Assessment of the Potential for Small, Grid-Connected, Run-of-the River Hydropower in Humboldt County

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for

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Goals & Objectives

The overall strategy is outlined in Redwood Coast Energy Authority's (RCEA) Local Small Hydropower Prospectus

We conducted two levels of assessment: 1) a broad-scale fundamental analysis of all potentially developable watersheds in the study area (Humboldt County), and 2) Selecting priority watersheds with identified high development potential for a focused and detailed analysis.

- Understand the potential for small, utility-scale, grid-connected, run-of-the-river (ROTR), high-head-low-flow hydropower in Humboldt County.
- Define a package of Best Practices for "hydropower done right", including assessment, siting, sizing, instream flows, low-impact roads, design, construction, O&M, risk amelioration, and decommissioning.
- Attract investors and landowners by reducing project environmental uncertainty and risks.
- Develop hydrologic assessment tools that provide high-reliability hydroelectric potential and reliability characterization that can be applied region-wide.
- Develop robust BMPs (Best Management Practices) for powerline access roads for all projects.
- Understand the problems and opportunities of remote small hydropower installations.
- Provide educational opportunities for graduate students at HSU Engineering and Schatz Energy Research Center.

Note: The project began with a broader set of goals. Due to a funding shortfall at RCEA and the pandemic-related difficulties of both field visits and retrieving environmental information from Forest Service and State agency field offices, the project was downsized in February 2021 to focus on what was judged to be the most important components--hydrology and related assessments that could be accomplished with minimal contact. The environmental contexts of the watersheds, such as fish and wildlife values, visual concerns, erosional risks, and others, were not evaluated at this time due to the constraints mentioned above.

Master's Thesis in preparation

A Master's Thesis project is being conducted by HSU Environmental Engineering graduate student Bikash Pradhan to test several hydrologic models for accuracy in flow estimation using the selected watersheds, and to estimate the power potential of the selected watersheds with significantly more detail than given here. When completed, the Thesis will be available from Humboldt State University, Department of Environmental Resources Engineering.

Key Concepts of "fish-friendly" Run-of-the-River hydropower

Damages from large impoundment-based hydropower include:

- Inundation and loss of highly productive floodplain forests upstream of the dam
- Decomposition of flooded vegetation leading to methane gas release (~25 times more powerful than CO2 as a greenhouse gas)
- Alteration of stream base level resulting in destabilization of side slopes and loss of active floodplain and associated forests
- Changes in species composition and groundwater levels due to dewatering downstream of the dam.
- Encroachment of vegetation into dewatered stream channels
- Alterations of peak flows, loss of overbank flooding and loss of associated channel complexity, delta formation, and increased coastal erosion

By contrast, small, Run-of-the-River hydropower:

- Provides carbon-free power from small streams that do not support anadromous fish.
- Has a streamflow regime that is unchanged upstream of the diversion and downstream of the powerplant
- Has low embedded GHG emissions in the required infrastructure
- Has no impoundments. Very small impoundments of diverted streamflow may exist for sediment settling or a small headpond behind a diversion weir.
- If properly sited, adds no barriers to fish migration across all life stages of fish and other migrating aquatic organisms.
- Best practices for small hydropower developed and implemented (including Best Management Practices for water quality protection)
- Most systems are eligible for State Renewable Portfolio Standard Programs
- Wintertime power has strong complementarity with solar and wind power

Features of small hydropower systems

A small hydropower installation typically requires six features:

1. **Diversion point:** Place on the stream where water is diverted to a penstock for movement downhill to a generating station ("powerhouse"). This usually involves a diversion weir in the stream channel, sometimes a small pond above the weir ("headpond"), and a settling facility to remove coarse sediments from the diverted streamflow.

2. **Diversion of streamflows:** A portion of the streamflow is diverted and carried downstream to the powerhouse to generate electricity. This results in lower flows in the diverted reach. Streamflow is returned to the stream channel below the powerhouse ("tailrace"). Thus the affected stream reach is between the diversion point and the tailrace of the powerhouse.
3. **Penstock:** Pipe that transmits the diverted flow from the diversion point to the powerhouse. This is typically a heavy-gauge pipe made of strong material laid across the landscape with supports.
4. **Powerhouse:** Building where the turbine and controls are housed that receives the diverted streamflow to generate electricity. Diverted streamflow: is returned to the natural stream channel at or near the powerhouse.
5. **Transmission lines:** to convey the generated power to the substation or point of interconnection to the larger grid.
6. **Access roads or trails:** Each of these features requires access for construction and maintenance, except for the penstock for which a road is not typically needed. Usually, this is in the form or roads or trails, depending on the equipment required to service the system component.

Each of these features must be planned and designed, and the associated environmental effects assessed, disclosed, and mitigated.

The most important impacts to consider for most systems are related to:

- Changes in streamflow in the stream reach between the diversion point and the powerhouse
- Land disturbance to accommodate the diversion structures, penstock, and powerhouse
- Access road impacts
- Impacts of decommissioning of the facility

Please refer to the "best practices" section for practices that limit environmental effects.

Steps of Analysis

1) Identify key contacts: inform and query on approach and key questions
2) Define objectives and study area
3) Identify priority watersheds based on selection criteria
4) Gather existing data on watershed and interconnection opportunities
5) Create a watershed inventory of needed information (deferred)
6) Identify data gaps
7) Collect additional data if needed.
8) Choose streamflow diversion points and powerhouse sites that minimize road impacts.
9) Define site hydrology to fully understand power generation potential
10) Analyze data and assess feasibility

11) Identify feasibility based on environmental and economic findings
12) Review and critique
13) Reach decisions on further actions
14) Implement actions to move forward if feasible and appropriate

Selection of Priority Watersheds

Appropriate Scale

The subwatershed (HUC-6, or 12-digit Hydrologic Unit Code) is the ideal scale for this assessment. These units average between ~10,000 and 40,000 acres. (https://water.usgs.gov/GIS/huc.html). This size and unit of watershed fits the criteria for small hydropower and are now widely used by land use planners and regulatory agencies as units of analysis and decision-making.

Humboldt County HUC-6 watersheds and transmission lines

Figure 1. Humboldt County 6-level watersheds and transmission lines. Trans   mission lines are the arteries of the electrical grid, which also includes distribution lines, substations, and transformers to supply power to end-users. Due to the size of small hydropower systems, it is often most feasible to interconnect them to the lower-voltage distribution system, which is not shown here.

Humboldt County has about ninety-eight 6th-level watersheds (HUC-6). A screening assessment of these yields just 6 top candidates for consideration of developing small hydropower.

Screening of Candidate Watersheds

A coarse assessment was conducted to select watersheds that appear to have the most significant acceptable hydropower development potential and appear feasible at the screening level. Humboldt County has about ninety-eight 6th-level watersheds (HUC-6). A screening assessment of these yields just 6 top candidates for consideration of developing small hydropower.

Selection Criteria

Not all criteria are necessarily applicable to all watersheds

- ✔ A suitable powerhouse location upstream of anadromous fish habitat is available (this may not be the case on tribal lands). This provides that streamflow regimes in anadromous fish habitats are unaffected.
- ✔ The watershed contains significant drainage area and relief. (>~5 square miles area) such that sufficient streamflow exists to support small, high-head and low-flow utility-scale hydropower.
- ✔ Power transmission or distribution lines or a substation is in close proximity for tenable interconnection to the grid
- ✔ Different land ownership types across the selected watersheds to enhance understanding of various development opportunities

The screening determination evaluated each significant-size watershed in the study area as: Available, Capable, and Suitable.

- **Available** - Land designation or zoning allows for power project development . Private landowners may be amenable. Special uses that are incompatible with power development are not present.
- **Capable** - Has the resource potential for utility-scale power production (>0.5 MW)
- **Suitable** - Can interconnect to the electrical grid. Has low and acceptable environmental impacts, with no special case conditions that preclude small hydropower development.

Six priority watersheds in Humboldt County were selected:

1. Boulder Creek
2. East Fork Willow Creek
3. Upper Willow Creek
4. Ruby Creek
5. Pecwan Creek
6. Madden Creek (AKA Old Campbell Creek)

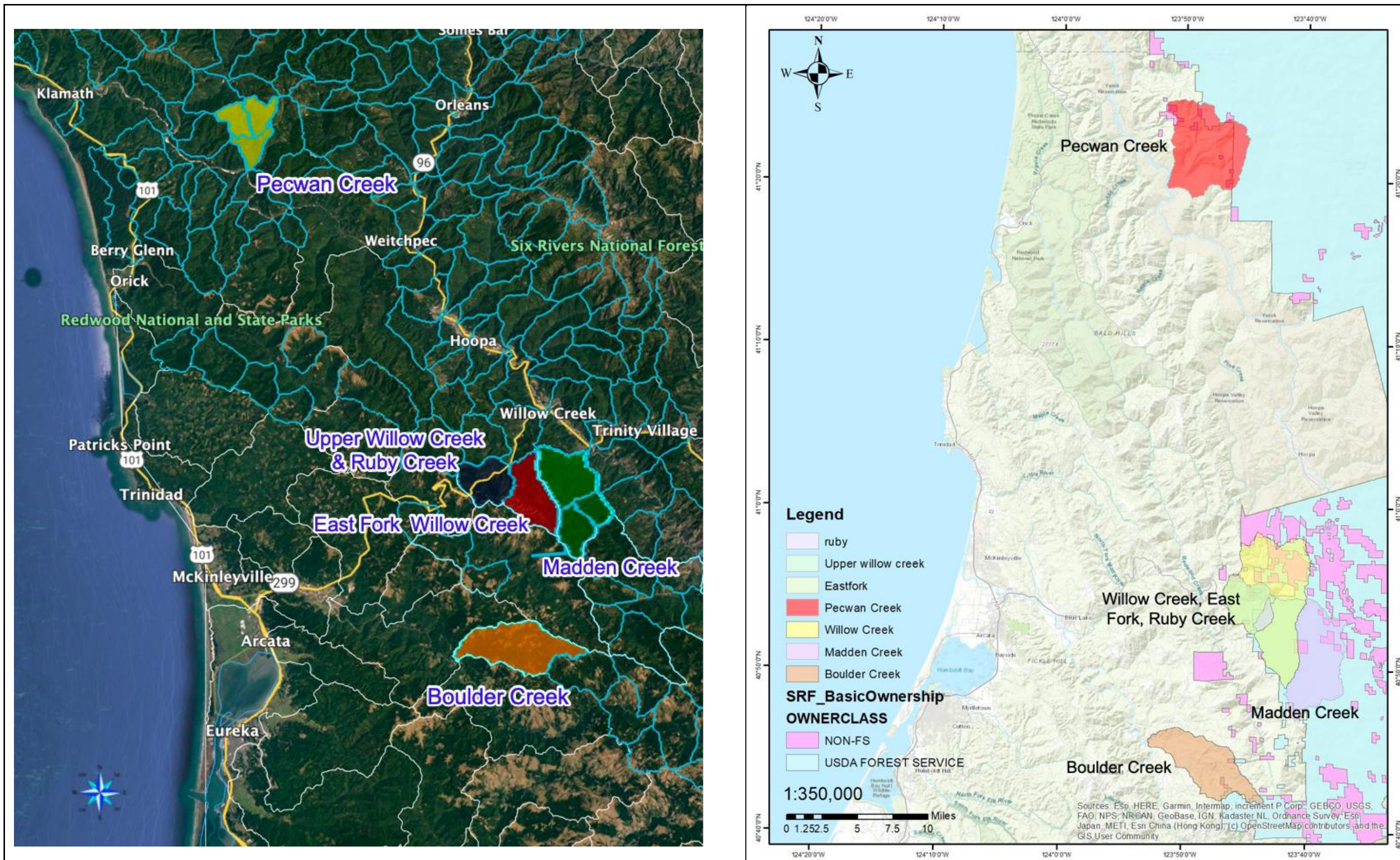


Figure 2. Selected priority watersheds following screening, aerial image and map showing Six Rivers National Forest boundaries. Colors are arbitrary.

Hydrologic Analysis Approach

A comparative streamflow estimation of the ungauged watersheds using the drainage-area-ratio method, lumped modeling (modeling the watershed area as a single unit and using catchment-averaged hydrologic and meteorological inputs), and distributed modeling(using parameter maps derived from geospatial data to simulate hydrologic processes.

The ratio area method is usually the simplest method of streamflow estimation for ungauged catchments. It uses the catchment area ratio relation to calculate the flow at an ungauged point using the flow data from nearby or downstream river gauging stations. Therefore, this method is ideal for estimating flow for gauging catchment with homogenous rainfall. This method has been used extensively has generally shown good results.

The basic modeling approach involves calibrating the model in a known catchment with observed data and transferring the calibrated model to an ungagged catchment.

Flow at an ungaged location can be estimated by multiplying the flow measured at the nearby reference gage with a sufficiently long streamflow record, by the ratio of the ungaged to gauged watersheds (Archfield and Vogel, 2010):

That is, as the watershed area decreases, the flow rate decreases at some fixed rate per unit area. The flow per unit area is the same at both the ungaged location and gaged reference location.

Along with the calibrated parameter, rainfall, temperature, elevation, evaporation, and land use data were used to refine the estimates of streamflows at selected diversion points.. The advantage of this method over other methods is the ability to account for non-homogenous rainfall distribution within the catchment. Depending on the type of data required, each method has its data requirements regarding length of streamflow records, complexity, precision, computation need, and model knowledge.

We recommend using the drainage-area-ratio method for the North Coast in future hydropower assessments for its practicality and acceptable results.

Selection of diversion points for assessment

Ideally, a physical field stream survey would be conducted to locate potential diversion points. However, because fieldwork-related travel was problematic during the pandemic, an alternative approach was used: Locate diversion points for assessment at confluences of major tributaries, and assess the hydrology and power potential above and below each (except for 2 watersheds where a single diversion point was indicated).

This quantifies the option of including or excluding the tributary by placing the diversion point either 1) above the confluence, with less diverted streamflow and power potential, but less water removed from the stream and additional flow inputs to the trunk stream immediately below the diversion point, or 2) located just below the confluence, with more streamflow and power potential but more potential impact on the affected stream reach. Option 1 is known as the "last tributary" mitigation for large reservoirs *(Bill Trush, personal communication)*. This concept may be helpful in evaluating allowable diversion rates and may offer potential mitigation that is desired for ROTR development.

The least steep terrain along stream channels nearly always occurs at and adjacent to stream confluences, where sediment dynamics cause significant flats, lesser slope gradients, and larger floodplains to develop. These are often the best places to access with roads or trails, and often would have the least impact from the disturbances needed for a diversion and headworks.

Selected Priority Watersheds

Watershed	**Average power** (MW)
Boulder Creek	6.41
East Fork Willow Creek	1.93
Upper Willow Creek	1.24
Ruby Creek	0.27
Pecwan Creek	6.80
Madden Creek	3.58

Figure 3. Summary of estimated power yields

Boulder Creek

Watershed Description

Boulder Creek is a tributary to the Mad River with a drainage area of about 12,290 acres. The watershed is bounded by a Board Camp Mountain at the to, Mad River Buttes and Graham Ridge on the left side and Snowcap Mountain on the right side. Mount Andy dominates the central portion of the catchment. Bug Creek Road follows the left catchment boundary. Maple Creek Road and Powerline Road traverse the entire catchment from the outlet to the top of the catchment. There are numerous roads providing access within the catchment from multiple entry points, and overall, most of the catchment is accessible by road. The small village of Maple Creek is located near the mouth of Boulder Creek. This watershed is largely owned by Green Diamond Resource company and the upper part of the watershed is National Forests (Six Rivers NF). The watershed has some notable instability that would be a geotechnical challenge for penstock routing.

The climate of Boulder Creek Boulder Creek is characterized by warm summer and cold and wet winter. The wet season is roughly October through April, accounting for more than 90% of the annual rainfall. The maximum precipitation occurs between December and January. The average temperature varies from -2.22 degrees Celsius to 22.78 degrees Celsius (NOAA 2021). Temperatures in the Boulder Creek watershed are moderate due to its proximity to the Pacific Ocean and the catchment facing the Pacific Ocean. Eureka, California, is the nearest weather station to Boulder Creek.

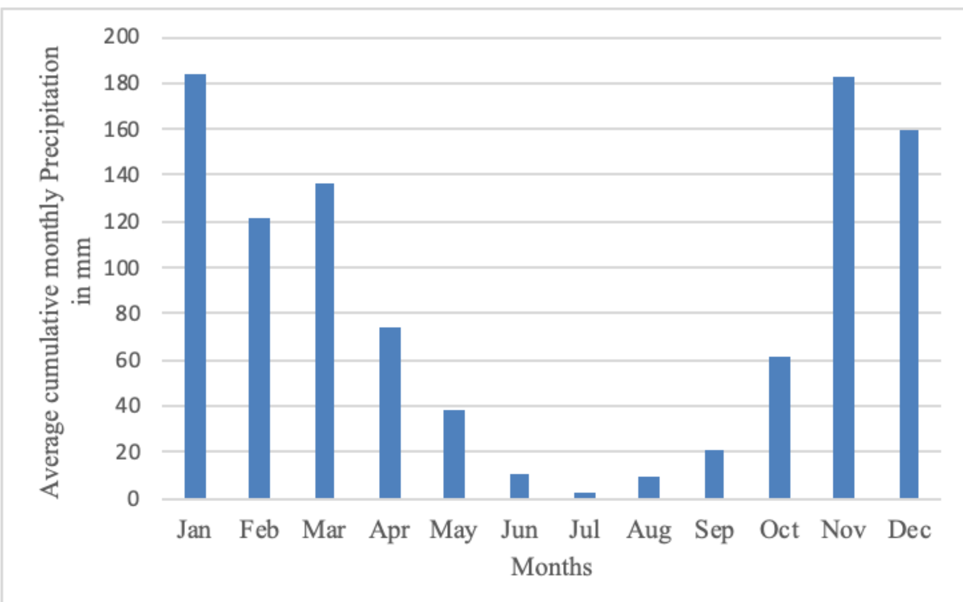


Figure 4. Average monthly cumulative rainfall for Eureka

Figure 5. Boulder Creek vicinity map

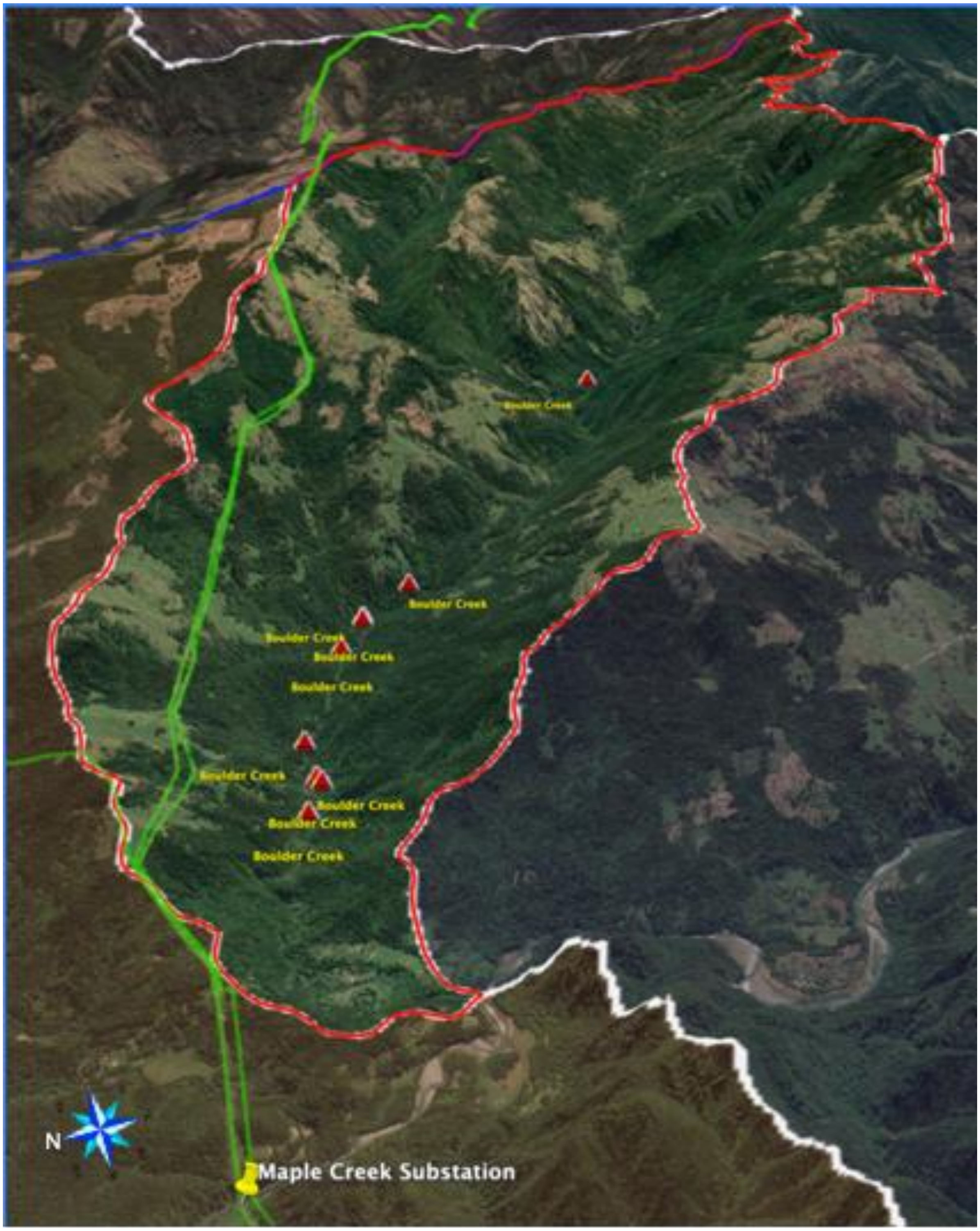


Figure 6. Boulder Creek watershed, a tributary to the Mad River, showing total fish migration barriers and nearby substation.

