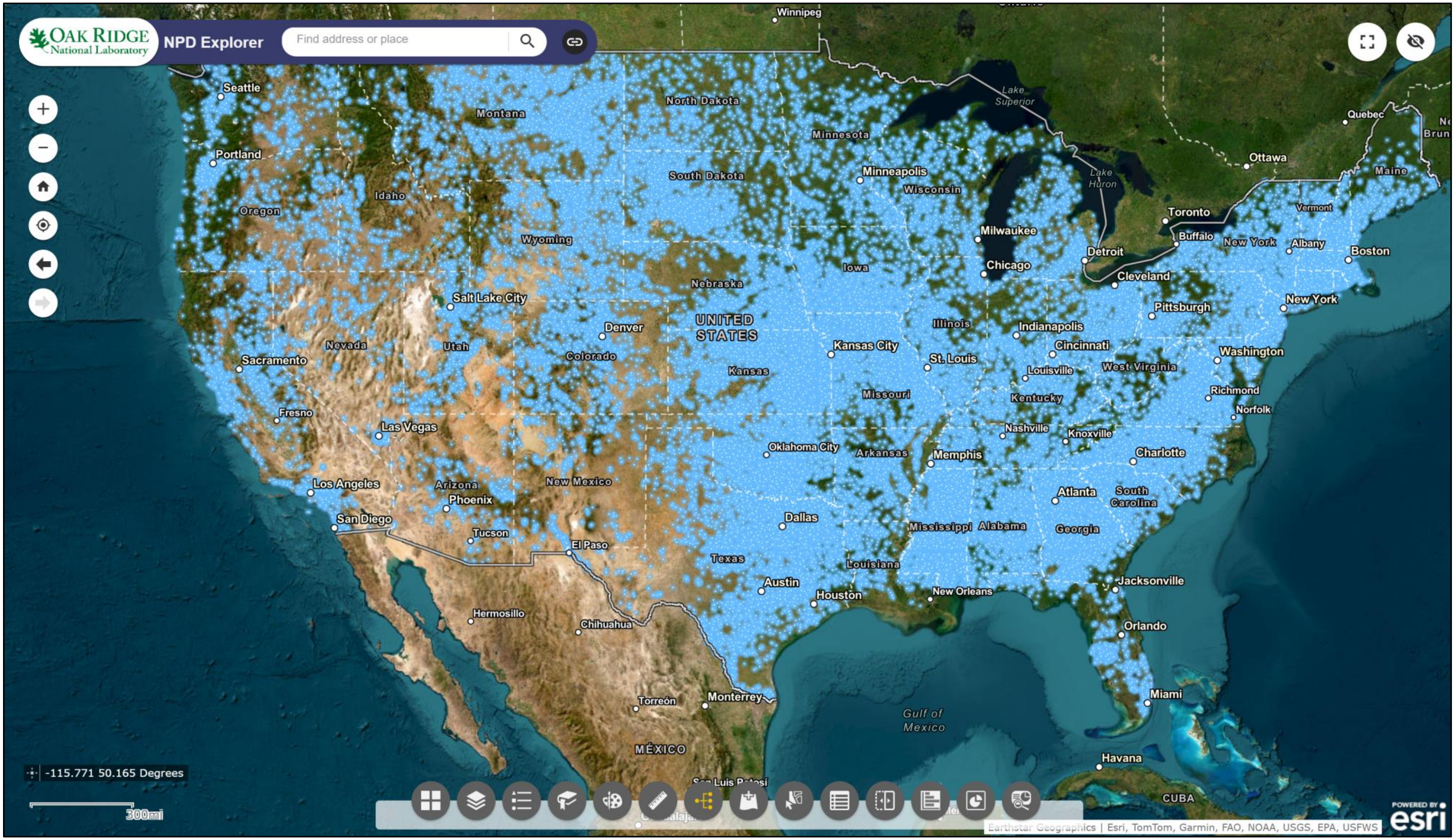

Figure A2: NPDamCat online software for accessing site-specific dam data.

Estimating Potential Energy

$$Potential\ Annual\ Generation = \frac{Q \times \Delta H \times \eta \times T}{11{,}800}\ \text{MWh} \qquad (1)$$

flow rate (Q), net head (ΔH), assumed efficiency (η), and the duration of generation (T).

Figure A3: Estimated Generation Equation from "An Assessment of Energy Potential at Non-Powered Dams in the United States".

Table A1: Initial dam selection for Arizona. Matrix was modified during further investigation into other dams.

Criterion	Weight	Bartlett Dam		Granite Reef Diversion		Horseshoe Dam		Palo Verde Diversion	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	5%	70	3.5	40	2	65	3.25	95	4.75
2. Flow Rate	8%	35	2.8	72	5.76	35	2.8	100	8
3. Distance to Existing Infrastructure (transmission lines/substations)	15%	57	8.55	88	13.2	5	0.75	62	9.3
4. Distance to Alternative Energy Sources	7%	30	2.1	38	2.66	0	0	24	1.68
5. Distance to Nearest City	5%	33	1.65	70	3.5	38	1.9	88	4.4
6. Amount of Watershed	7%	43	3.01	38	2.66	7	0.49	35	2.45
7. Dam Ownership Type	7%	80	5.6	85	5.95	75	5.25	80	5.6
8. Potential Environmental Impact	10%	60	6	75	7.5	35	3.5	65	6.5
9. Dam Integrity	4%	33	1.32	23	0.92	31	1.24	40	1.6
10. Cost of Development/Economic Viability	10%	30	3	85	8.5	3	0.3	60	6
11. Water Storage Capacity	5%	90	4.5	65	3.25	83	4.15	68	3.4
12. Availability of Historical Flow Data	3%	75	2.25	73	2.19	70	2.1	69	2.07
13. Accessibility (ease of access for construction and maintenance)	5%	30	1.5	68	3.4	35	1.75	54	2.7
14. Local Community Support	5%	43	2.15	76	3.8	22	1.1	55	2.75
15. Technical Feasibility	4%	38	1.52	63	2.52	43	1.72	72	2.88
Total	**1**		**49.45**		**67.81**		**30.3**		**64.08**
Relative Rank			**1**		**2**		**3**		**3**

Table A2: Point scoring legend for revised matrices for remaining states.

Criterion	Weight	Soring Legend (0-100 point)	
		given score	Key
1. Potential Energy	25%	0-100	1 MW =10 pts
2. Flow Rate	10%	0-100	1000-2500+ cfs (5 pts per 1000 cfs
3. Distance to Existing Power Infrastructure	10%	0-100	20+ -> 0 miles away (-5pts per mile away)
4. Dam Ownership Type	5%	0-100	Hydropower developers = 100, private companies = 90, army corps = 80, Federal = 70, state = 60, municiplaities = 50, join ventures = 40, coops = 30, beuro of reclemation = 20 , other =10
5. Potential Environmental Impact (risk)	10%	0-100	risk level 1 = 100, 2 = 70, 3 = 40, else = 10
6. Dam Integrity (age)	12%	0-100	for each year old it is -1 pt
7. dam type	13%	0-100	concrete = 100, gravity or arch = 50, rock = 70, earth =30
8. Accessibility (access for construction and maintenance)	5%	0-100	for every mile away -5 pts
9. Local Community Need	10%	0-100	determine from research; include economic indices and local tribes/communities nearby
Total	**100%**		
Relative Rank			

Table A3: Kentucky and Indiana dam selection matrix.

Criterion	Weight	KR Lock & Dam #4 KY03016		Williams Dam IN00805		Mishawaka Fish Ladder IN00806	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	25%	30	7.5	15	3.75	15	3.75
2. Flow Rate	10%	90	9	80	8	75	7.5
3. Distance to Existing Power Infrastructure	10%	30	3	20	2	60	6
4. Dam Ownership Type	5%	60	3	30	1.5	50	2.5
5. Potential Environmental Impact (risk)	10%	45	4.5	0	0	90	9
6. Dam Integrity (age)	12%	60	7.2	40	4.8	80	9.6
7. Dam Type	13%	80	10.4	100	13	75	9.75
8. Accessibility (access for construction and maintenance)	5%	100	5	35	1.75	100	5
9. Local Community Need	10%	80	8	5	0.5	90	9
Total	**100%**		**57.6**		**35.3**		**62.1**
Relative Rank							

Table A4: Colorado dam selection matrix.