Geologic map and landslide hazards

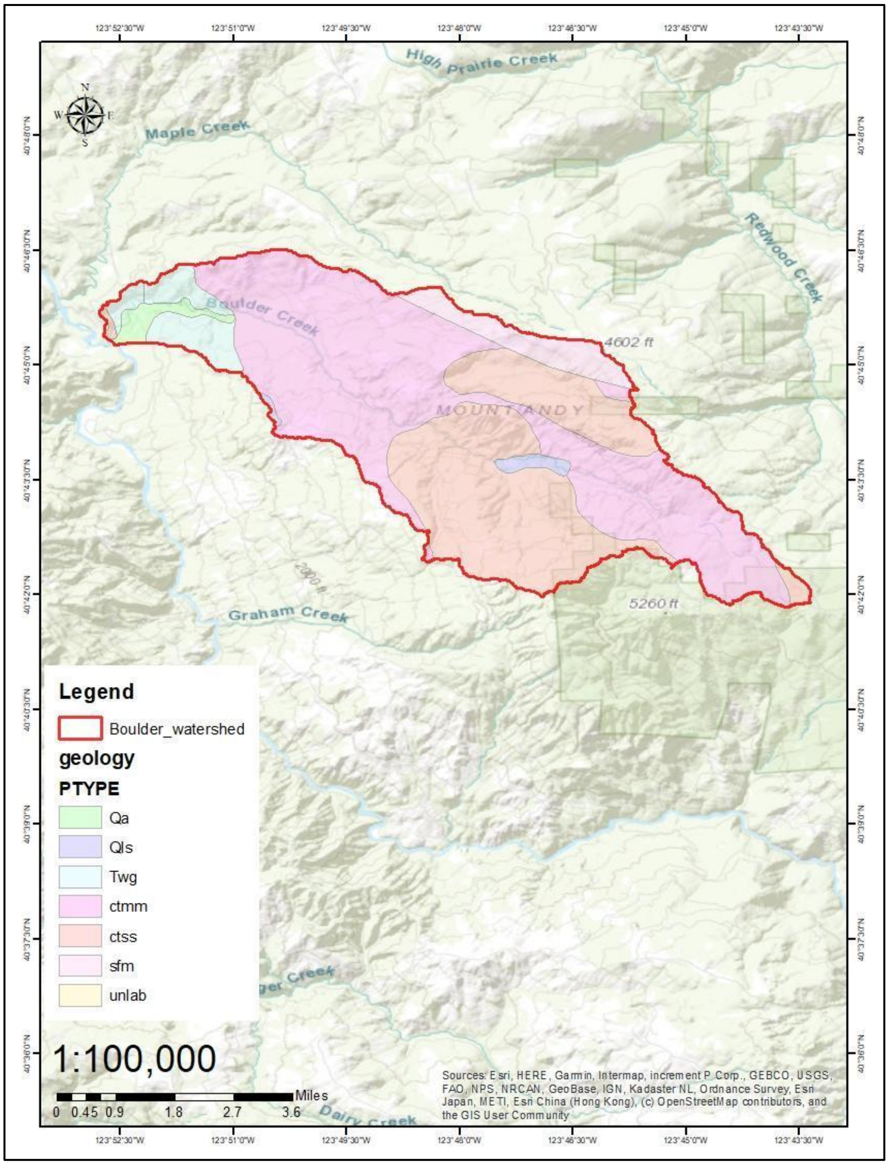
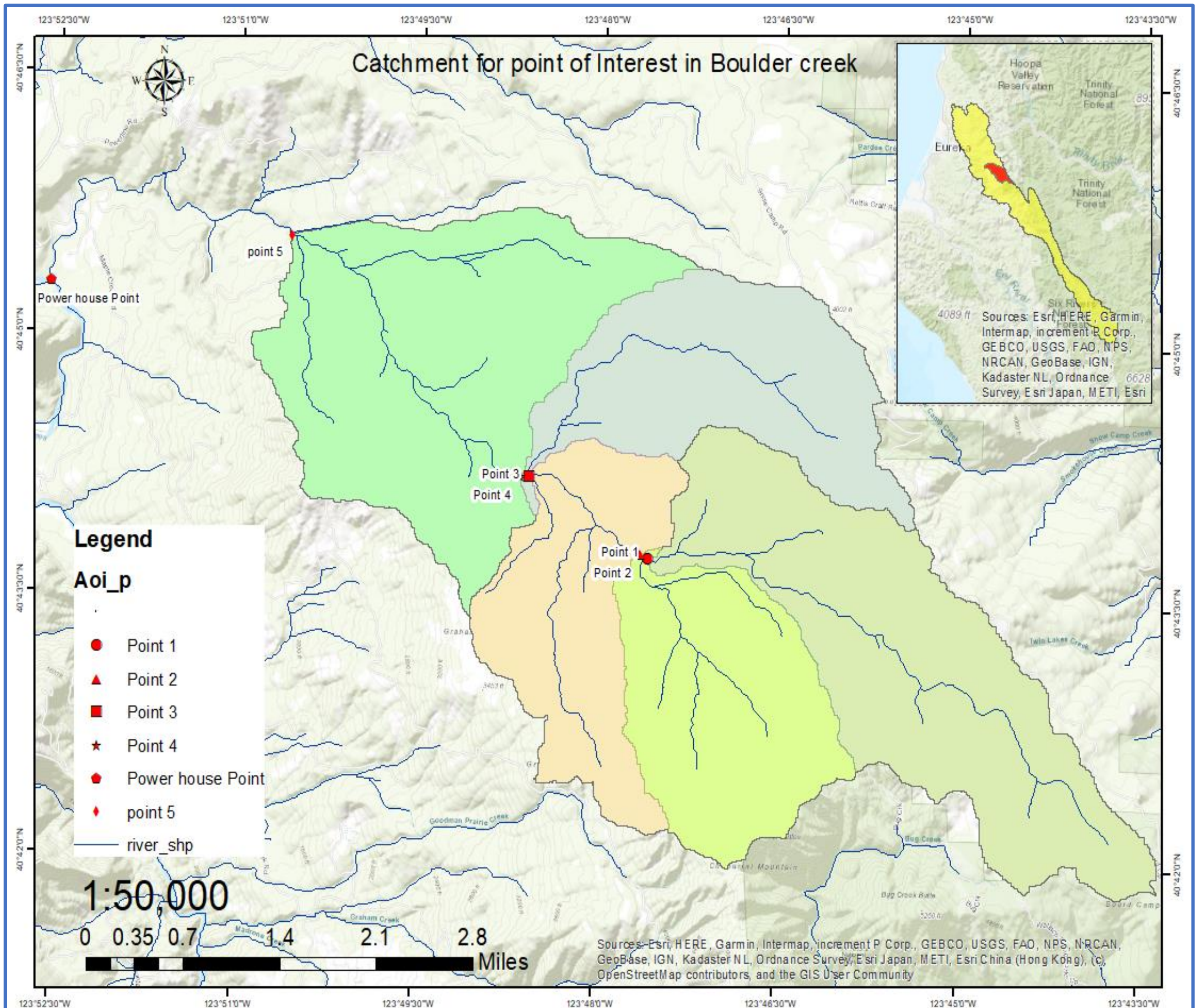


Figure 7. Geologic map of the Boulder Creek catchment.

The upper watershed consists of a Melange matrix of Upper Jurassic to Lower Cretaceous and sandstone in the upper catchment. Melange matrix of Upper Jurassic to Lower Cretaceous covers most of the middle reaches of the catchment. The lower part of the catchment is dominated by the Wildcat Group of the Upper Miocene to Pliocene period and Alluvium and colluvium of the Holocene period. (Luis A. Fraticelli et al. 2012). The watershed has notable areas of instability that could challenge ROTR systems and impose significant maintenance requirements.

Diversion points for assessment



Name of Point	Area (Acres)	Head (ft)
Point 1	2592	2486
Point 2	4124	2155
Point 3	5519	1774
Point 4	7145	1715
Point 5	9927	686

Figure 8. Diversion points for analysis

Interconnection opportunities

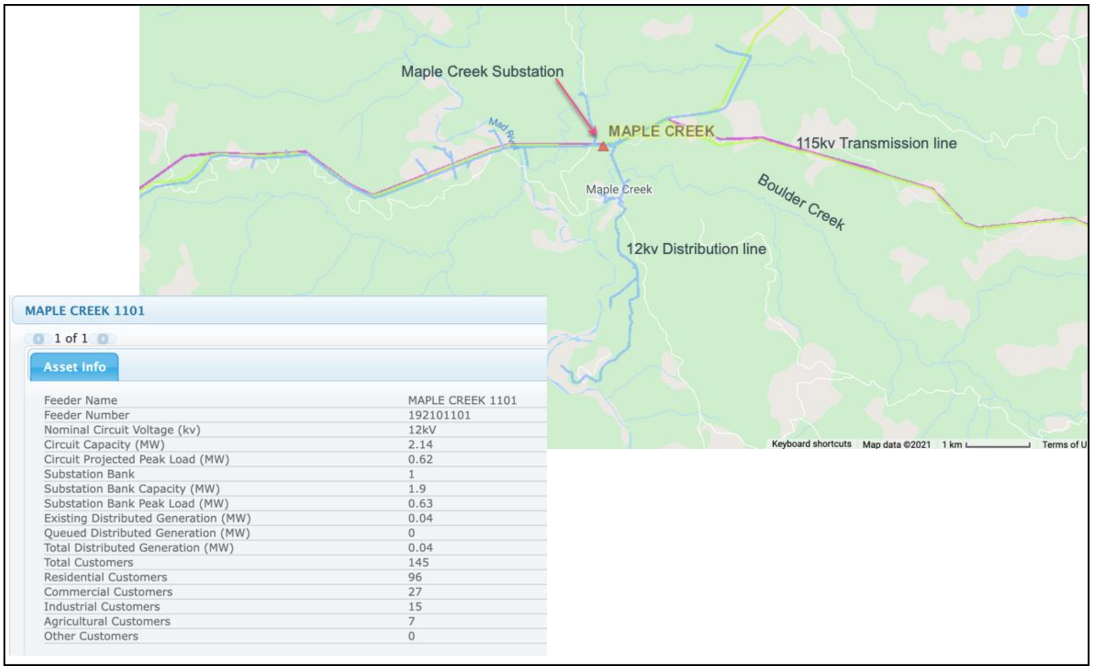


Figure 9. PG&E PV RAM Map showing 115kv transmission lines, 12kv distribution lines, and a substation that serves the local rural community. A nominal 1.52 MW of unused capacity exists on the distribution line.

Boulder Creek site hydrology

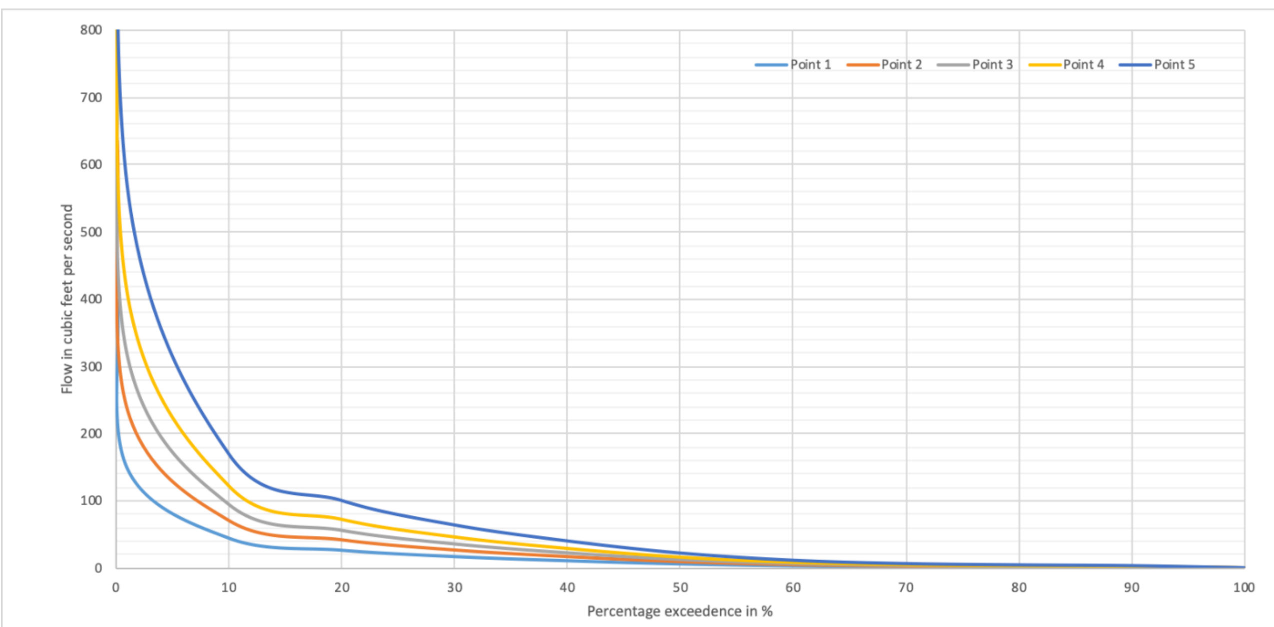


Figure 10. Boulder Creek flow duration curves for five diversion points selected for analysis.

Watershed Power Potential

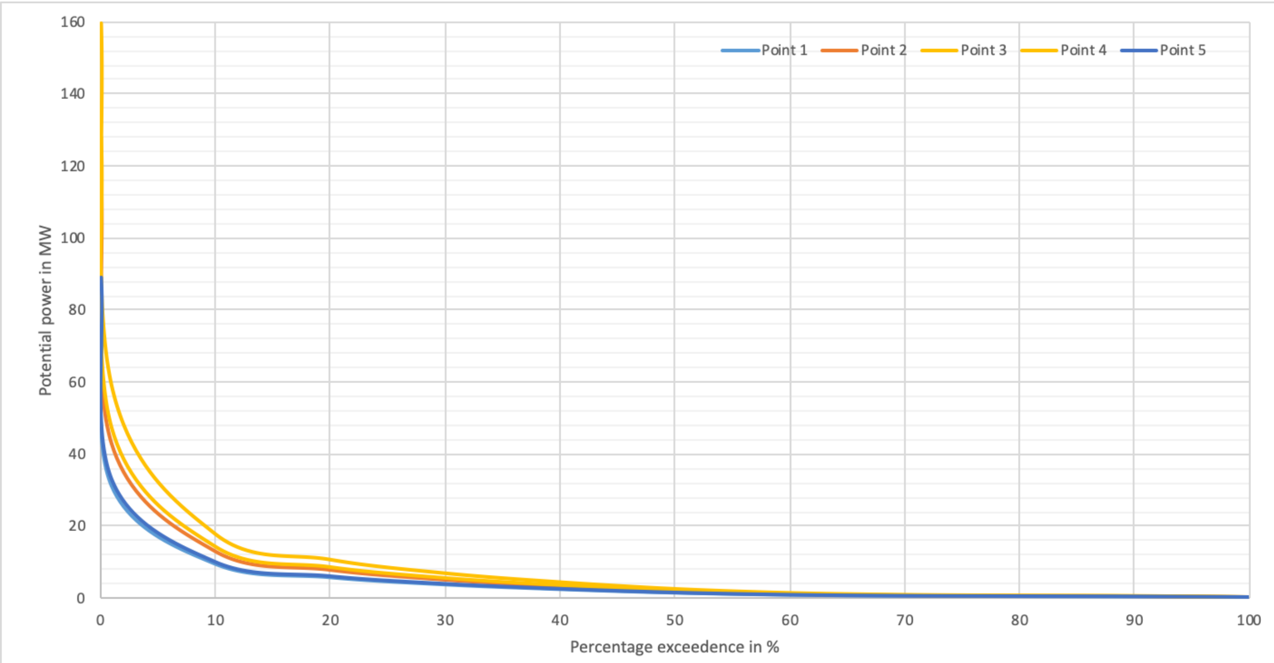


Figure 11.Boulder Creek potential power generating capacity without power system efficiency or environmental flow reductions.

Watershed Power Potential

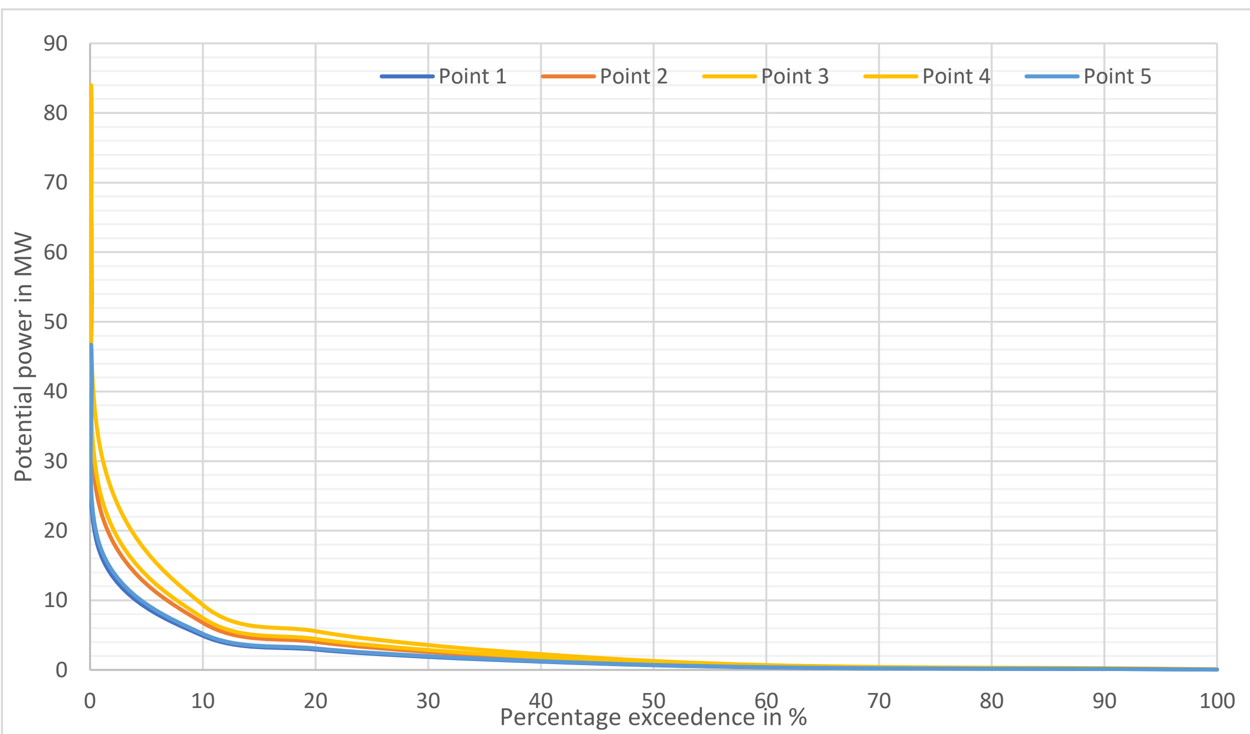


Figure 12. Boulder Creek potential power generating capacity duration curve with reductions for power system efficiency (75.1%) and flow reduction (67%)

Power generation potential by month

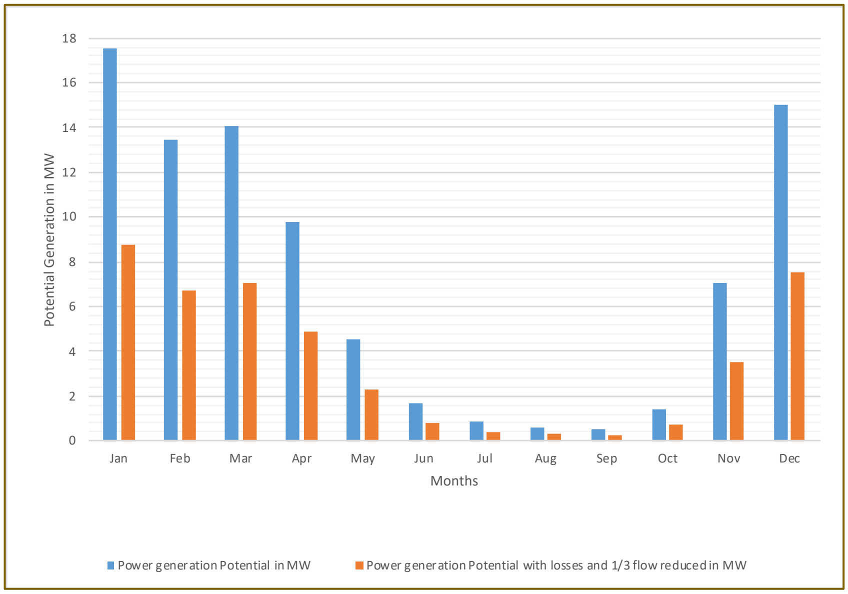


Figure 13. Average power genera tion potential by month with and without reductions for system efficiency and environmental flows.

Streamflow variability

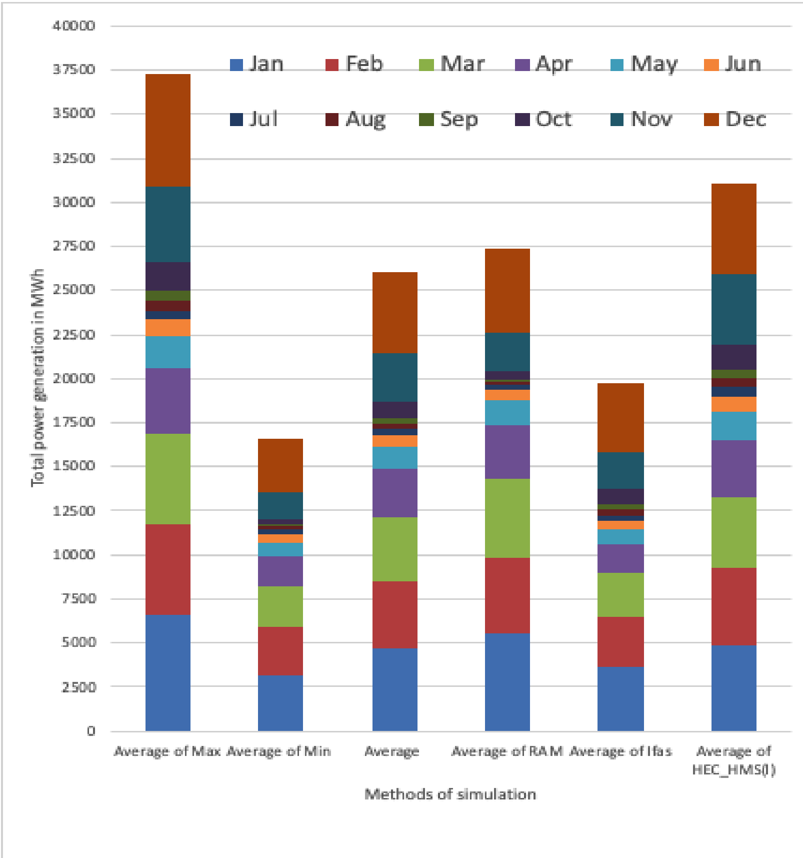


Figure 14. Boulder Creek power generation (with assumed 75.1% efficiency) variability by month using three methods of streamflow estimation

Willow Creek Complex (East Fork, Upper Willow, Ruby Creek)

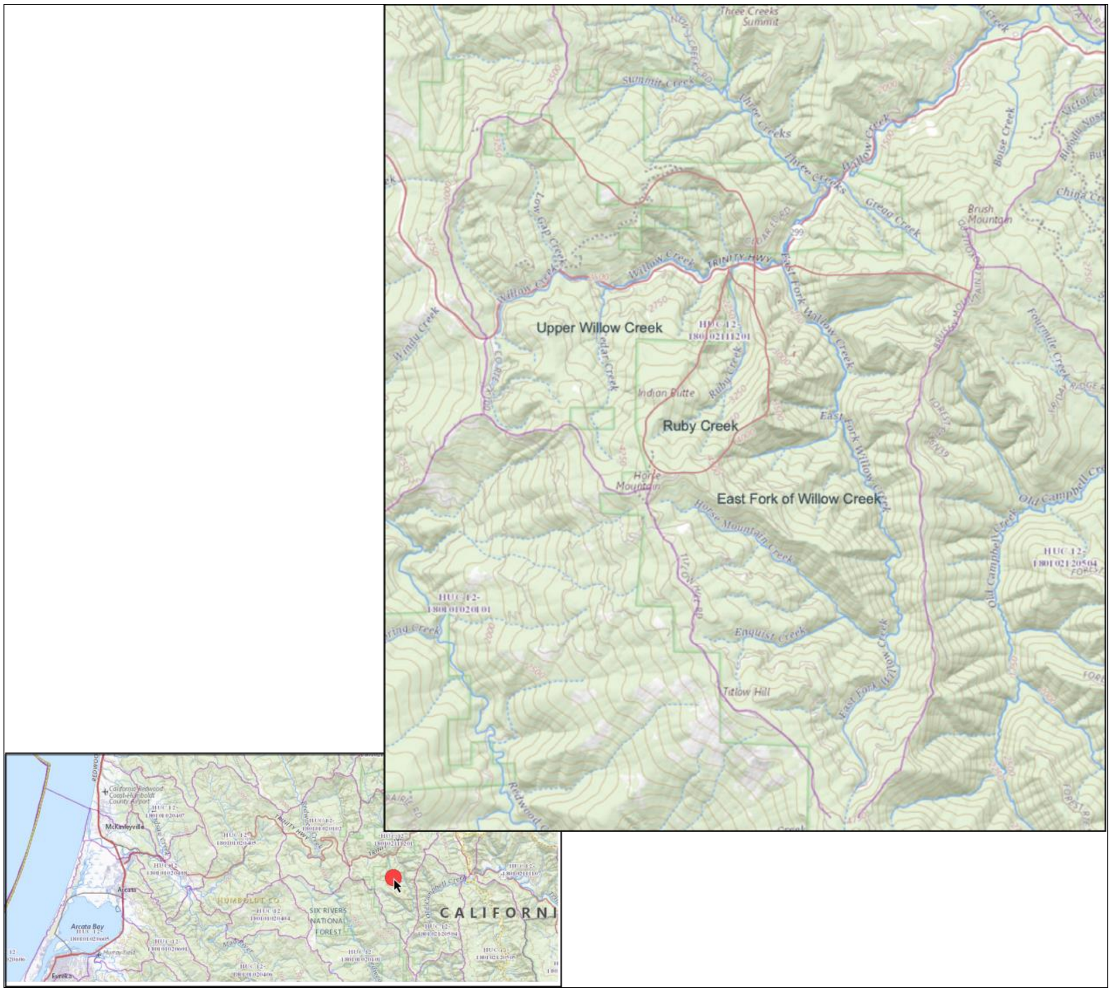


Figure 15. Vicinity Map of three watersheds. Watershed boundaries are approximate. USGS National Map

This complex of 3 adjacent watersheds was selected based on

- Significant drainage area and relief
- Anadromous fish barrier ~ 1 mile from the mouth of the East Fork of Willow Creek. Upper Willow Creek has an anadromous limit just upstream from the mouth of the East Fork. No anadromous habitat in Ruby Creek
- The East Fork of Willow Creek and Ruby Creek are almost entirely National Forest (Six Rivers NF), with a small inholding at the highway on Ruby Creek. Upper Willow Creek has complex ownership, including National Forest and a mosaic of private lands.
- East Fork and Ruby Creek are almost entirely National Forest, Six Rivers National Forest. Upper Willow Creek has a complex of large and medium-size private owners as well as some National Forest land. Distribution lines are nearby with unused capacity
- Fair road access

Figure 16. Aerial image showing the complex of watersheds, including Madden Creek and the South Fork Trinity River.