Criterion	Weight	Lake Catamount Dam		Ritschard Dam		Windy Gap Dam		Trinidad Dam	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	20%	25	5	57	11.4	15	3	54	10.8
2. Flow Rate	10%	3	0.3	1.2	0.12	4	0.4	1.3	0.13
3. Distance to Existing Infrastructure (transmission lines/substations)	10%	59	5.9	100	10	100	10	97	9.7
4. Dam Ownership Type	5%	60	3	60	3	60	3	70	3.5
5. Potential Environmental Impact	10%	70	7	40	4	70	7	40	4
6. Dam Integrity (age)	12%	29	3.48	10	1.2	44	5.28	36	4.32
7. Dam Structure type	13%	85	11.05	30	3.9	30	3.9	30	3.9
8. Accessibility (access for construction and maintenance)	10%	60	6	95	9.5	95	9.5	100	10
9. Local community need	10%	30	3	25	2.5	35	3.5	40	4
Total	**100%**		**44.73**		**45.62**		**45.58**		**50.35**
Relative Rank					**3**		**2**		**1**

Table A5: California dam selection matrix.

Criterion	Weight	New Woodbridge Diversion ID CA01461		Anderson Cottonwood CA00226		Healdsburg Recreation CA00791		Russian River No. 1 CA00849	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	20%	30	6	90	18	40	8	45	9
2. Flow Rate	10%	6	0.6	43	4.3	13	1.3	13	1.3
3. Distance to Existing Power Infrastructure	10%	100	10	60	6	45	4.5	70	7
4. Dam Ownership Type	5%	80	4	80	4	60	3	60	3
5. Potential Environmental Impact (risk)	10%	70	7	60	6	100	10	60	6
6. Dam Integrity (age)	12%	82	9.84	0	0	29	3.48	39	4.68
7. Dam Type	13%	20	2.6	40	5.2	100	13	50	6.5
8. Accessibility (access for construction and maintenance)	10%	100	10	60	6	45	4.5	90	9
9. Local Community Need	10%	40	4	25	2.5	50	5	40	4
Total	**1**		**54.04**		**52**		**52.78**		**50.48**
Relative Rank			**3**		**1**				**2**

Table A6: Washington dam selection matrix.

Criterion	Weight	Fish Barrier Dam WA00769		Barrier Dam WA00555		Howard A. Hanson Dam WA00298		Hiram M. Chitten Den locks & Dam WA00301		Zosel Dam (osoyoos) WA00556	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	25%	25.8	6.45	40	10	100	25	100	25	50	12.5
2. Flow Rate	10%	13.5	1.35	32.9	3.29	5.5	0.55	7.5	0.75	3	4.05
3. Distance to Existing Power Infrastructure	10%	100	10	96	9.6	93	9.3	100	10	95	9.5
4. Dam Ownership Type	5%	50	2.5	50	2.5	70	3.5	70	3.5	60	3
5. Potential Environmental Impact (risk)	10%	50	5	50	5	50	5	100	10	50	5
6. Dam Integrity (age)	12%	37	4.44	46	5.52	39	4.68	0	0	63	7.56
7. Dam Tyoe	13%	100	13	100	13	30	3.9	50	6.5	50	6.5
8. Accessibility (access for construction and maintenance)	5%	100	5	100	5	100	5	100	5	100	5
9. Local Community Need	10%	25	2.5	50	5	100	10	75	7.5	10	1
Total	**100%**		**50.24**		**58.91**		**66.93**		**68.25**		**54.11**
Relative Rank											

Table A7: Idaho dam selection matrix.