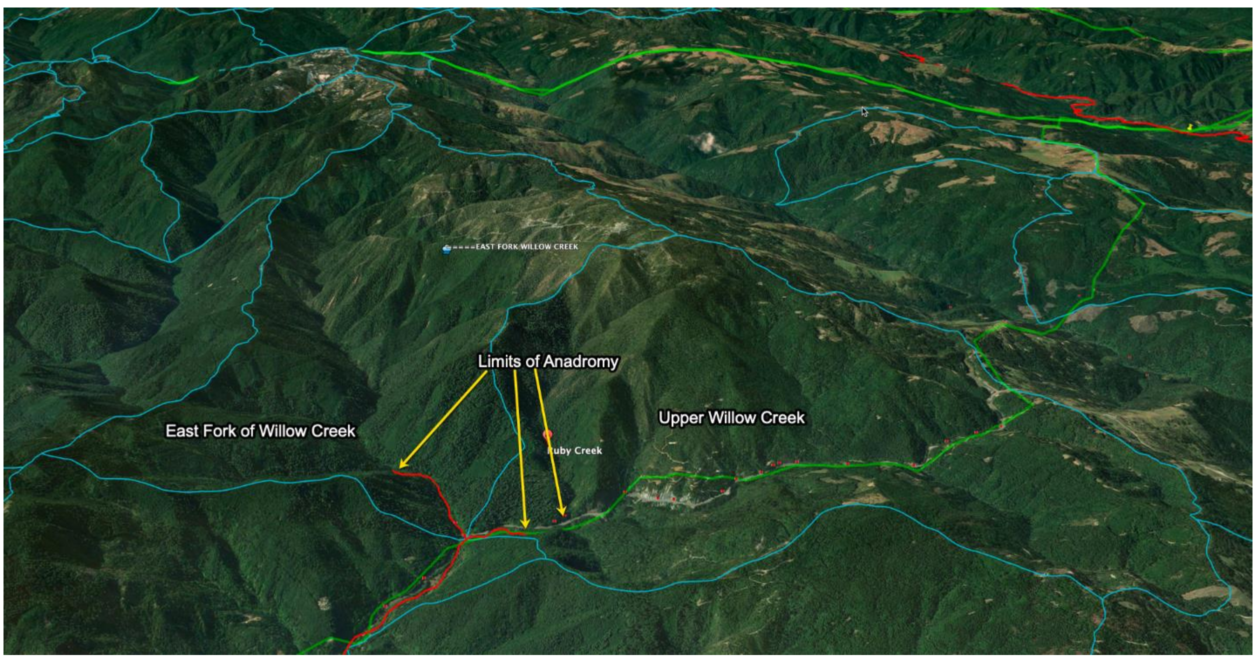


Figure 17. The 3-basin complex of East Fork Willow Creek, Ruby Creek, and Upper Willow Creek. 12kv distribution lines with unused capacity run along Hwy in the vicinity.

East Fork Willow Creek

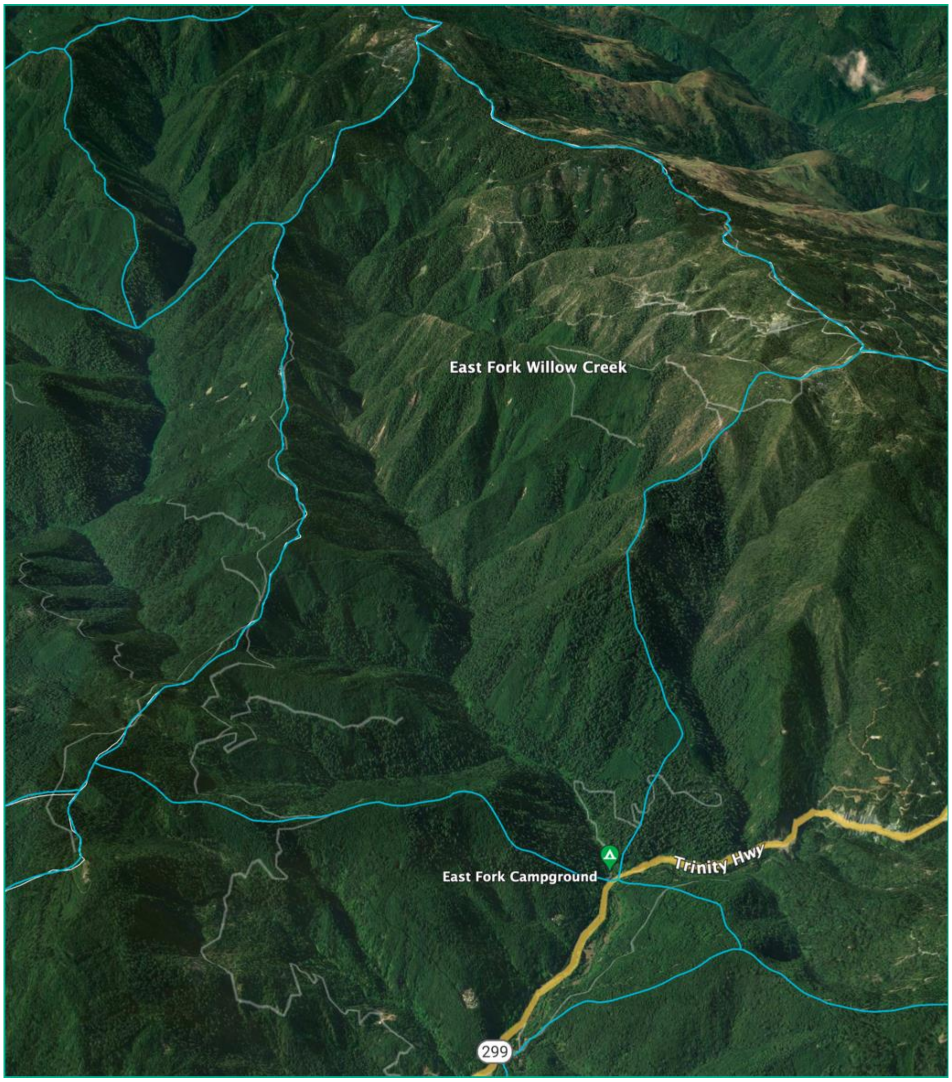


Figure 18. Watershed map of the East Fork Willow Creek. Base image from NASA

Watershed Description

East Fork Willow Creek is located between horse mountain and brush mountain. The East Fork of Willow Creek intersects State Highway 299 at its mouth. It is approximately five and a half-mile from the town of Willow Creek. The East Fork of Willow Creek has a drainage area of about 8,132 acres and is one of the major tributaries of Willow Creek, having roughly 31% of the total area of Willow Creek watershed.

The climate of East Fork Willow Creek is characterized by warm summer and cold and wet winter. The wet season is typically October through April, accounting for more than 90% of the annual rainfall. The maximum precipitation occurs between December and January. The average temperature varies from -4.7 degrees Celsius to 31.4 degrees Celsius (NOAA 2021). Precipitation is dominated by rain with snowfall at higher elevations but little persistent snowpack. seasonal variation from global atmospheric and oceanic conditions.

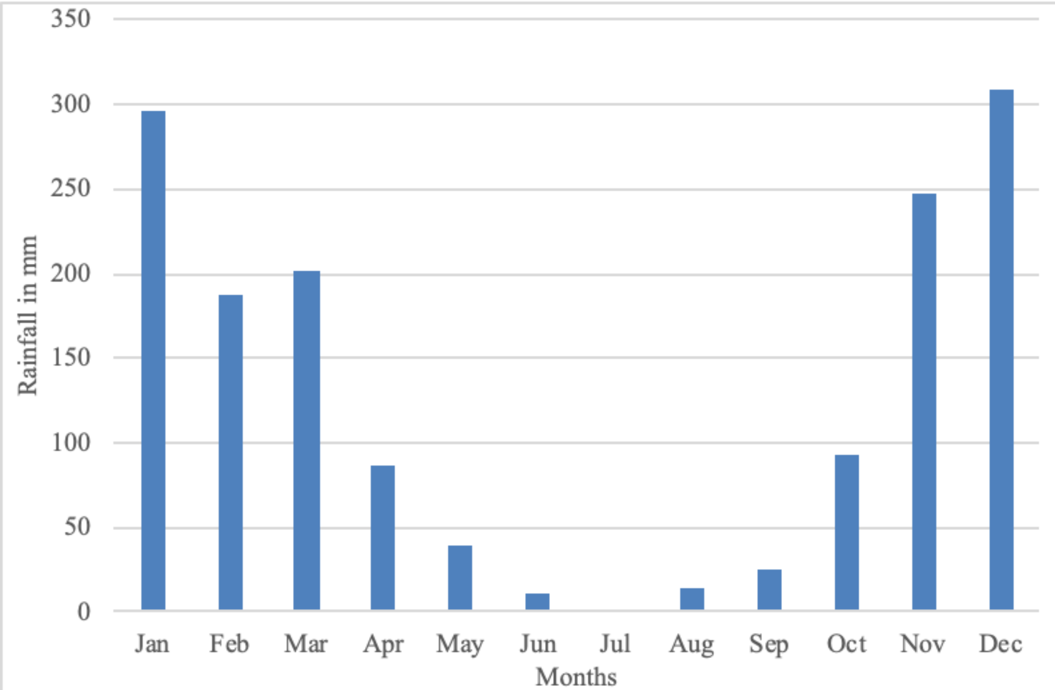


Figure 19. Average monthly cumulative rainfall for Hoopa (Data from NOAA)

Geology and landslide hazards

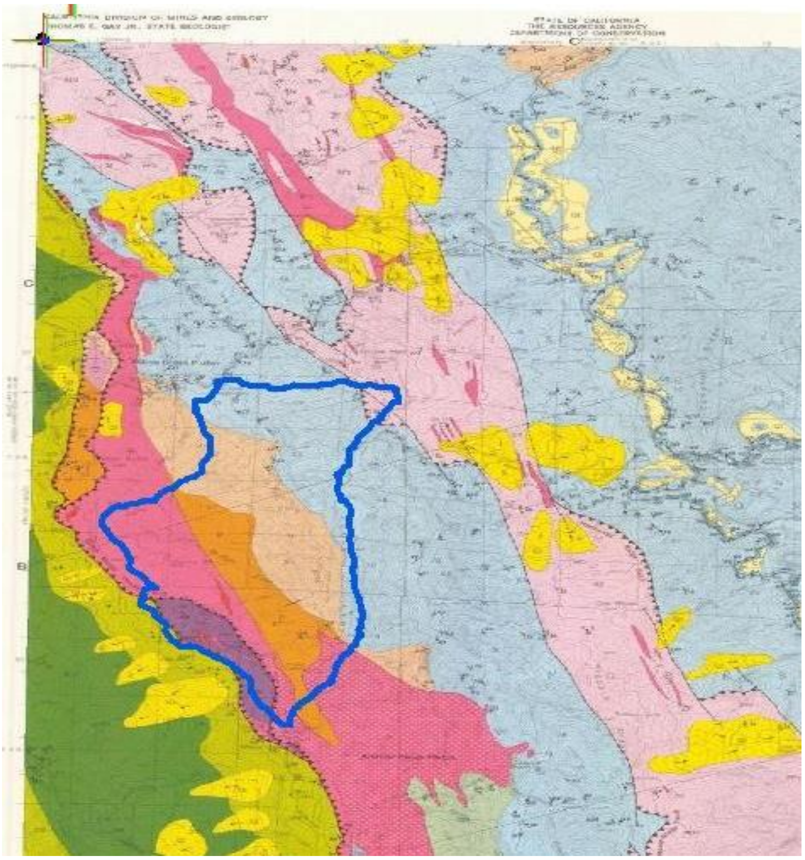
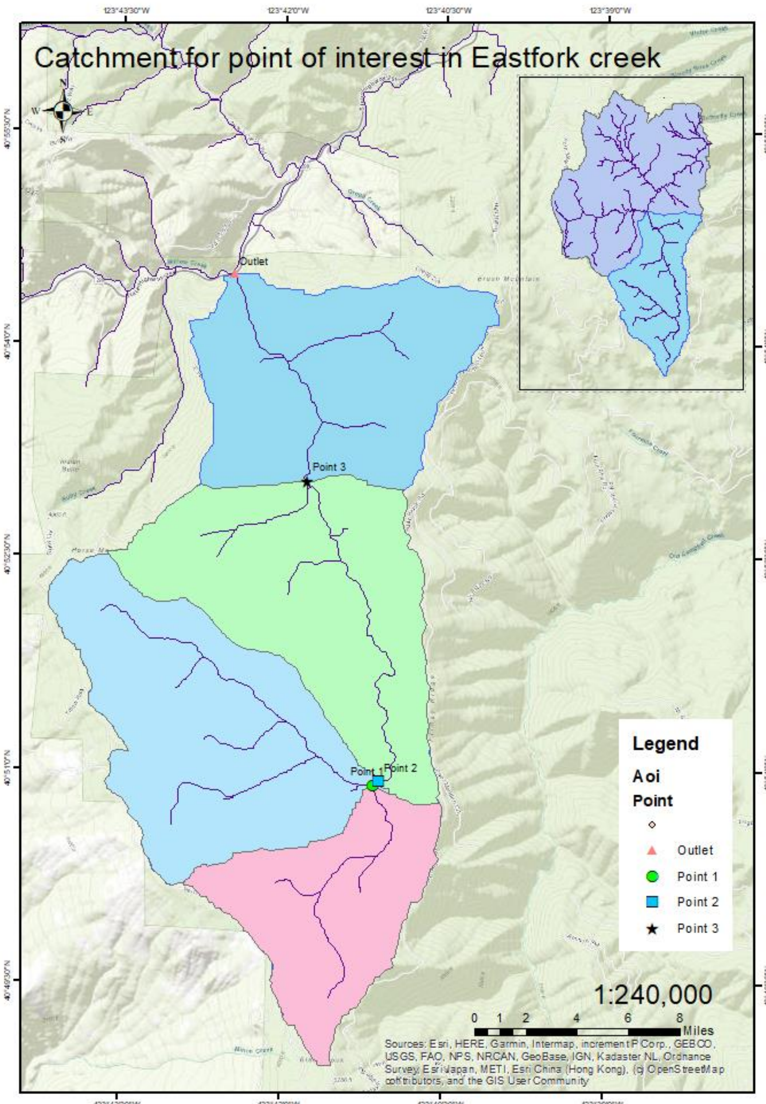


Figure 20.Geologic map showing the East Fork Willow Creek watershed.

Watershed geology consists of Foliated greenstone, metagraywacke, serpentinite, and diorite intermingled in the coast ranges thrust zone, Ultramafic rocks, and Ammon ridge pluton in the upper catchment. Friday Camp Gneiss, Rogue Formation, which is mafic to intermediate volcanic flows and tuffs, now altered to greenstones in the middle reaches of the catchment. The lower part of the catchment is dominated by Galice formation, Western Paleozoic, and the Triassic belt of rocks called mélange. The East Fork of Willow Creek has formations ranging from the late Jurassic to the cretaceous period. (J.C Young 1978) Few and minor landsliding hazards exist in the upper watershed. Existing active or young landsliding is minor and associated with the inner gorge and old timber-haul roads, as shown in the next figure. Few active or young landslides are present in the upper watershed of the East Fork Willow Creek. None are observed on air photos of the lower watershed.

Figure 21. Aerial image showing recent landsliding in the East Fork Willow Creek watershed. (circles) Base image from NASA

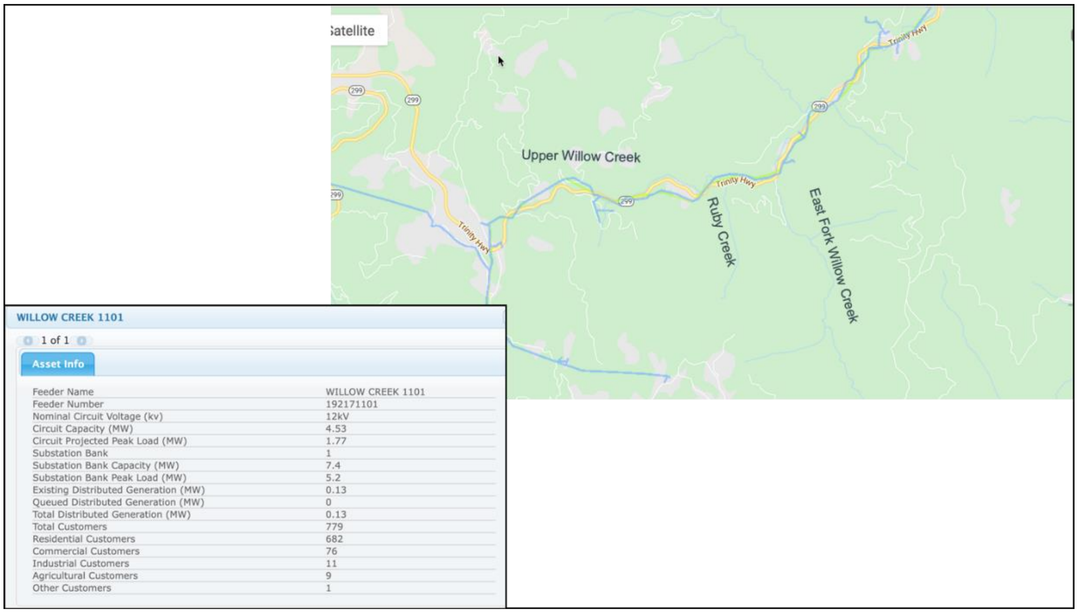
Diversion points for assessment



Name of Point	Area (Acres)	Head (ft)
Point 1	1383	987
Point 2	3788	974
Point 3	6148	272

Figure 22. Diversion points selected for analysis

Interconnection opportunities



Feeder Name	WILLOW CREEK 1101
Feeder Number	192171101
Nominal Circuit Voltage (kv)	12kV
Circuit Capacity (MW)	4.53
Circuit Projected Peak Load (MW)	1.77
Substation Bank	1
Substation Bank Capacity (MW)	7.4
Substation Bank Peak Load (MW)	5.2
Existing Distributed Generation (MW)	0.13
Queued Distributed Generation (MW)	0
Total Distributed Generation (MW)	0.13
Total Customers	779
Residential Customers	682
Commercial Customers	76
Industrial Customers	11
Agricultural Customers	9
Other Customers	1

Figure 23. PG&E PVRAM map for East Fork Willow Creek area. A nominal unused capacity of 2.76 MW exists on a local 12KV line that runs along State Highway 299.

Watershed hydrology

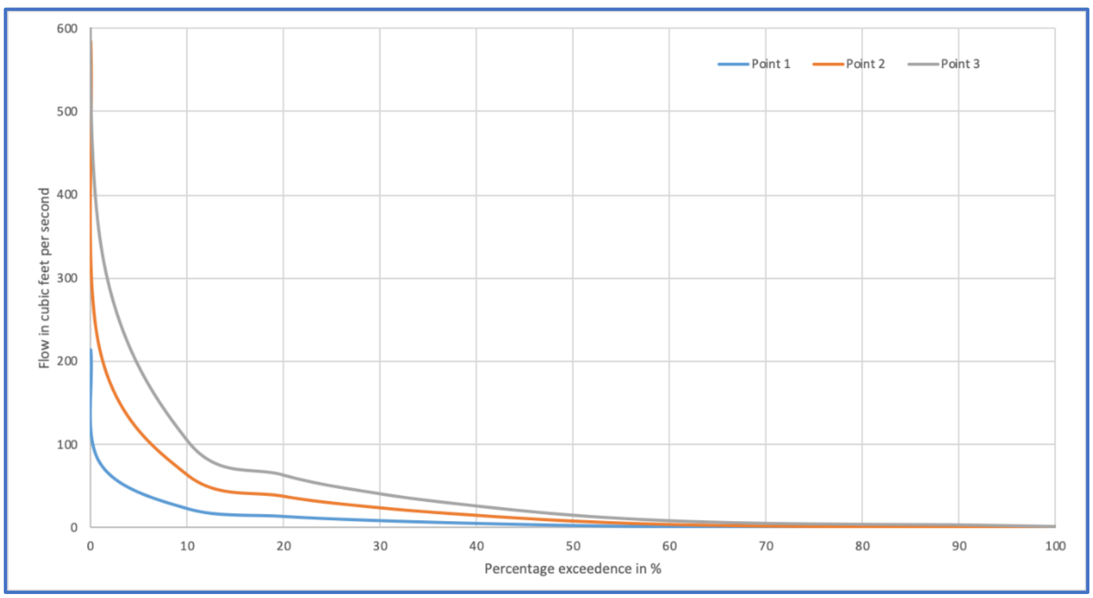


Figure 24. East Fork Willow Creek flow duration curves for each of the three diversion points selected for analysis.

Power potential

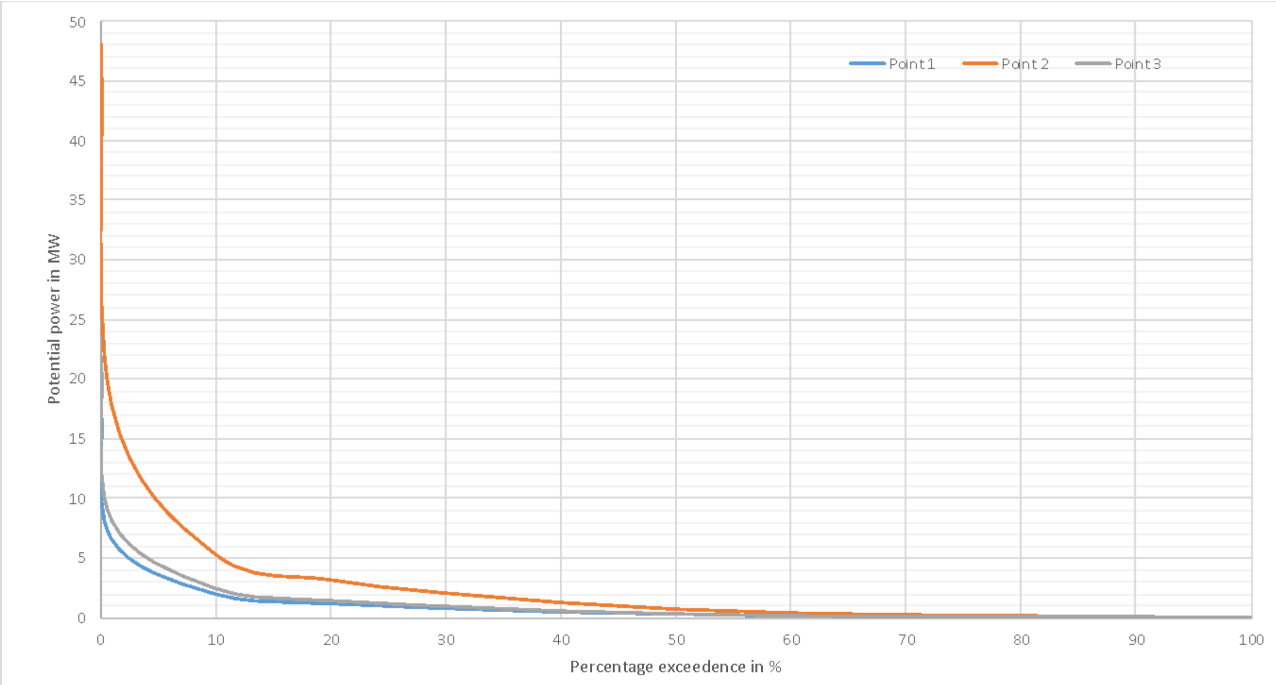


Figure 25.East Fork Willow Creek potential power generating capacity without efficiency or environmental flow reductions

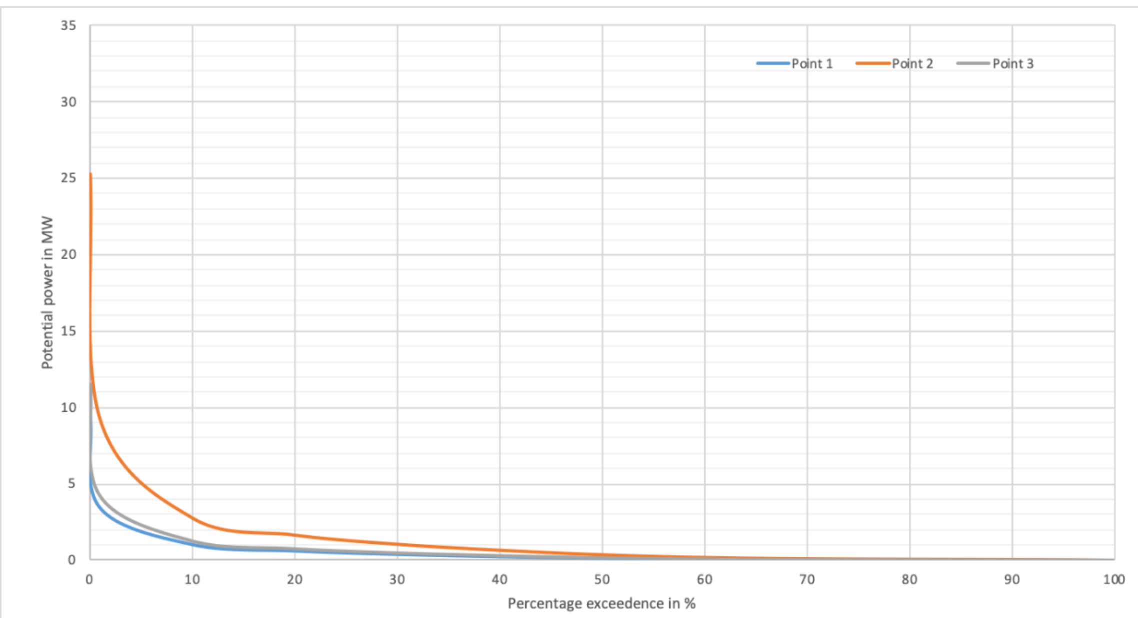


Figure 26. Potential power generating capacity duration curve with reductions for efficiency (75.1) and 1/3 *flow reduction*

Power generation potential by month

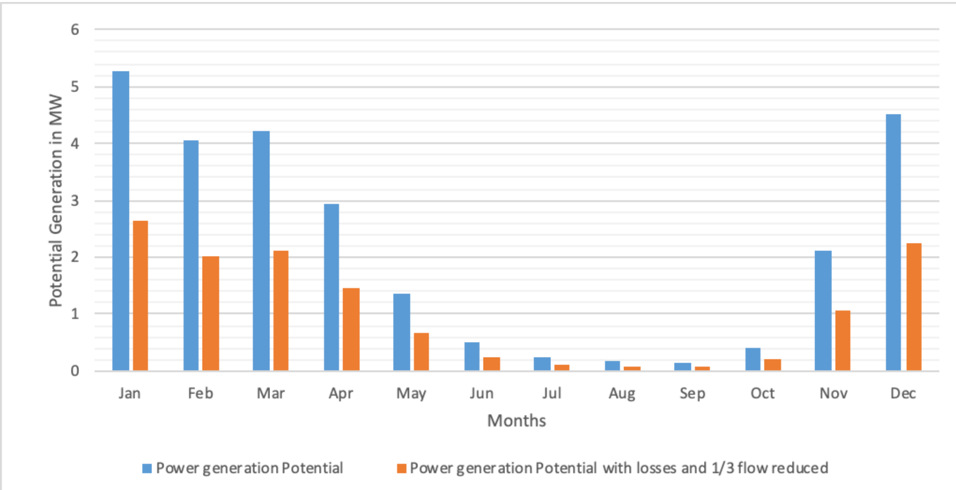
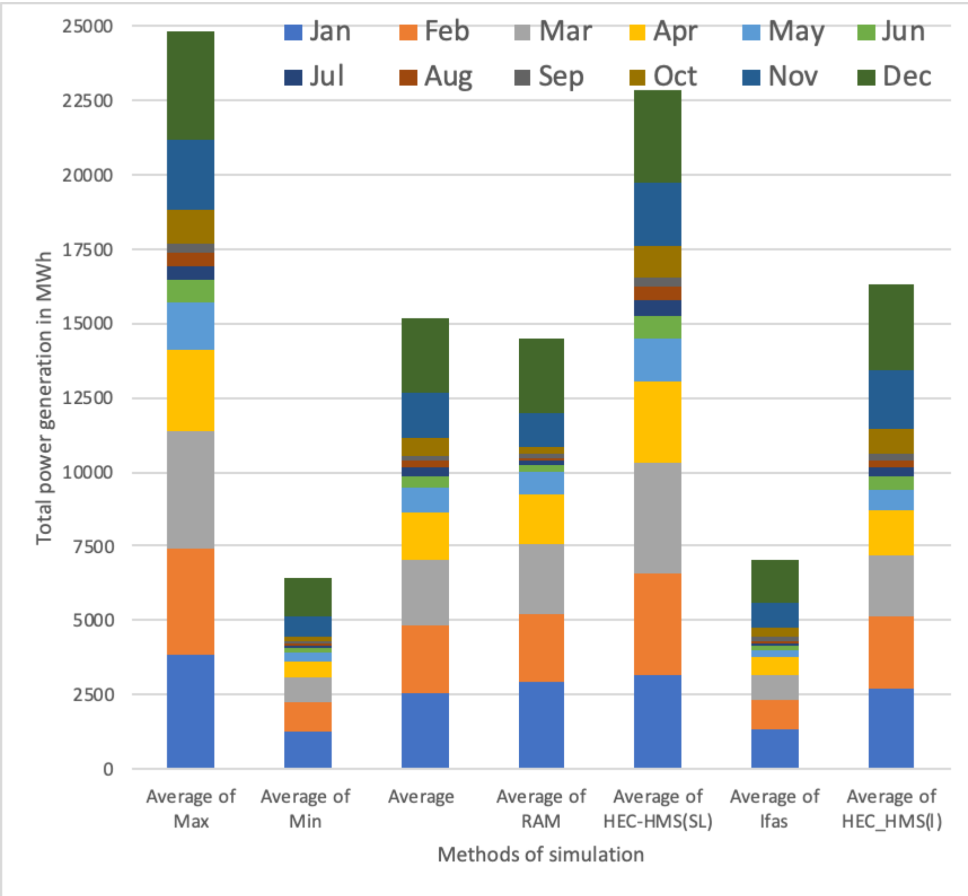


Figure 27 East Fork Willow Creek average power generation potential by month with and without reductions for efficiency and environmental flows.



Power potential variability

Figure 28. Power generation (with assumed 75.1% efficiency) variability by month using three methods of streamflow estimation.

Upper Willow Creek

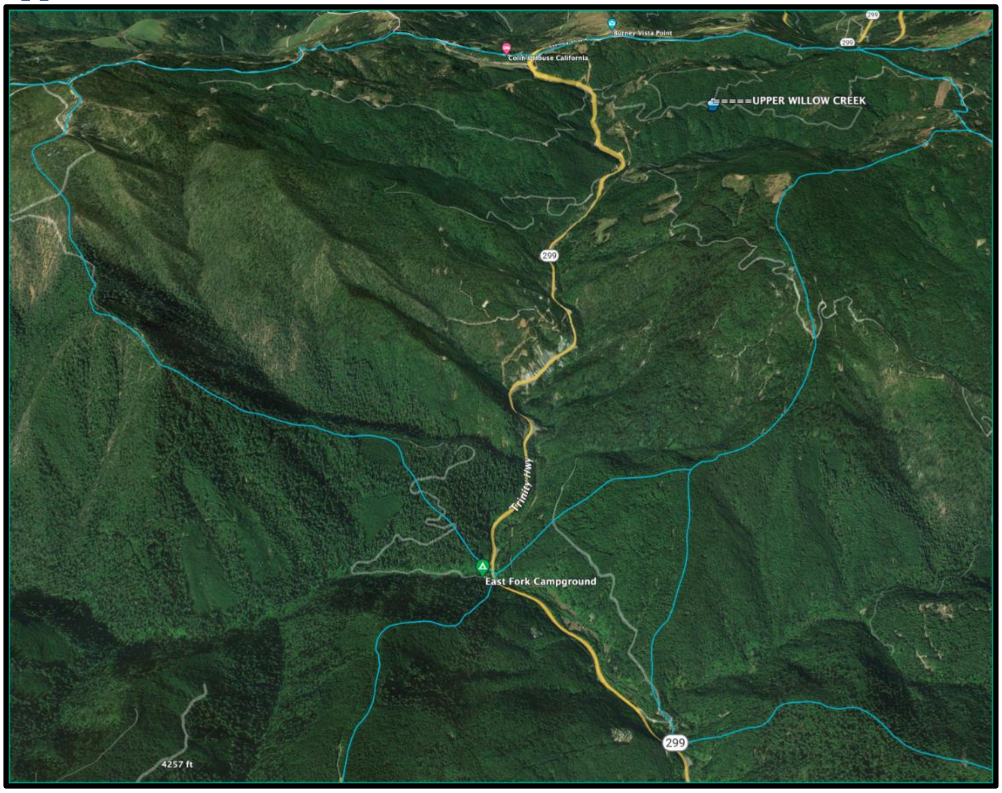


Figure 29. Upper Willow Creek watershed vicinity. Base image from NASA

Watershed Description

Upper Willow Creek is located between the Horse Mountain, Indian Field Ridge, and Berry Summit. The Upper Willow Creek meets State Highway 299. It is approximately five and a half-mile from the town of Willow Creek. Upper Willow Creek has a drainage area of about 6,622 acres. The Upper Willow Creek is one of the major tributaries of Willow Creek, having roughly 26% of the total area of the Willow Creek catchment.

The climate of Upper Willow Creek is similar to East Fork Willow Creek. See description above for East Fork Willow Creek.

Geology and landslide hazards

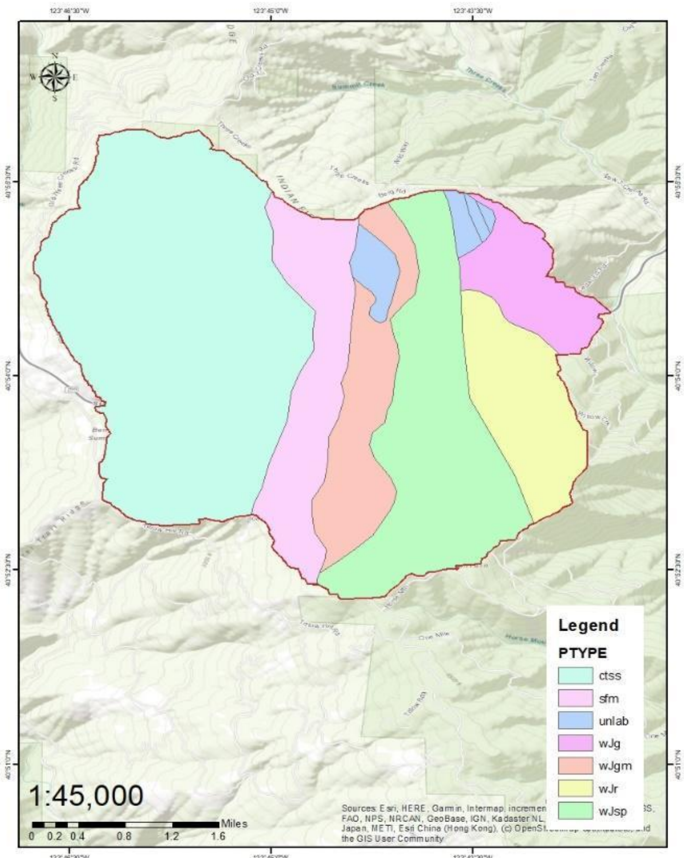
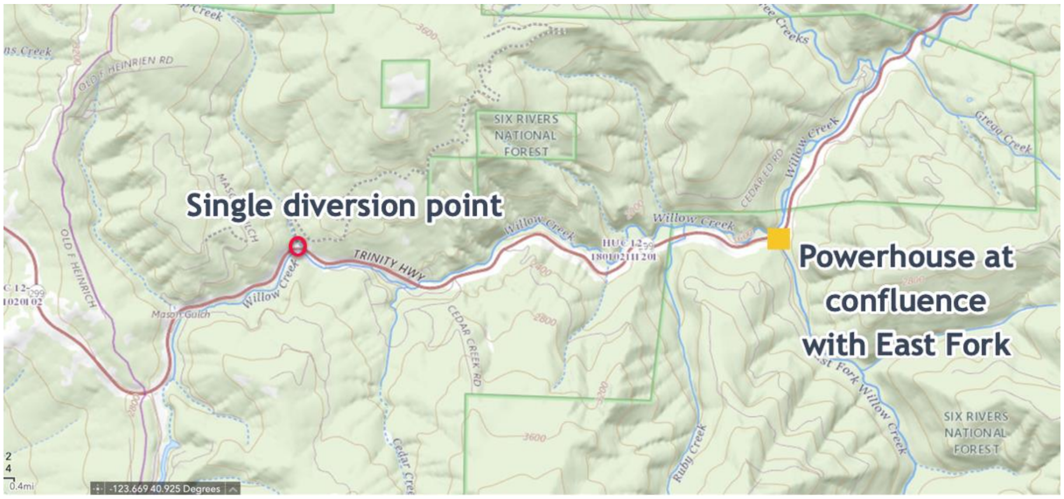


Figure 30. Geologic Map of the Upper Willow Creek watershed.

The lithology consists of South Fork Mountain schist, Franciscan rocks in the upper areas of the catchment. The Coast Range Thrust Fault bisects the watershed. Ultramafic rocks and Friday Camp Gneiss in the middle reaches of the catchment. The middle reaches also has landslide or slump, which might become sources to sediments in the future. The lower part of the catchment is dominated by Rogue Formation, which is mafic to intermediate volcanic flows and tuffs, now altered to greenstones and Galice formation. The Upper Willow Creek has formations ranging from the late Jurassic to the cretaceous period. (ref). This watershed has significant landsliding potential, especially along the Coast Range Trust Fault complex. Active and severe landsliding is visible along Hwy 299, where the Coast Range Thrust Fault zone intersects the highway. Landslide hazards in this watershed pose a significant likelihood of high maintenance requirements and failure potential of a ROTR system. (J.C Young 1978)

See East Fork Willow Creek section for Interconnection potential

Diversion Point for Assessment



Name of Point	Area (Acres)	Head (ft)
Point 1	2434	912

Figure 31. Diversion point selected for analysis

Site hydrology

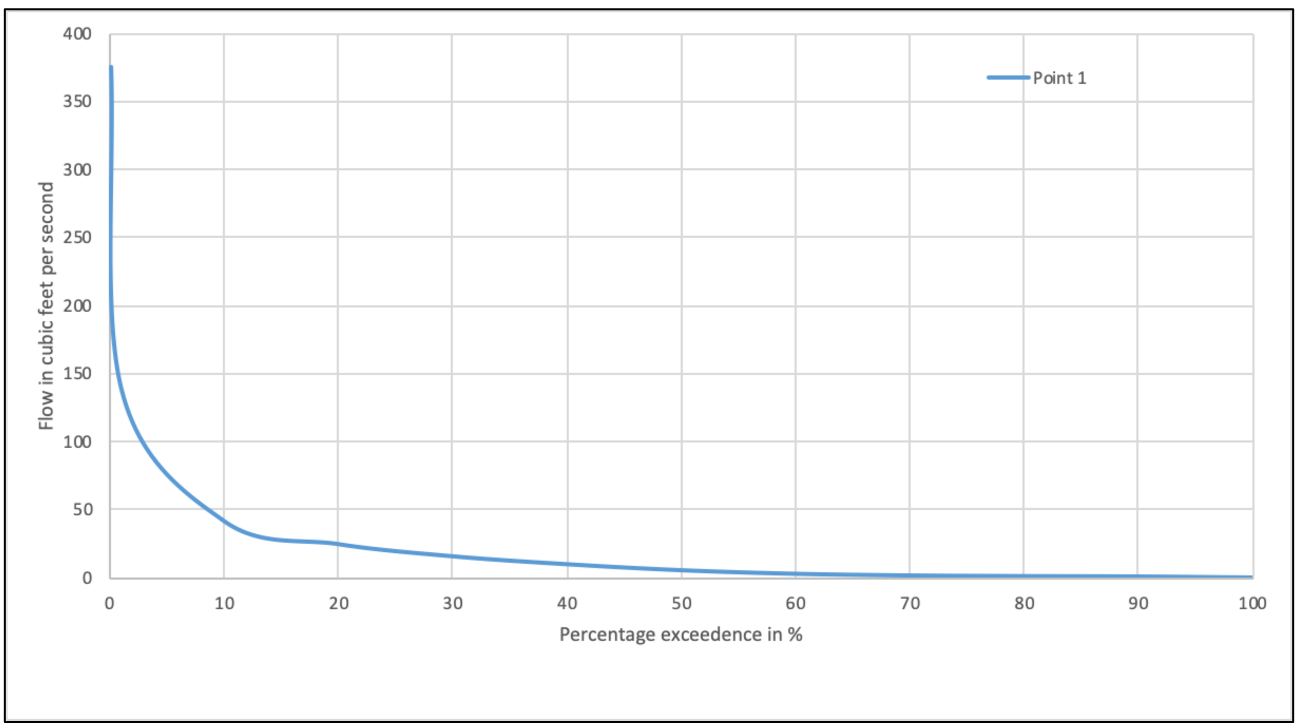


Figure 32. Upper Willow Creek flow duration curve for the diversion point selected for analysis

Upper Willow Creek power potential

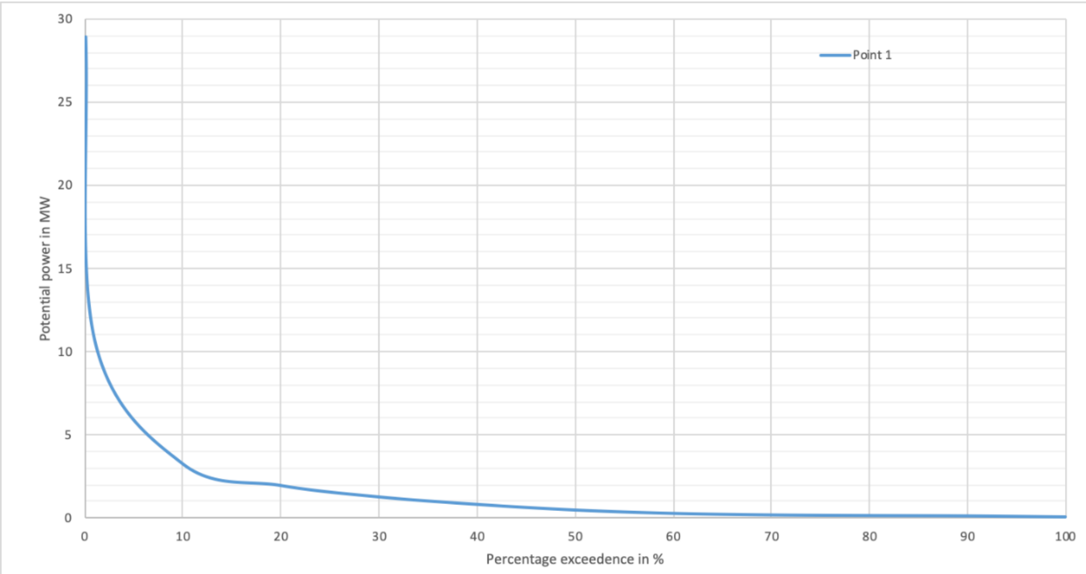


Figure 33. Upper Willow Creek potential power generating capacity without efficiency or environmental flow reductions.