Criterion	Weight	Priest Lake ID00318		Payette Lake ID00244		Boise Diversion Dam (cant develop) ID00281		Murtaugh Lake Dam ID00156	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	25%	0	0	0	0	81.6	20.4	100	25
2. Flow Rate	10%	0	0	0	0	14.2	1.42	38	3.8
3. Distance to Existing Power Infrastructure	10%	0	0	0	0	90.6	9.06	92	9.2
4. Dam Ownership Type	5%	0	0	0	0	70	3.5	90	4.5
5. Potential Environmental Impact (risk)	10%	0	0	0	0		0	40	4
6. Dam Integrity (age)	12%	0	0	0	0		0	0	0
7. Dam Type	13%	0	0	0	0		0	30	3.9
8. Accessibility (access for construction and maintenance)	5%	0	0	0	0		0	100	5
9. Local Community Need	10%	50	5	75	7.5	100	10	25	2.5
Total	**100%**		**5**		**7.5**		**44.38**	**57.9**	
Relative Rank									

Table A8: Oregon dam selection matrix.

Criterion	Weight	Crane Prairie Dam Do Not Develop		Winchester		Blue River Dam		Wickiup		Fern Ridge Dam	
		OR00279		OR00263		OR00013		OR10022		OR00016	
		Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score	Score out of 100	Weighted Score
1. Potential Energy	25%	0	0	70	17.5	64	16	23.2	5.8	11.7	2.925
2. Flow Rate	10%	0	0	21.885	2.1885	2.5	0.25	2.5	0.25	2.5	0.25
3. Distance to Existing Power Infrastructure	10%	0	0	100	10	88.3	8.83	50	5	100	10
4. Dam Ownership Type	5%	0	0	30	1.5	70	3.5	70	3.5	70	3.5
5. Potential Environmental Impact (risk)	10%	0	0	70	7	70	7	80	8	75	7.5
6. Dam Integrity (age)	12%	0	0	0	0	45	5.4	23	2.76	16	1.92
7. Dam Type	13%	0	0	30	3.9	30	3.9	20	2.6	30	3.9
8. Accessibility (access for construction and maintenance)	5%	0	0	100	5	93.25	4.6625	50	2.5	100	5
9. Local Community Need	10%	0	0	50	5	100	10	25	2.5	75	7.5
Total	**100%**		**0**		**52.0885**		**59.5425**		**32.91**		**42.495**
Relative Rank											

Appendix B

Table B1: Siting Risk Matrix for feasibility and decision matrix considerations

Siting Project Risk Mitigation Matrix's (1 = low impact, 5 = extreme impact)																						
Feasibility Risk	**Construction and Civil Impact**				**Energy and Grid Impact**				**Technichal/other Impact**				**Mechanical Impact**				**Enviromental Impact**				**RISK SCORE**	
		Time	Cost	Risk		Time	Cost	Risk		Time	Cost	Risk		Time	Cost	Risk		Time	Cost	Risk	Max individual	Total Score
Potential Energy (20 MW max)	Large civil impact, the larger the more time to impliment	5	5	3	The larger the system the more we can add to the grid and earn $	1	1	1	While larger, it will likely require more upkeep	3	3	3	More size more impact	3	4	4	Again the larger our system the larger the possible fallout	4	4	4	60	48
Flow Rate (20,000 cfs max)	Higher flow rate means more complex civil techniques	5	5	5	Higher flow results more possibility for implementation and production	1	1	1	Will require more complex solutions	5	5	5	More stress on systems.	5	5	3	Less impact if constat run of river	2	3	2	60	53
Distance to existing power infrastructure	Makes contruction and operation difficult and expensive	3	5	2	Loss in transmission and effeciencies	3	4	2	Further from power the more difficult to repair/operate	3	3	3	Longer shut off/on time further away, harder O&M	4	3	3	Further is harder for emergency midigation in case of disaster	3	4	4	60	49
Ownership Type	Makes construction feasable	5	4	2	may have to pay/rent the land	2	3	3	Not much	1	1	1	Type of operation, noise and when power is generated	2	2	2	Impose or don't risk	2	2	1	60	33
Community Need	Community must need/see impact to allow	3	3	3	Most places need renewbale power with government initiatives	1	1	1	Community may complicate construction methods	3	2	2	Not much impact on mechanichal	1	1	1	Can decide if a dam is built or not; attend to community needs	4	4	5	60	35
Environmental	Largly decides operations	4	4	4	Green energy yay!	1	1	1	May increase difficulty of technichal solutions	3	3	2	Solutions have to be considered for enviromental sustainability	3	4	2	Obviously!	5	5	5	60	47
Dam Integrity (time since last refurbishment	The older the more upgrades required	3	3	3	Not much impact besides powerhouse	1	2	1	Technichal solutions may be required	3	3	1	Not much impact on mechanichal	1	1	1	Large consqeunces for improper upgrades the older the dam	2	3	2	60	30
Dam Type	Huge impact on cost and time	5	5	4	Not Applicable	1	1	1	May require technical solutions	3	3	2	Not much impact on mechanichal	2	2	1	Earth dams require more development and more risk	3	3	4	60	40
Accessability	Will increase cost and effecincy	5	4	2	Expensive infastructure	3	4	2	Not much	2	2	1	Not much impact on mechanichal	2	2	2	More driving and less acess	2	2	4	60	39

Table B2: Washington Dam risk ID

Washington Risk	Possible Impact			RISK SCORE
Protected Species	there are a multitude of protected species in the state			Max individual 30
	Chance	Cost	Risk	Total Score
	6	8	5	19
Earthquakes	washington is near a tectonic plate			Max individual 30
	Chance	Cost	Risk	Total Score
	8	10	10	28
Floods	storm and snowmealt season in the PNW			Max individual 30
	Chance	Cost	Risk	Total Score
	10	5	8	23
Sedimentation	erosion from nearby mountains			Max individual 30
	Chance	Cost	Risk	Total Score
	7	5	7	19
Wildfires	the US has seen an increase in wildfires			Max individual 30
	Chance	Cost	Risk	Total Score
	6	7	6	19
Debris Flow	happens from heavy floods			Max individual 30
	Chance	Cost	Risk	Total Score
	5	4	5	14
Invasive Species	possiblity			Max individual 30
	Chance	Cost	Risk	Total Score
	4	8	3	15
Structural Failure	not likely			Max individual 30
	Chance	Cost	Risk	Total Score
	1	10	1	12

Table B3: Kentucky Dam risk ID

Kentucky Risk	Possible Impact			RISK SCORE
Natural Disasters	Tornadoes and severe winds			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	8	7	21
Erosion	Harsh weather and errosion of embankments			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	6	6	18
Floods	Storm and flood season			Max individual
				30
	Chance	Cost	Risk	Total Score
	10	6	8	24
Sedimentation	Build up from erosion and agriculture runoff			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	5	7	18
Water Quality	Agriculture runoff and other risks posed to dam water			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	7	6	19
Debris Flow	Happens from heavy floods			Max individual
				30
	Chance	Cost	Risk	Total Score
	5	4	5	14
Invasive Species	Invasive asian carp and more			Max individual
				30
	Chance	Cost	Risk	Total Score
	4	8	3	15
Structural Failure	Not likely			Max individual
				30
	Chance	Cost	Risk	Total Score
	1	10	1	12

Table B4: Indiana dam risk ID

Indiana Risk	Possible Impact			RISK SCORE
Natural Disasters	Tornadoes and severe winds			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	8	7	21
Erosion	Harsh weather			Max individual
				30
	Chance	Cost	Risk	Total Score
	5	5	5	15
Floods	Storm and flood season			Max individual
				30
	Chance	Cost	Risk	Total Score
	10	5	8	23
Sedimentation	Build up from erosion			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	5	7	18
Water Quality	Agriculture runoff and other risks posed to dam water			Max individual
				30
	Chance	Cost	Risk	Total Score
	6	7	6	19
Debris Flow	Happens from heavy floods			Max individual
				30
	Chance	Cost	Risk	Total Score
	5	4	5	14
Invasive Species	Zebra muscles and invasive carp			Max individual
				30
	Chance	Cost	Risk	Total Score
	4	8	3	15
Structural Failure	not likely			Max individual
				30
	Chance	Cost	Risk	Total Score
	1	10	1	12