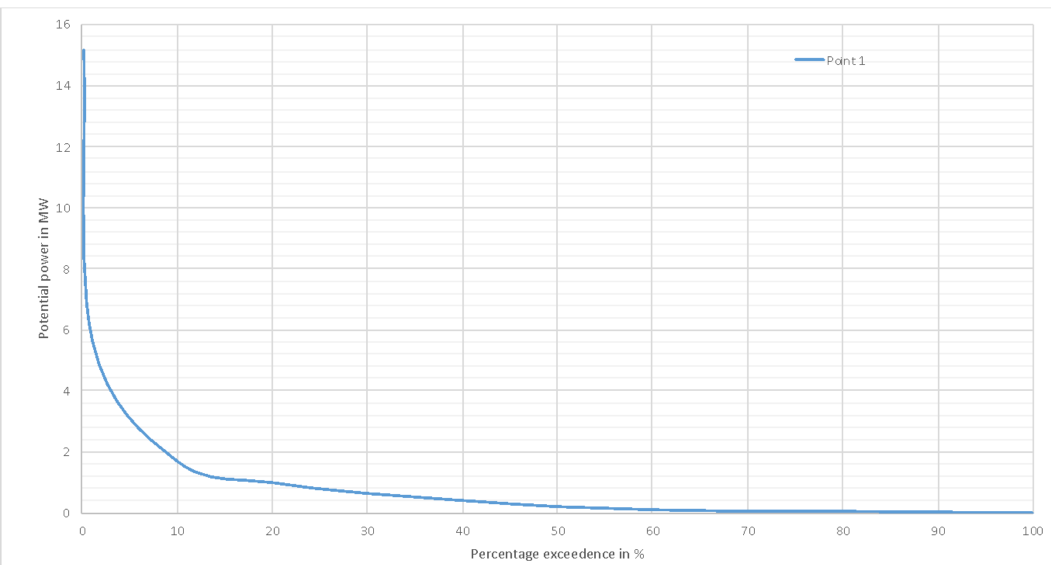


Figure 34. Upper Willow Creek potential power generating capacity duration curve with reductions for efficiency (75.1) and $1/3$ *flow reduction*

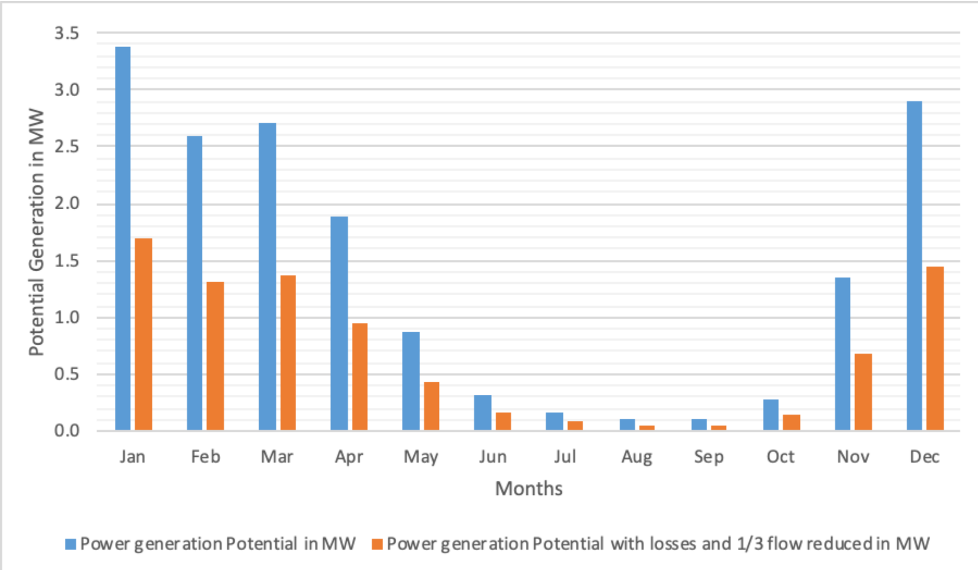


Figure 35. Upper Willow Creek average power generation potential by month with and without reductions for efficiency and environmental flows.

Power generation variability

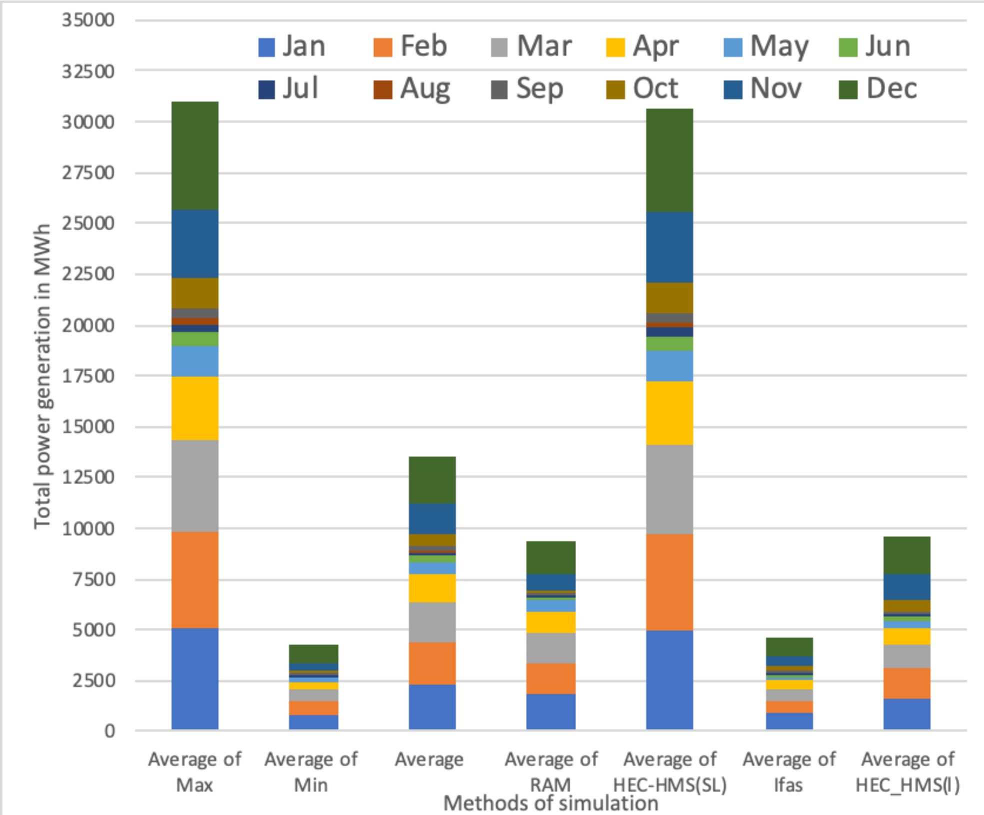


Figure 36. Upper Willow Creek power generation variability by month (with assumed 74.9% efficiency) using three methods of streamflow estimation.

Ruby Creek

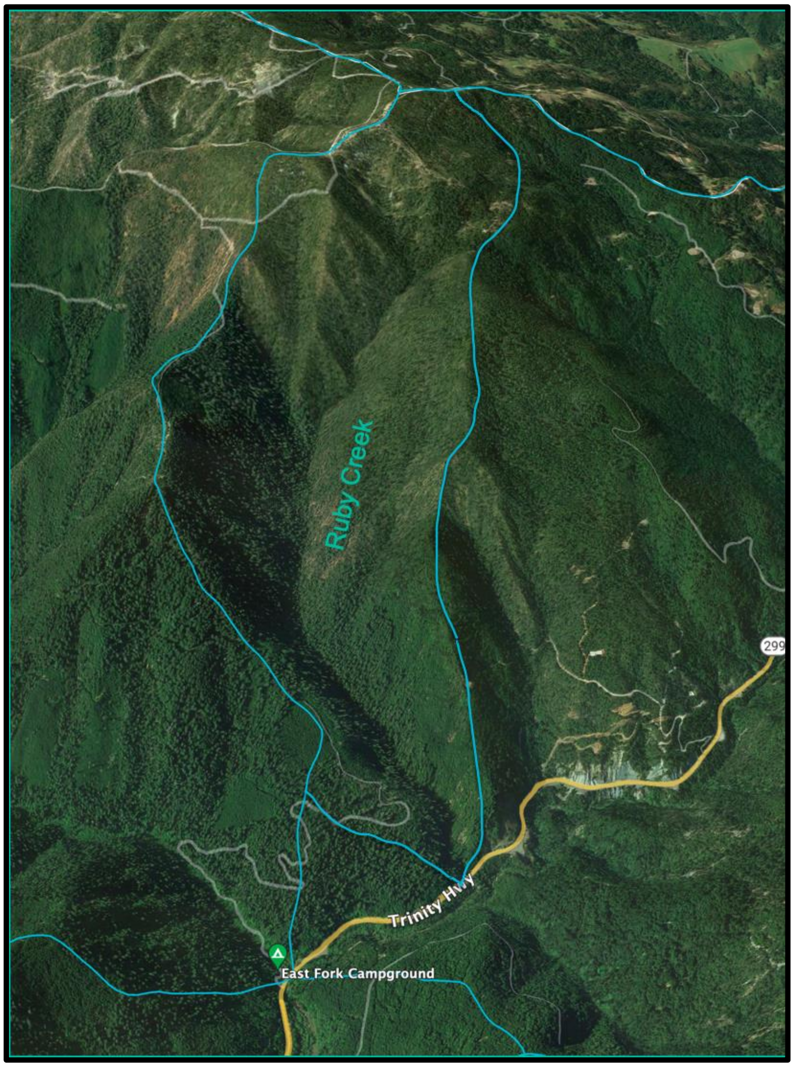


Figure 37. Watershed vicinity of Ruby Creek

Watershed Description

Ruby Creek is a part of the Upper Willow Creek hydrologic unit. It is located between Horse Mountain and Indian butte. Ruby Creek meets State Highway 299 near its mouth. Ruby Creek basin outlet is approximately six miles from the town of Willow Creek. Ruby Creek has a drainage area of about 1,032 acres. Ruby Creek is a tributary to Willow Creek, having roughly 4% of the total area of Willow Creek watershed.

Geology and landslide hazards

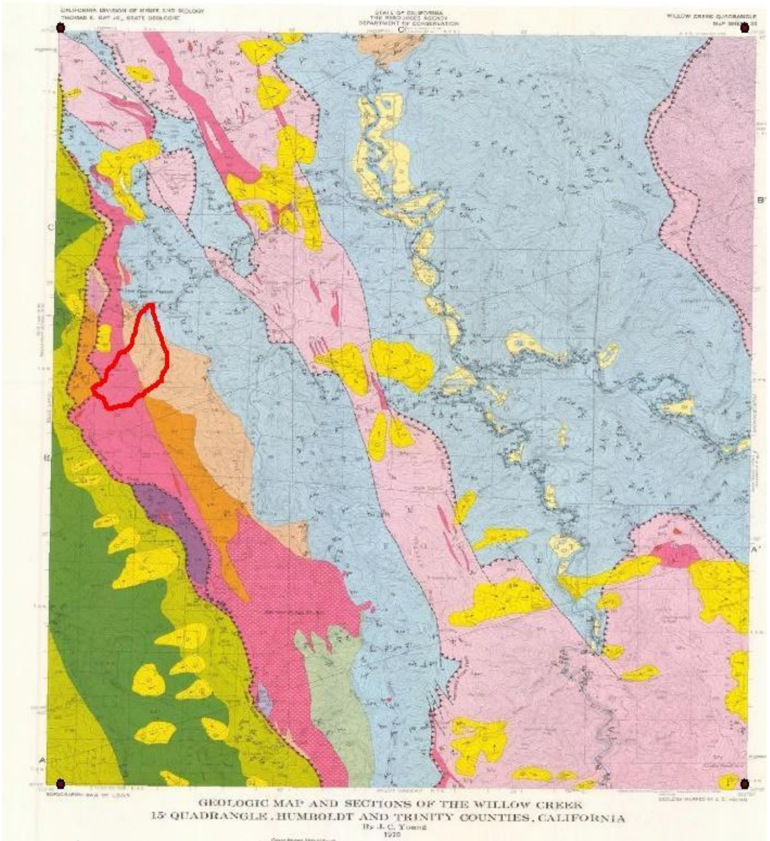
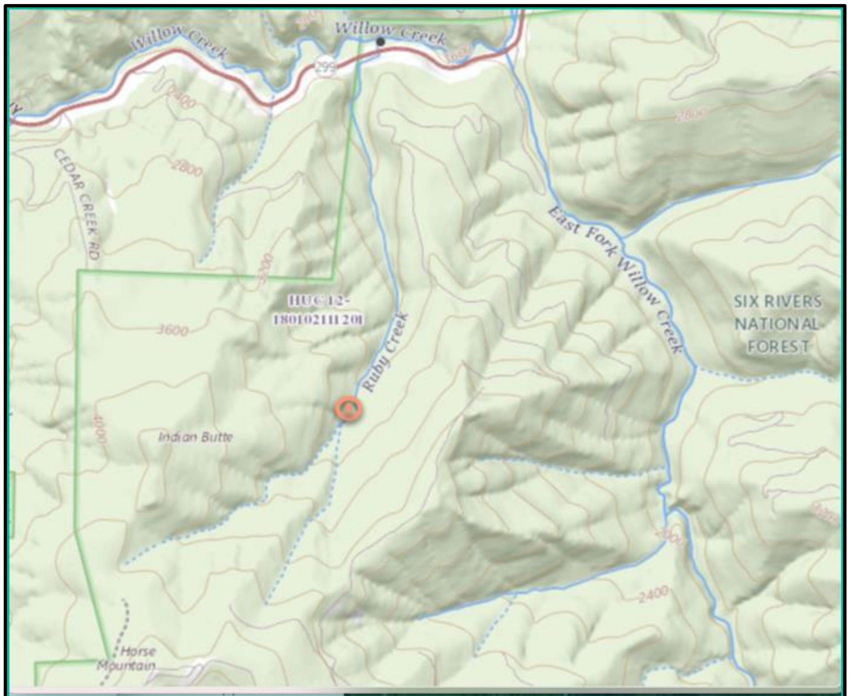


Figure 38. Geologic map showing the Ruby Creek watershed.

See the East Fork Willow Creek for a detailed description of the lithology. The Ruby Creek watershed has high stability and low landslide hazards. (J.C Young 1978)

Diversion point for assessment



Name of Point	Area (Acres)	Head (ft)
Point 1	527	1260

Figure 39. Streamflow diversion point for Ruby Creek

Site hydrology

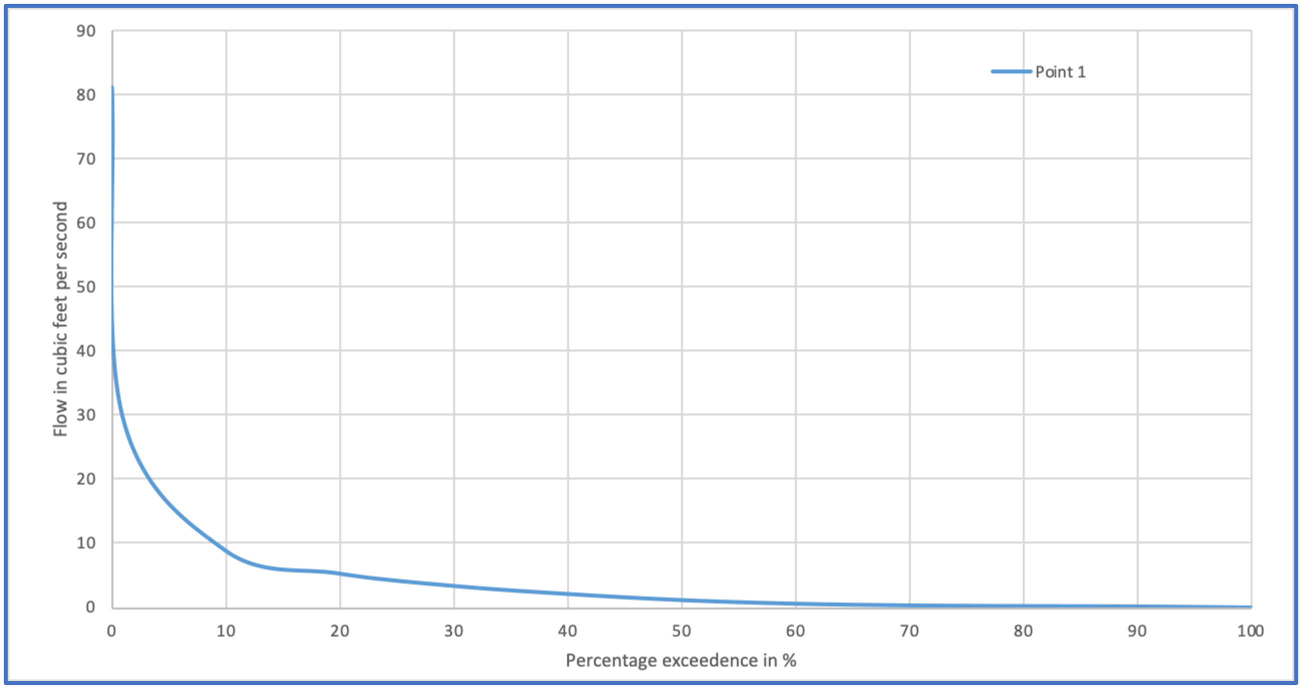


Figure 40. Ruby Creek flow duration curve for the diversion point selected for analysis.

Ruby Creek power generation potential

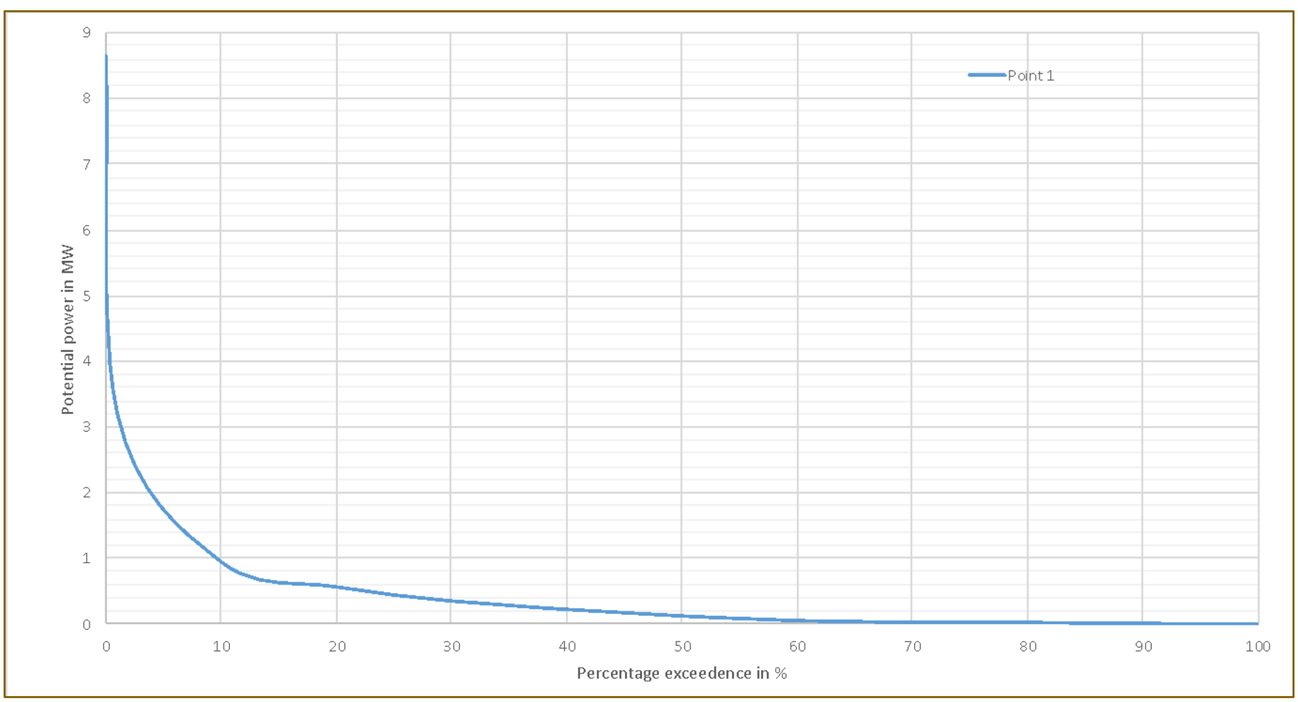


Figure 41. Ruby Creek potential power generating capacity without efficiency or environmental flow reductions.

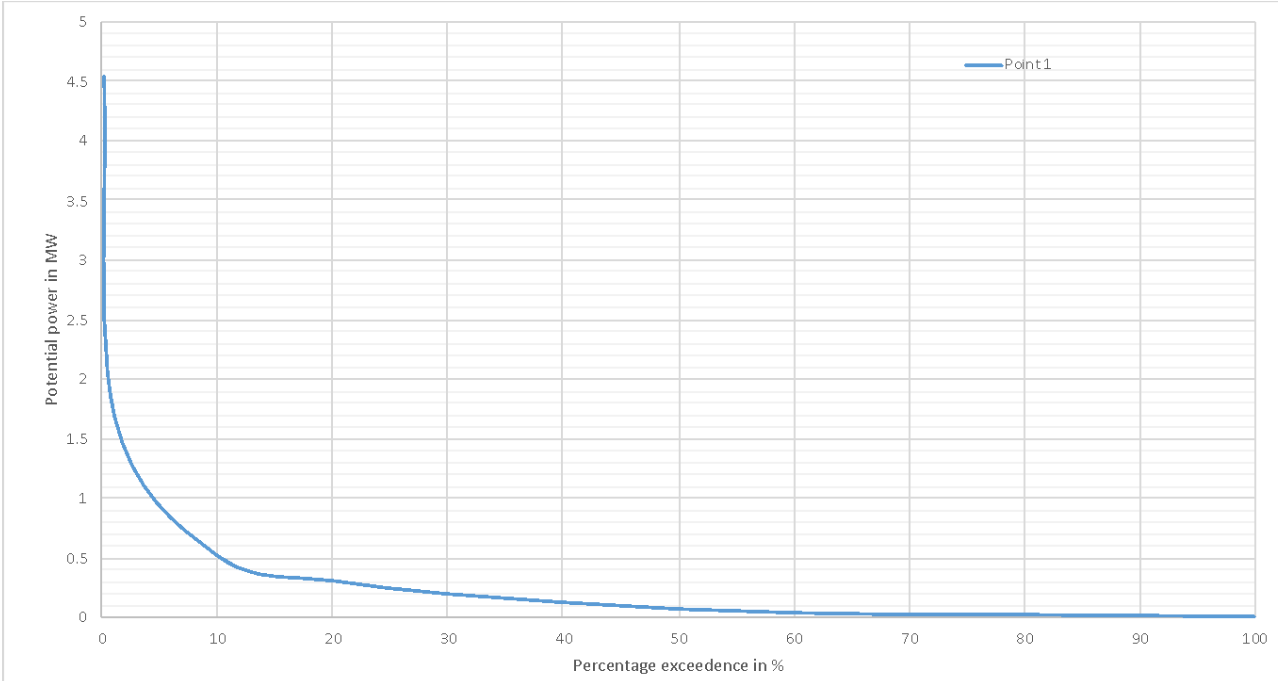


Figure 42. Ruby Creek potential power generating capacity duration curve with reductions for efficiency (75.1) and 1/3 flow reduction

Power generation potential by month

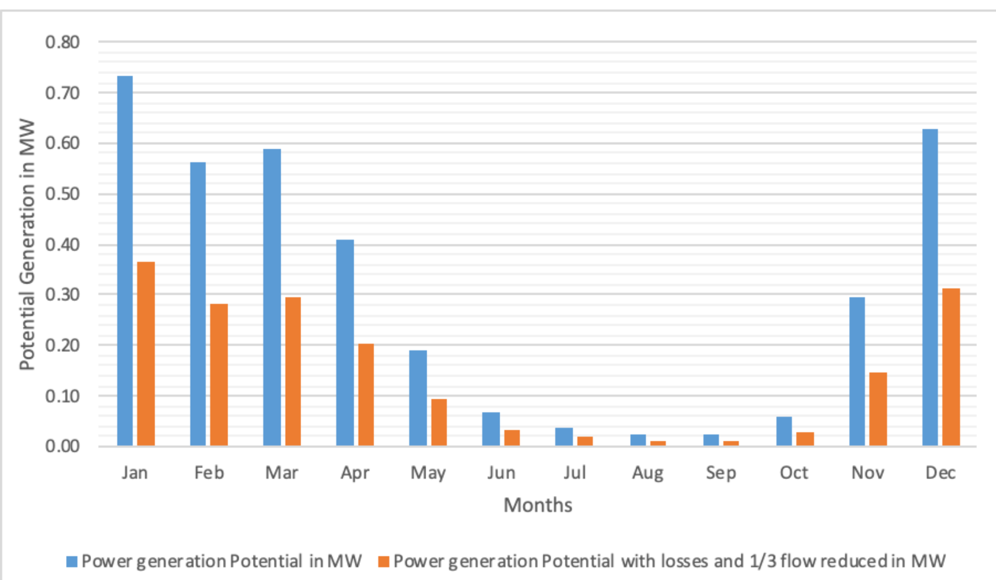


Figure 43. Average power generation potential by month with and without reductions for efficiency and environmental flows.

Power generation variability

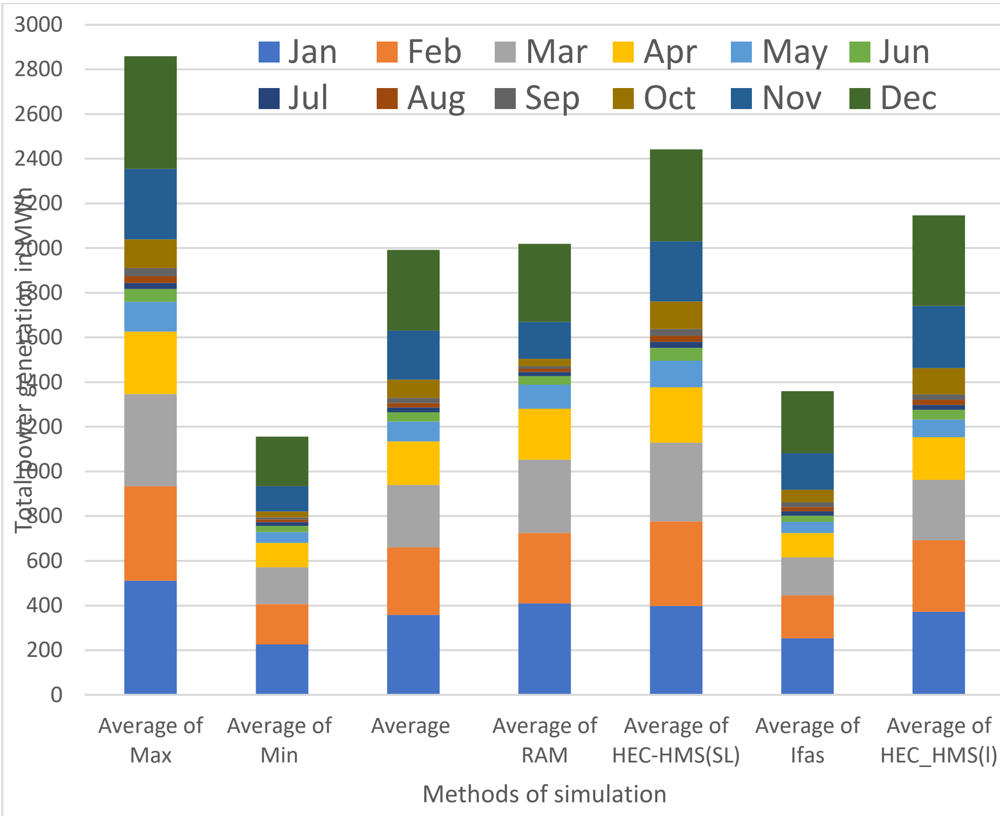


Figure 44. Power generation variability by month (with assumed 74.9 efficiency) using three methods of streamflow estimation

Pecwan Creek (Yurok Tribe)

Watershed description

Pecwan creek is a tributary to the Klamath River The watershed is bounded by Onion Mountain on the left side and Blue Creek Mountain Range on the right side. Road access into the upper and lower reaches of the Pecwan Creek watershed is good. Logging roads provide access to most Pecwan Creek (Schatz Energy Research Center 2007). The Yurok Tribe owns the majority of the land in Pecwan creek. The uppermost areas are part of Six Rivers National Forest. The Pecwan Creek has a drainage area of approximately 18,299 acres.

The climate of Pecwan Creek is characterized by warm summers and cold and wet winters. The maximum precipitation occurs between December and January. The average temperature varies from -1.67 degrees Celsius to 34 degrees Celsius (NOAA 2021). Temperatures in the Pecwan Creek watershed are moderate due to its proximity to the Pacific Ocean and the catchment facing the Pacific Ocean. Orleans, California, is the nearest weather station to Pecwan Creek.

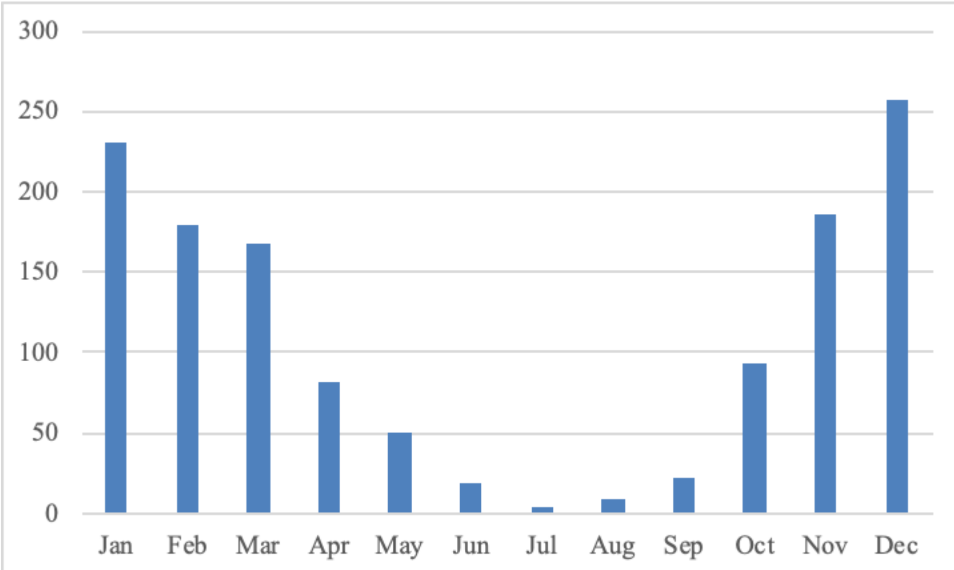


Figure 45. Average monthly cumulative rainfall for Eureka

Vicinity Maps

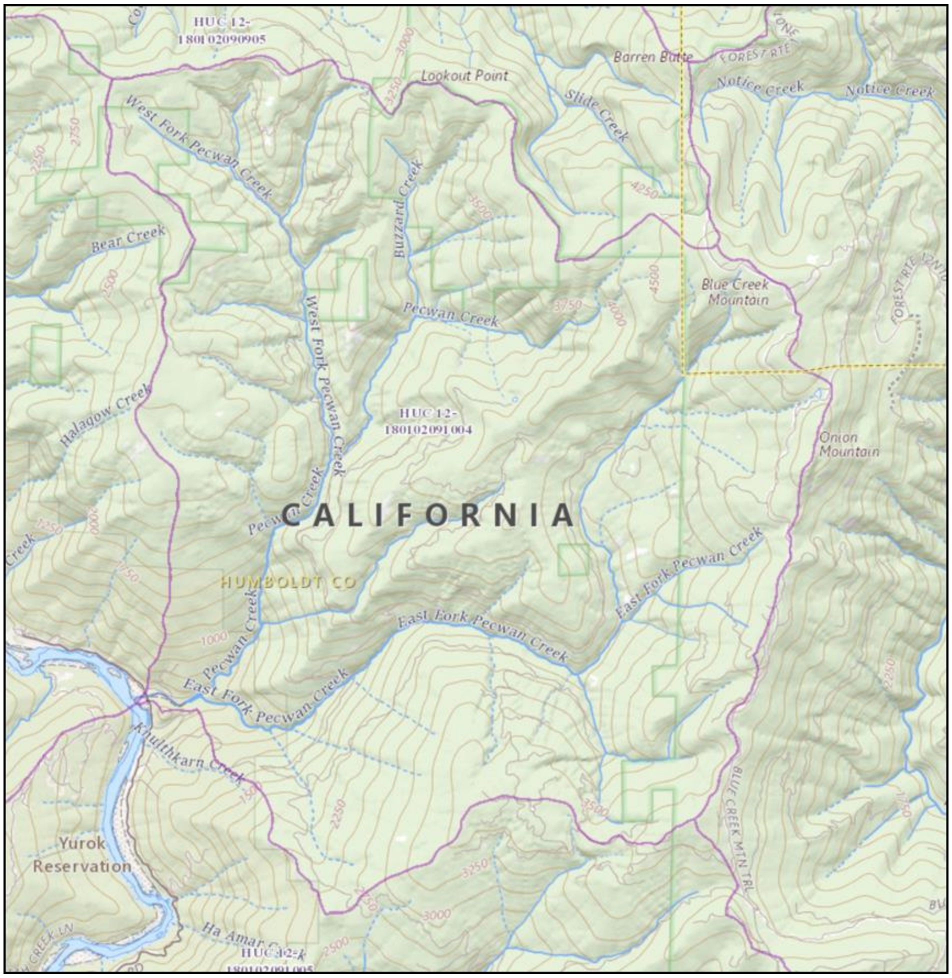


Figure 46. Watershed Vicinity: Pecwan Creek, Tributary to the Klamath River. Much of the watershed was acquired by the Yurok Tribe in 2011.

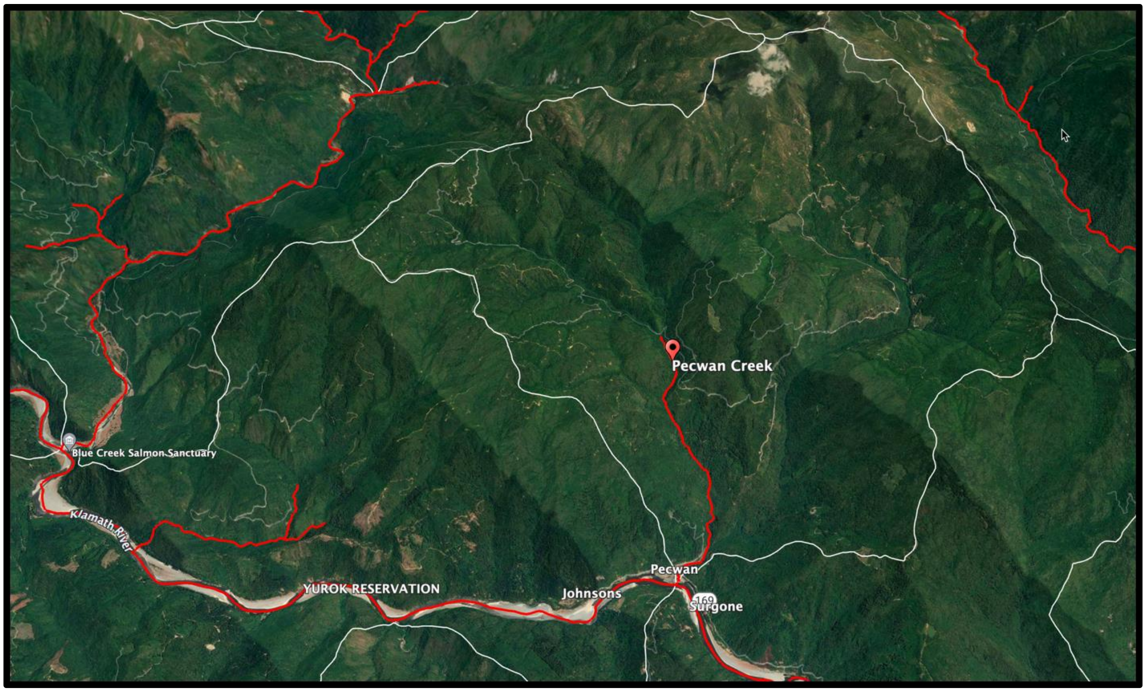


Figure 47. Pecwan Creek, tributary to the Klamath River, showing the extent of anadromous fish habitat.

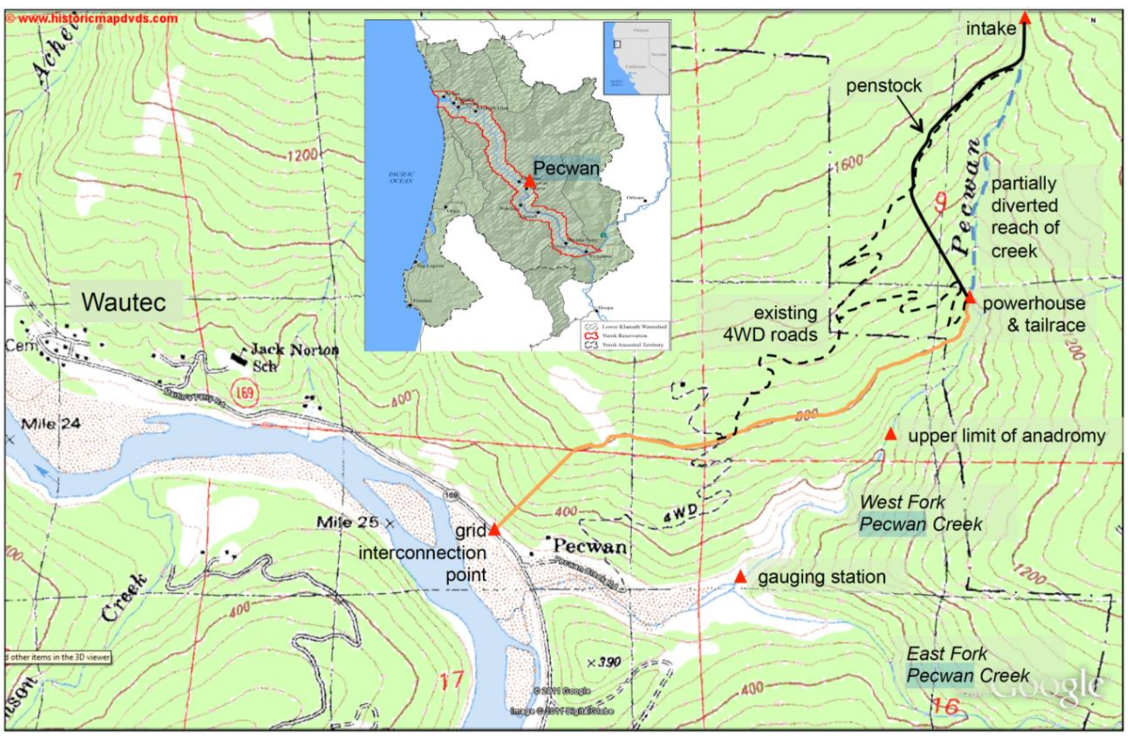


Figure 48. Pecwan Creek Development map from [Zoellick et al. 2011 assessment]() A potential grid interconnection point is show n.

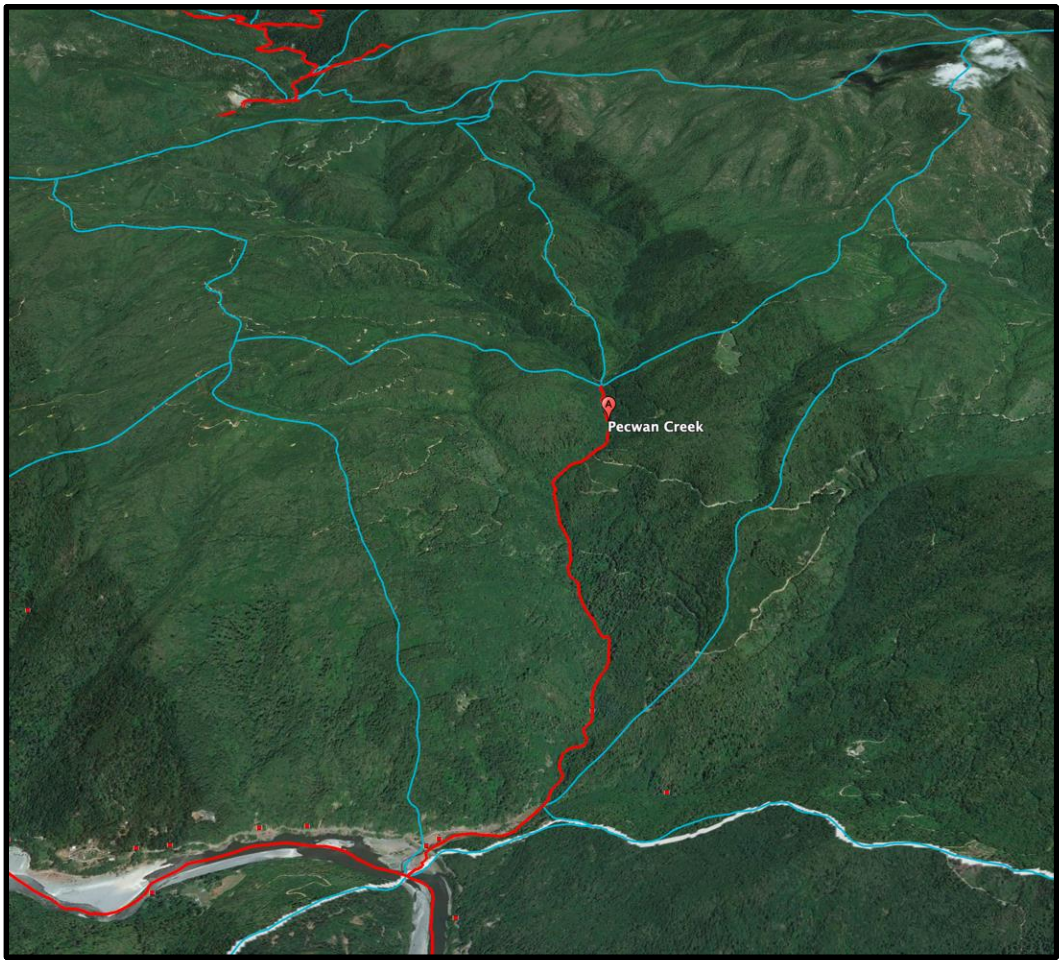


Figure 49. Pecwan Creek showing limit of anadromy (red line)

Pecwan Creek and an adjacent watershed were called out in a 2011 assessment (Zoelick et al., 2011.) These are largely owned by the Yurok Tribe and have significant flow and relief.

Need for added energy resilience for tribal lands subject to weather-related outages, and potential further electrification of off-grid settlements

Geology and landslide hazards

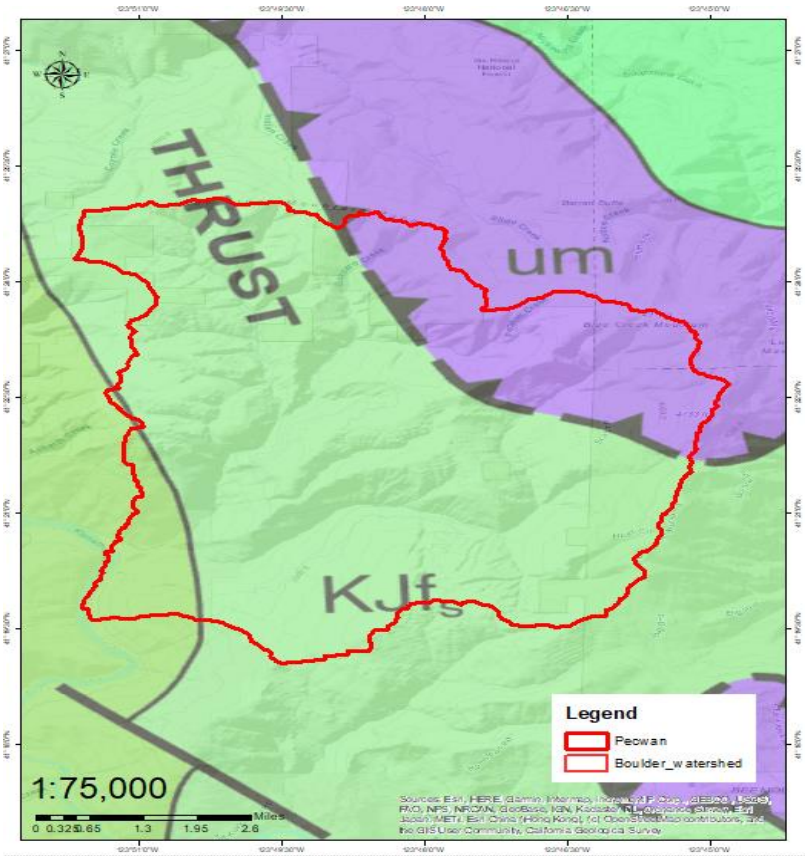
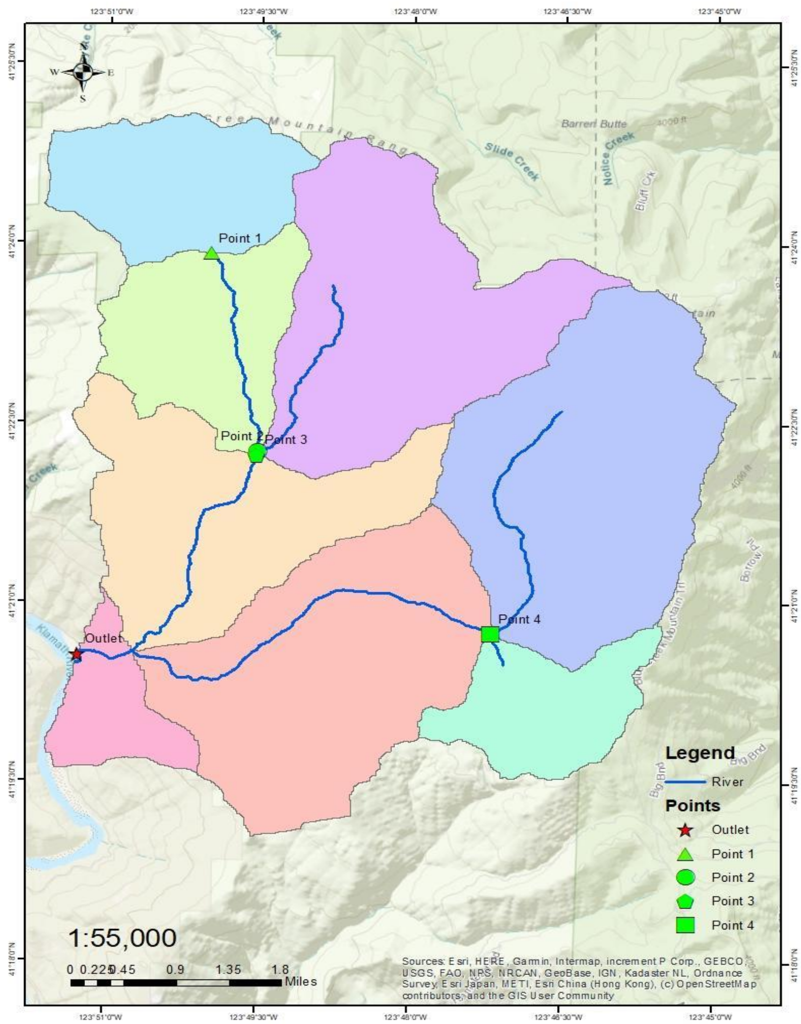


Figure 50. Geologic map of Pecwan Creek.

Mesozoic ultramafic rocks dominate the upper watershed, primarily composed of serpentinite and related ultramafics. The middle and most of the lower reaches are dominated by schist formed from the Cretaceous to Jurassic period. The lower portion of the catchment and catchment outlet is dominated by the Franciscan Complex, mainly sandstone formed from the Cretaceous to the Jurassic period. The watershed is moderately stable but the fault contact area between the ultramafics and the schist is subject to significant landslide hazards that would present risks of high maintenance and failure potential for a ROTR system. Source: California Geologic Survey.

Diversion points for analysis



Name of Point	Area (Acres)	Head (ft)
Point 1	1551	2400
Point 2	3136	2017
Point 3	6491	2004
Point 4	4966	2214

Figure 51. Diversion points selected for analysis for Pecwan Creek.

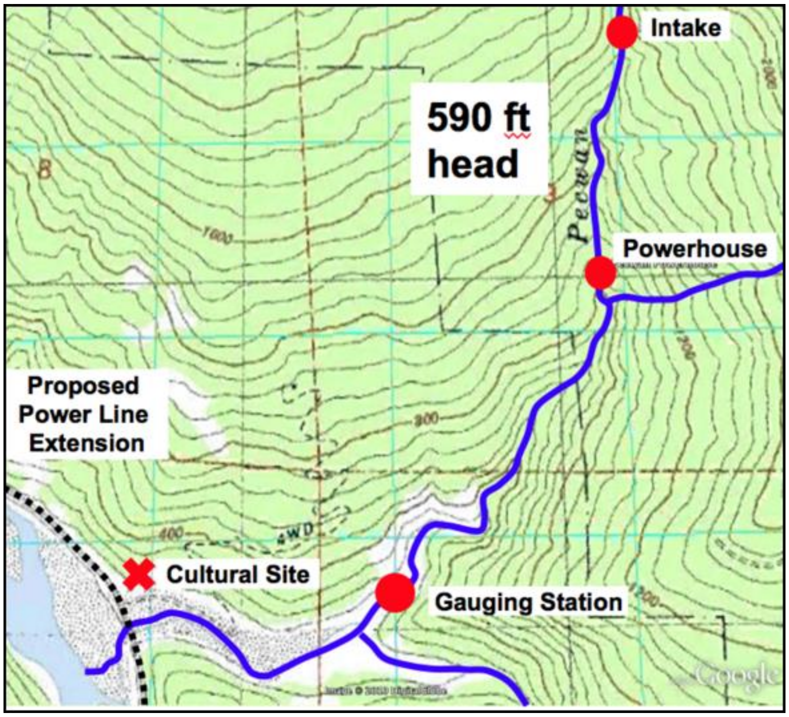


Figure 52. Hydropower schema from Zoelick et al. 2011). Included for reference.

Interconnection opportunity

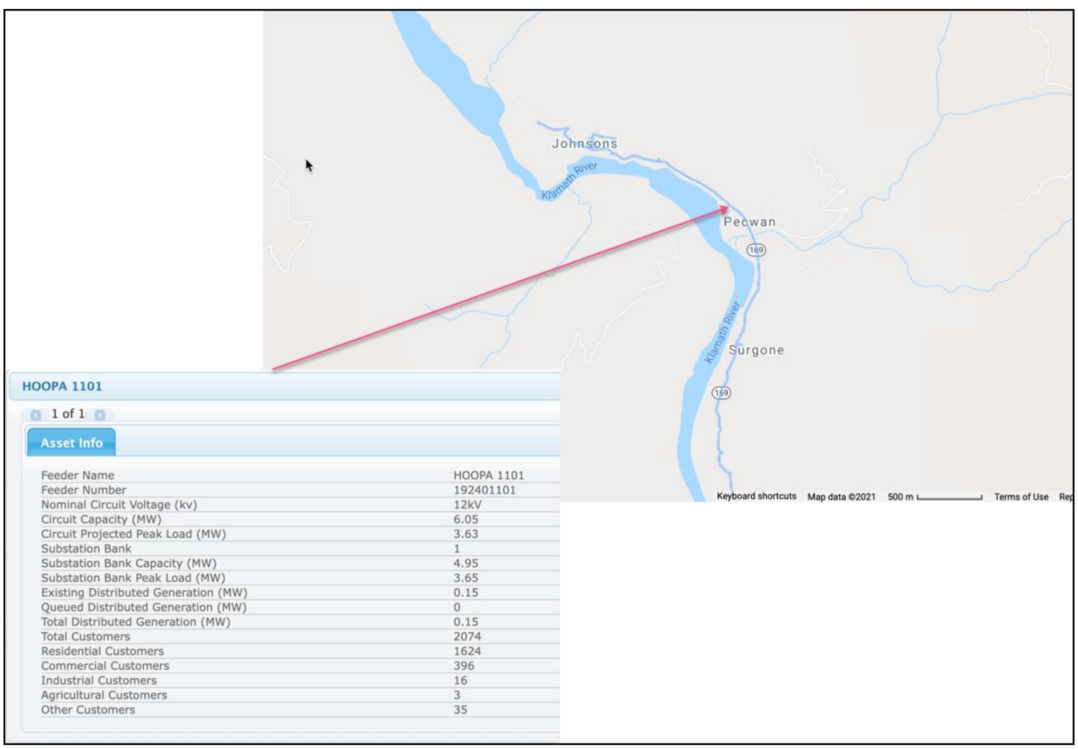


Figure 53. PG&E PV-RAM map. The extant 12kv distribution line goes upstream to the Hoopa vicinity. A distribution line to the primary electric loads of the Yurok Tribe does not presently exist. A nominal 2.42MW of capacity is unused on the existing distribution line.

Pecwan Creek hydrology

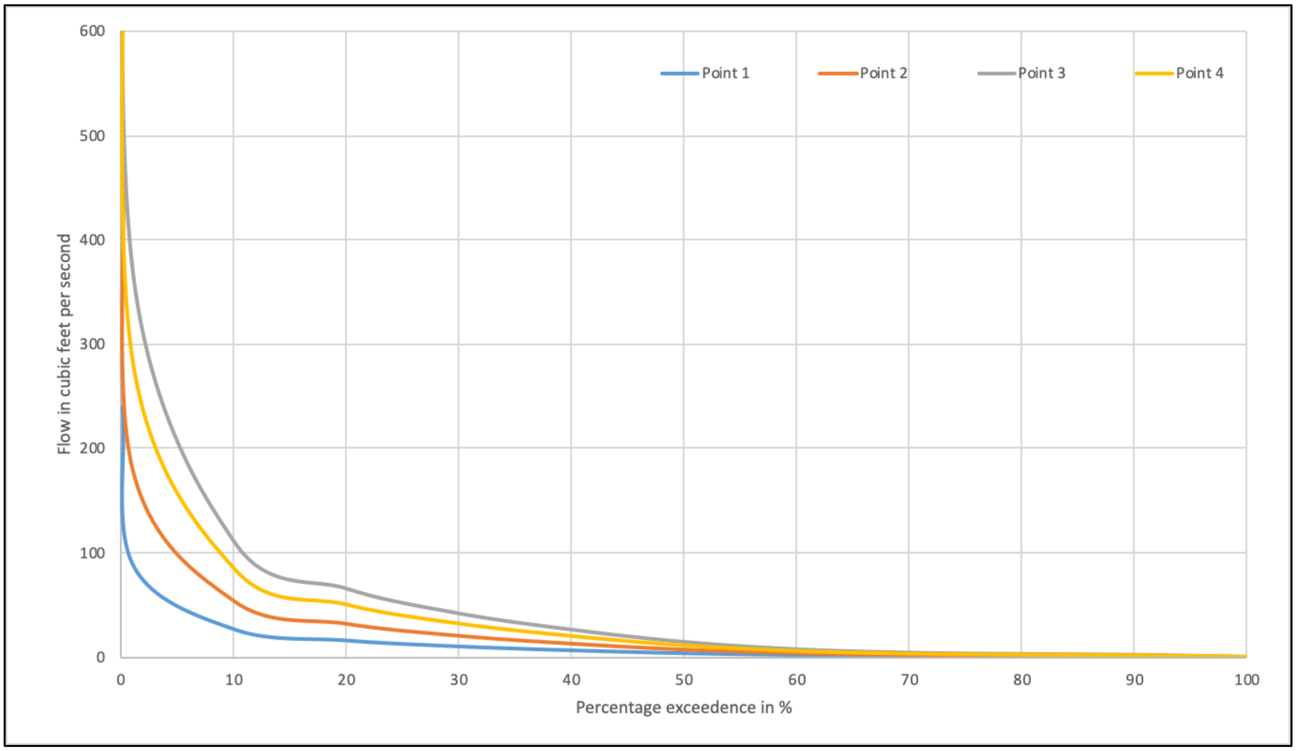


Figure 54. Pecwan Creek flow duration curves for each of the 4 diversion points selected for analysis.

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Pecwan Creek power potential

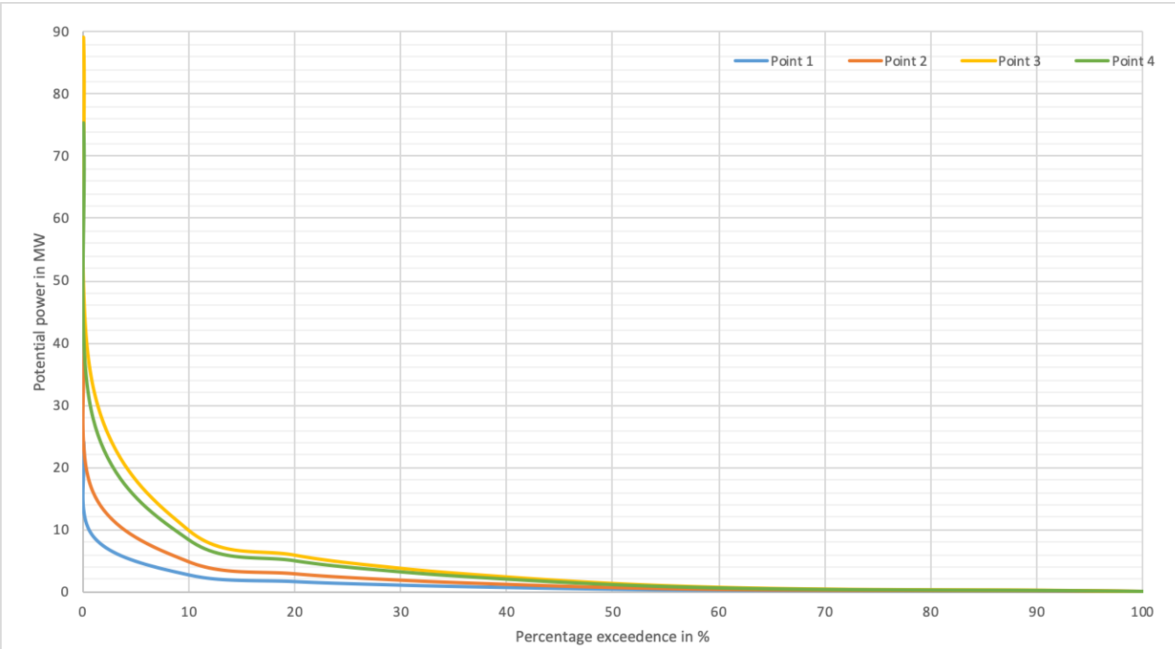


Figure 55. Pecwan Creek potential power generating capacity without efficiency or environmental flow reductions.

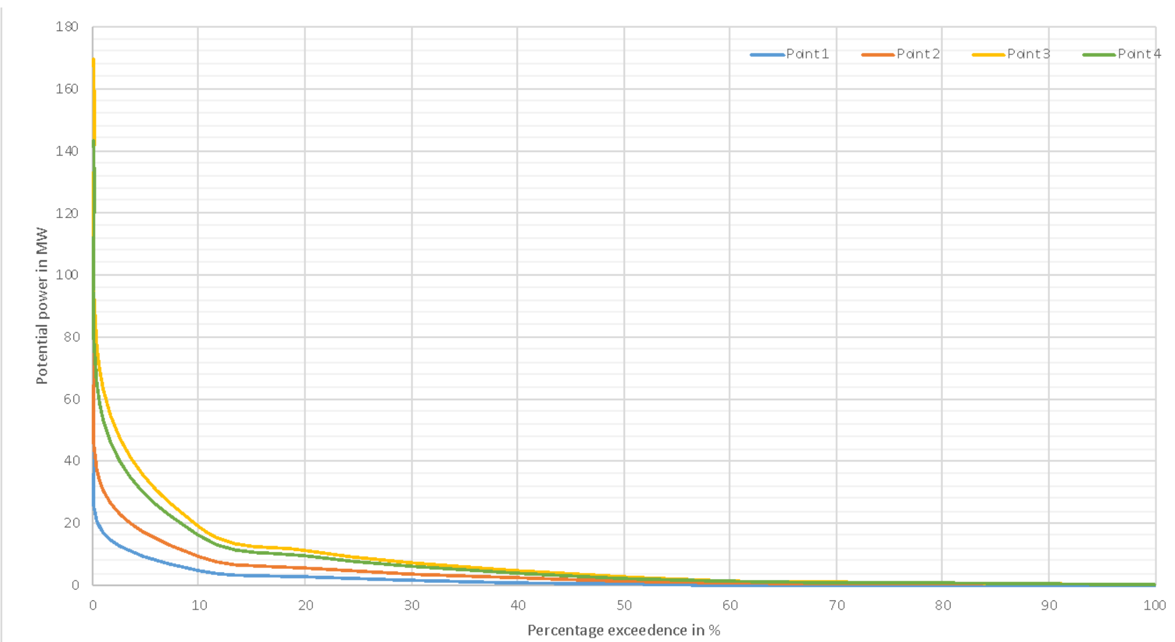


Figure 56. Pecwan Creek potential power generating capacity duration curve with reductions for efficiency (75.1) and 1/3 *flow reduction*

Power potential by month

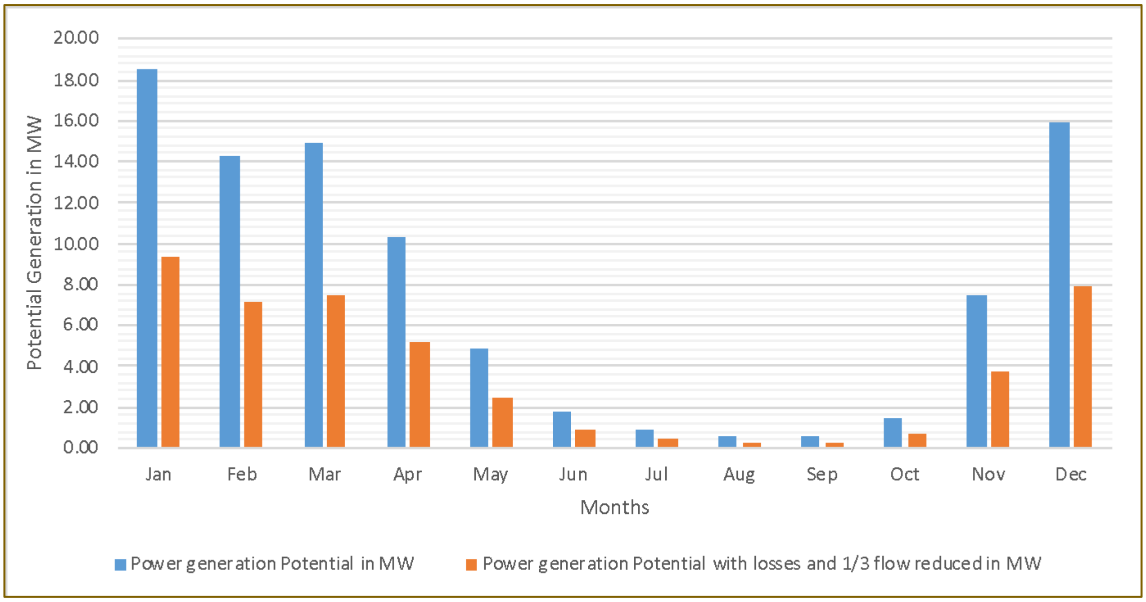


Figure 57. Pecwan Creek average power generation potential by month with and without reductions for efficiency and environmental flows.

Power generation variability

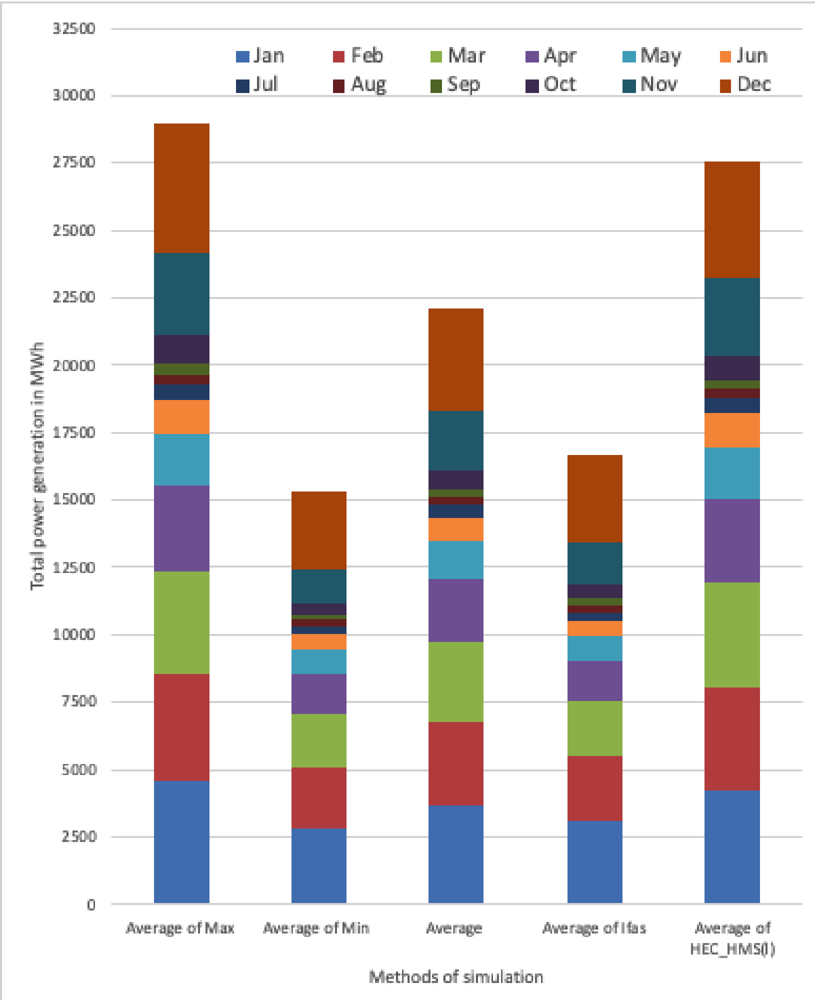


Figure 58. Pecwan Creek power generation variability by month (with assumed 74.9% efficiency) using three methods of streamflow estimation

Madden Creek (Also known as Old Campbell Creek)

Watershed Description

Madden Creek is also known as Old Campbell Creek and is shown as such on USGS mapping. Land management agencies and locals know it as Madden Creek. Madden Creek is a tributary to the South Fork of the Trinity River with a drainage area of around 14,930 acres.

The watershed is bounded by Buck Flat, Black Rock, and Friday Ridge on the left side of the catchment. Ammon Ridge and Hogback Ridge surround the right side of the catchment. Barry Summit -Mad River Road passes from the top of the catchment, and Friday Ridge Road and NF-6N06 Road give access to the lower catchment and the catchment outlet. There are numerous roads providing access within the catchment from multiple entry points, and overall, most of the catchment is quite accessible by road. The creek outlet can be accessed by driving about four miles on NF-6N06 Road, taking a diversion from Highway 299 approximately 1 mile south of Willow Creek. Madden Creek has The madden creek is one of the tributaries of the Trinity River.

The climate is similar to East Fork Willow Creek described above.

Figure 59. Madden Creek, tributary to the South Fork of the Trinity River, showing the limit of anadromous fish habitat. Madden Creek is also called Old Campbell Creek (USGS preferred name).

Geologic map and landslide hazards

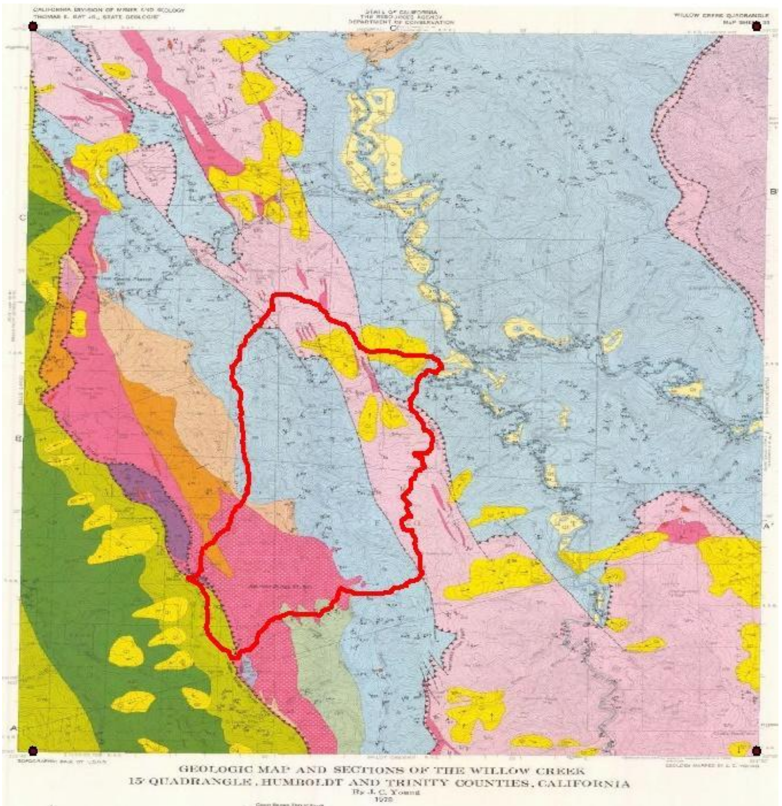
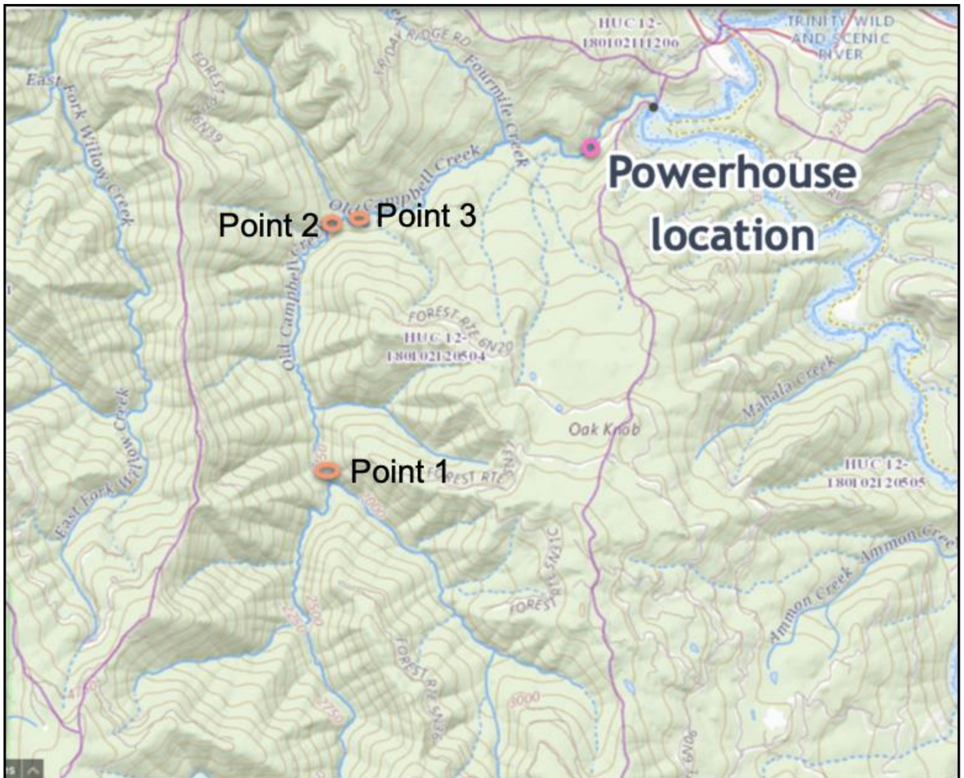


Figure 60. Geologic map showing the Madden Creek watershed.

The upper watershed consists of South Fork Mountain Schist, Ammon Ridge Pluton, Friday Camp Gneiss. Galice Formation covers most of the middle reaches of the catchment. The lower part of the catchment is dominated by the Western Paleozoic and Triassic belt of rocks. (J.C Young 1978) Instability is notable in contact areas. Significant landslide potential exists that would sometimes challenge a ROTR system, with significant likelihood of occasional system failure and relatively high maintenance requirements.

Streamflow diversion points for assessment



Name of Point	Area (Acres)	Head (ft)
Point 1	6775	3270
Point 2	9229	2174
Point 3	10432	2152

Figure 61. Diversion points selected for analysis

Interconnection opportunity

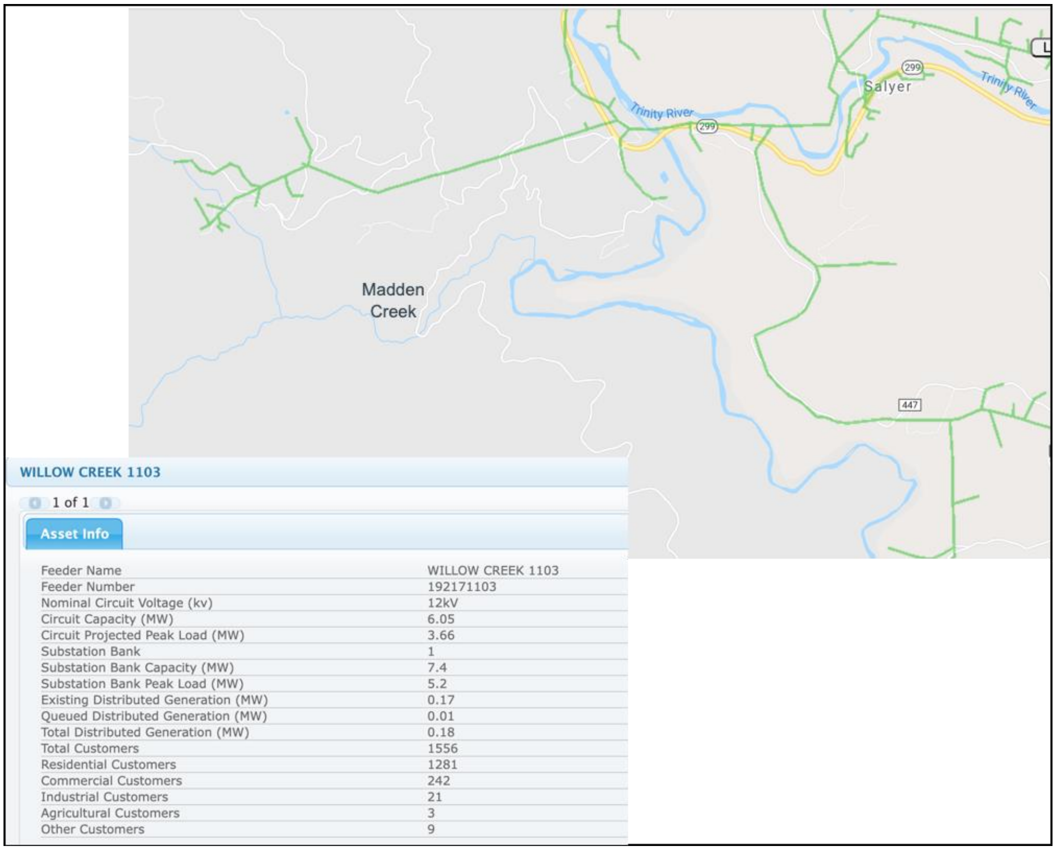


Figure 62. PG&E PV-RAM map showing 12kv distribution lines. A nominal 2.39 MW of capacity is unused.

Madden Creek hydrology

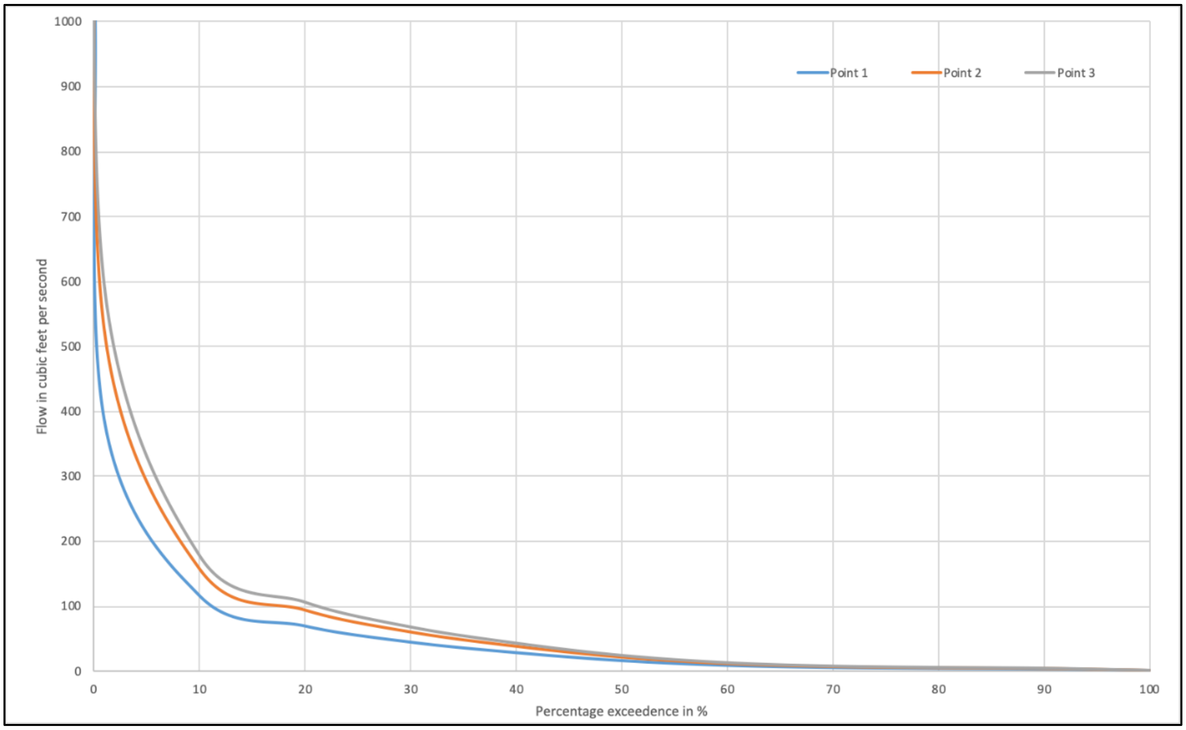


Figure 63. Madden Creek flow duration curves for each of the three diversion points selected for analysis.

Power generation potential

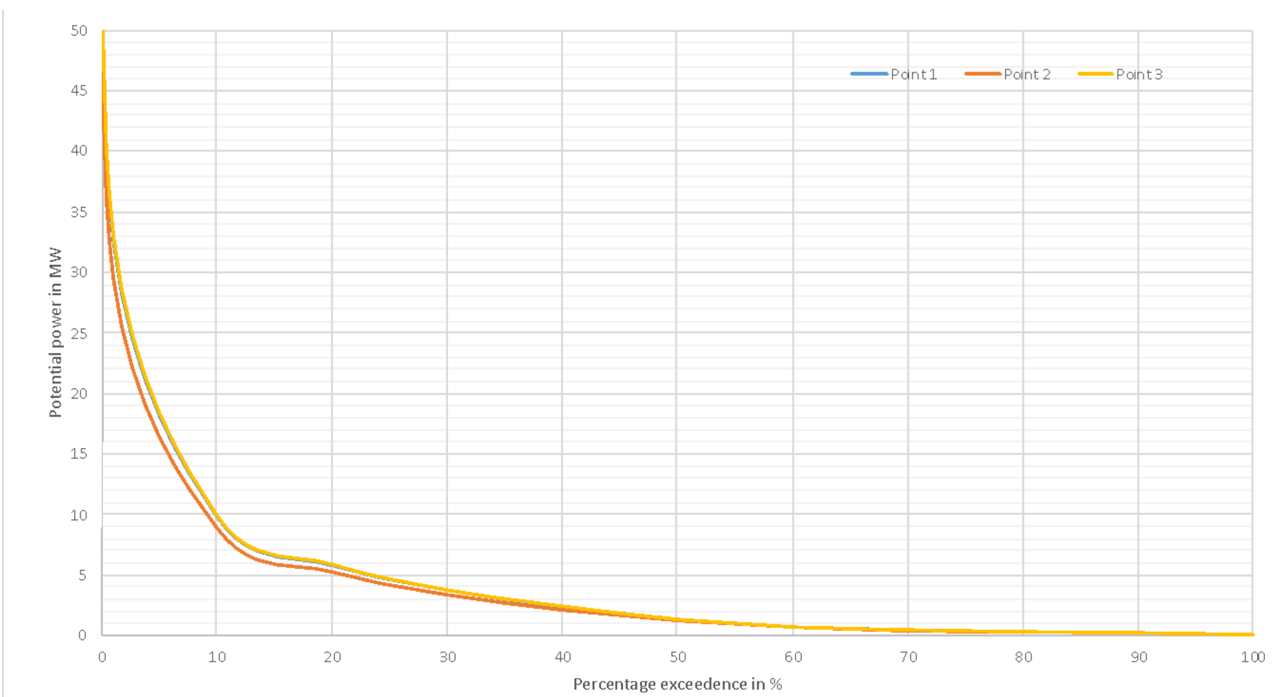


Figure 64. Madden Creek potential power generating capacity without efficiency or environmental flow reductions. Note: The curves for Points 1 and 3 overlap.

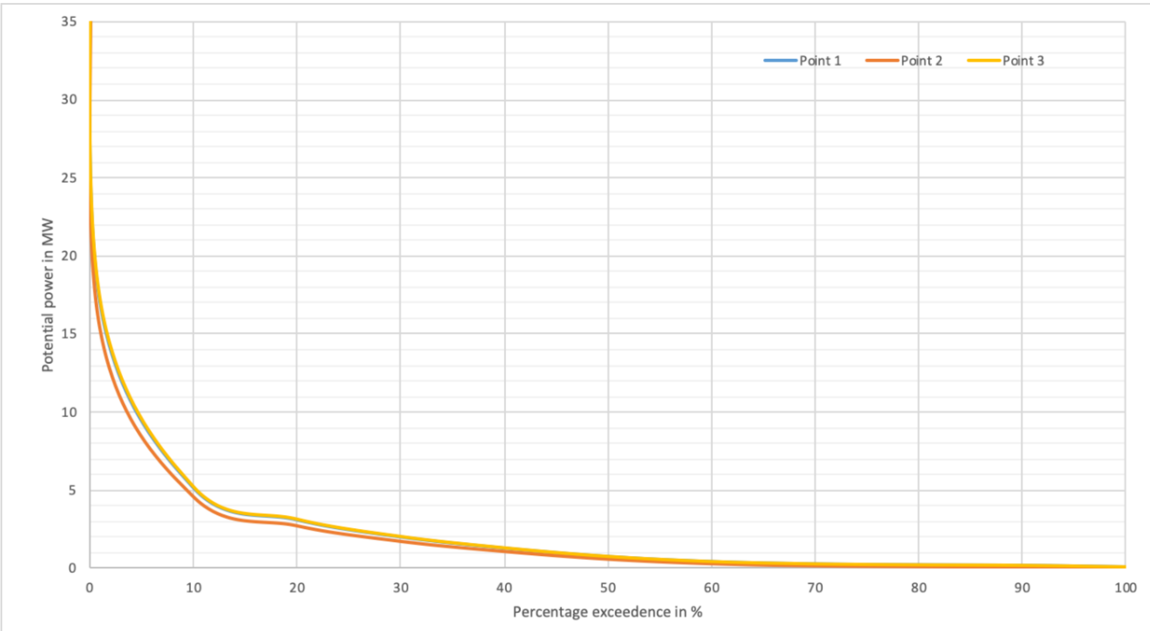


Figure 65. Madden Creek potential power generating capacity duration curve with reductions for efficiency (75.1) and 1/3 flow reduction. Note: The curves for Points 1 and 3 overlap.

Power generation potential by month

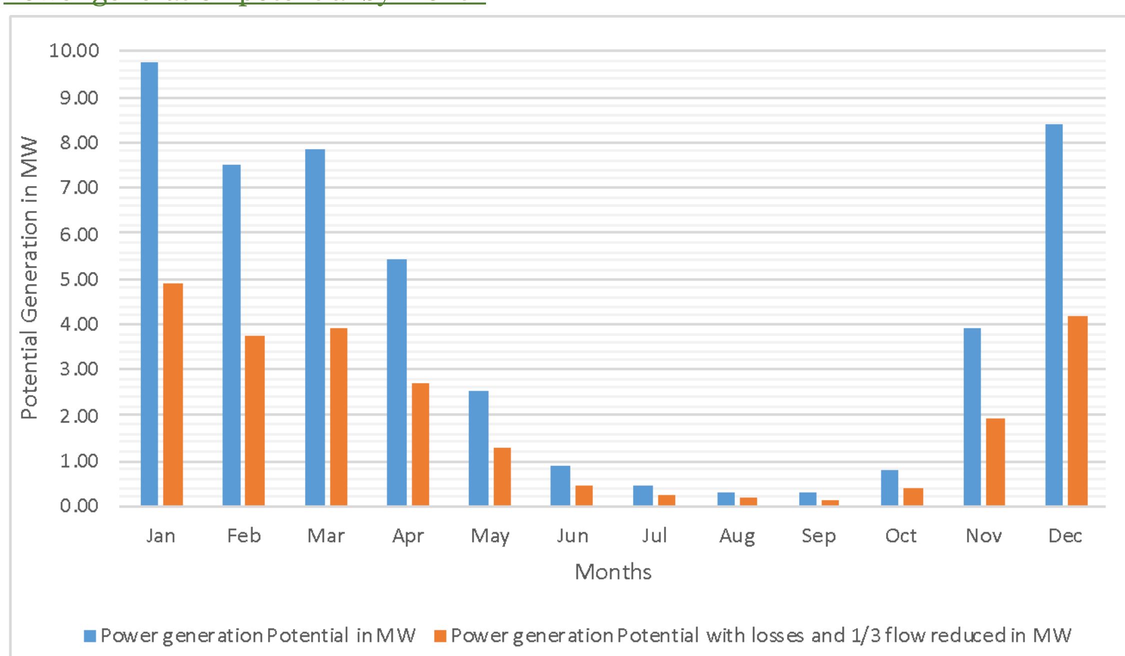


Figure 66. Madden Creek average power generation potential by month with and without reductions for efficiency and environmental flows.

Power generation variability

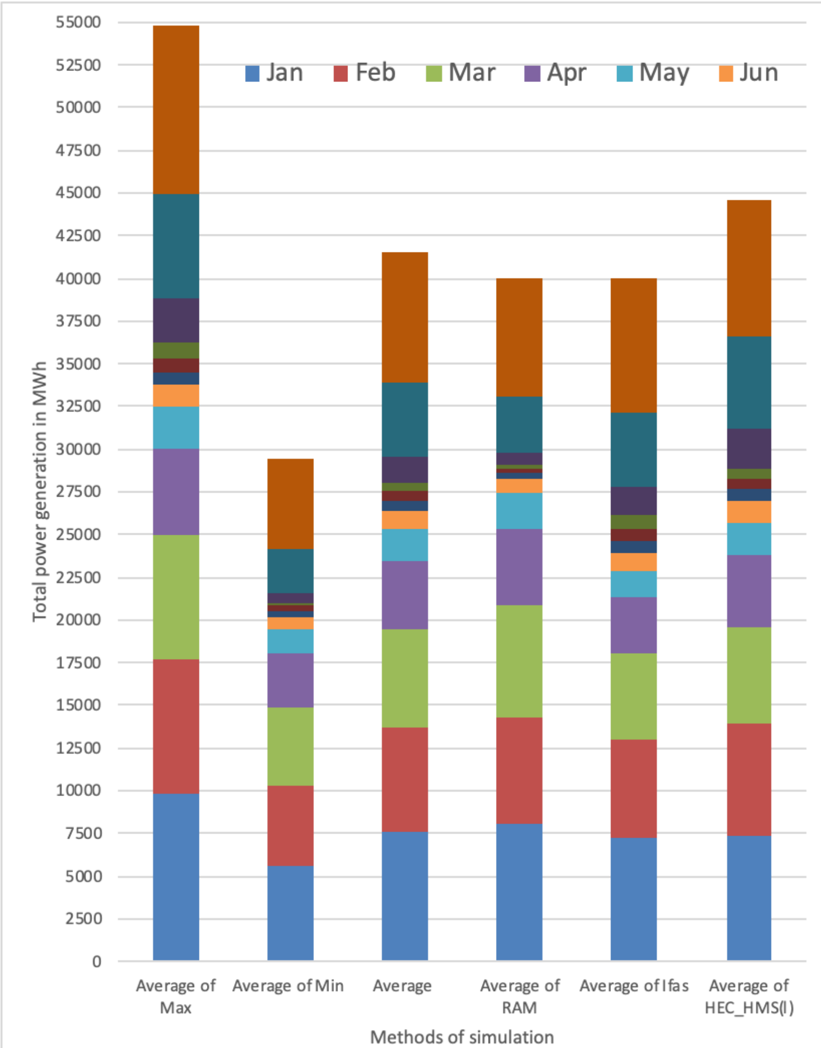


Figure 67. Madden Creek power generation variabilty by month (with assumed 74.9% efficiency) using three methods of streamflow estimation

Watershed Power Profile: Generalized Analysis Advice

What is a Watershed Power Profile?

To assess and plan for the development of small ROTR hydropower that has minimal effects on the environment and can be seen as feasible for the development of this renewable, non-GHG-emitting power source, an outline of a procedure for analysis of a candidate watershed is briefly presented here.

This is a form of "watershed analysis" that is focused on the assessment of a specific activity: small hydropower, but short of a full environmental assessment (NEPA/CEQA) when a project is proposed for development. Because small hydropower involves disturbance of land and modification of streamflows, a full assessment of watershed conditions, processes and functions is needed.

The intent of any such analysis is to develop and document a scientifically based understanding of the processes and interactions occurring within a watershed. This understanding, which focuses on specific issues, values, and uses within the watershed, is essential for making sound management decisions. Protecting beneficial uses, such as those identified by the States in water quality standards and criteria under the Federal Clean Water Act, is a fundamental motivation for Watershed Analysis. Because of the linkages between headwater areas, valley floors, and downstream users, watershed analyses should encompass the entire watershed - from the highest ridge to the mouth of the trunk river and including all ownerships.

There is a growing impetus to manage wildlands as ecosystems. Federal agencies, for example, are to manage ecosystems - all components and species - to protect and sustain the natural systems that society depends on. To do this, we must understand how the requirements of various species overlap and affect one another in an area before we can develop projects that sustain the ecosystem there. Watershed analysis provides a vehicle to identify and balance multi-species concerns efficiently. This requires an understanding of the interactions between land-use activities, the physical environment, and the biological environment in an area. Developing this understanding is the essence of Watershed Analysis.

Application of the watershed analysis procedure outlined here results in reports that describe the distribution pattern, types, and relative importance of resource values, altered environmental conditions, and mechanisms of environmental change in watersheds. Analysis reports identify issues to consider during project planning in different parts of the watershed and outline specific considerations for all aspects of small ROTR hydropower development, including cumulative effects analyses and monitoring programs.

Relationship to existing analysis and planning processes

Watershed analysis, as presented here, is not a decision process in that it does not produce a formal decision notice or record of decision as required by the National Environmental Policy Act (NEPA) or California Environmental Policy Act (CEQA). Watershed analysis is an intermediate level of analysis that derives information from larger-scale (River Basin, Provincial, County, National Forest) plans and which provides information to smaller scale, site analyses, both of which are formal decision points under NEPA and CEQA. Because ecosystem analysis and planning is a continuum at all scales, watershed analyses can also provide information to river basin planning and receive information from site analyses.

Key components of the analysis

Public Involvement

Awareness of the full range of values, resource needs, and public expectations associated with the watershed being analyzed is fundamental to the analysis. The degree of public involvement used in any Watershed Analysis will vary based on the type and intensity of the issues involved, the prevalence of existing information, and the history of public participation within or adjacent to the watershed.

Definition of the analysis watershed

The area to be evaluated will normally be a watershed or watershed complex ranging from roughly 20 to 200 square miles, usually delineated in the National Watershed Hierarchy as a 6th level "subwatershed" or HUC-6. Wherever possible, each analysis watershed will be a complete tributary watershed to the confluence with a larger channel. Where this is not possible, several smaller tributaries may be grouped for analysis if they are expected to be similar. Some watersheds are likely to include adjacent small tributary watersheds along main-stem rivers. The boundaries should be selected to simplify analysis as much as possible by delineating a reasonable hydrologic unit.

Who conducts the analysis?

Watershed Analysis is ideally carried out by interdisciplinary/interagency teams of resource specialists who are professionally qualified to assess and interpret the structure, composition and function of the ecosystems within a given watershed.

Steps

1. Identify issues, describe desired conditions, and formulate key questions for potential ROTR hydropower development
2. Identify key processes, functions and conditions
3. Assemble analytic information needed to address the key questions
4. Describe past and current conditions
5. Describe condition trends and predict effects of future land management
6. Integrate, interpret, and present findings
7. Manage information, monitor, and revise

Products

- A description of the watershed including its natural and cultural features.
- A description of the beneficial uses and values associated with the watershed and, when supporting data allow, statements about compliance with water quality standards.
- A description of the distribution, type, and relative importance of environmental processes.
- A description of the potential for the watershed to provide electric power via ROTR hydropower while maintaining ecosystem and societal values.

Elements of environmental consideration and design of Run-of-the-River Hydropower

Activities that could cause disturbance and adverse environmental effects

A small hydropower installation typically requires six features that cause disturbance and potential environmental effects:

1. **A diversion point:** Places on the stream where water is diverted to a penstock for movement downhill to a generating station (powerhouse). This usually involves a diversion weir in the stream channel, sometimes a small pond above the weir ("headpond"), and a settling facility to remove coarse sediments from the diverted streamflow.
2. **Diversion of streamflows:** A portion of the streamflow is diverted and carried downstream to the powerhouse to generate electricity. This result in lower flows in the diverted reach. Streamflow is returned to the stream channel below the powerhouse. Thus the affected stream reach is between the diversion point and the tailrace of the powerhouse.
3. **A penstock:** (or tailrace and penstock) that transmits the diverted flow from the diversion point to the powerhouse. This is typically a heavy-gauge pipe made of strong material laid across the landscape, often with supports.
4. **A powerhouse** that receives the diverted streamflow to run a turbine to generate electricity. Diverted streamflow is returned to the natural stream channel at or near the powerhouse.
5. **Transmission lines:** to convey the generated power to the point of interconnection or use.
6. **Access roads or trails:** Each of these features requires access for construction and maintenance. Usually, this is in the form or roads or trails, except for the penstock, for which a road is not normally needed.

Biology

Fisheries biology & Aquatic ecology

In-stream flows

The largest potential environmental effect of ROTR is the effect of the diversion of water from the channel between the intake and the powerhouse, with less streamflow remaining in the stream channel. The amount of streamflow that may be diverted and thus the amount of streamflow remaining is that channel section is a critical determination. It is usually made through study, assessment, and negotiation among biologists and earth scientists during the NEPA/CEQA environmental analysis process. More allowable diversion means more power generation.

Key Questions

- What amount of streamflow may be diverted, over what distance, to generate ROTR hydropower and maintain habitat conditions for aquatic organisms present in the bypassed stream reach? What minimum environmental streamflows are needed to support habitat for species present or potentially present in the affected stream reaches?
- What are the minimum and maximum streamflow diversions ?
- What seasons of operation allow the diversions and maintain the environmental flows needed for habitats?
- How does interannual variability affect determinations of allowable diversions/environmental flows?
- How could climate change modify streamflow regimes, and what level of change would indicate that allowable diversion needs to be modified?

Endangered and sensitive herp species

- Are there amphibians and/or reptiles that are known to inhabit the affected stream reach, or is there suitable habitat for these animals?
- How would diverting streamflow from the affected reach potentially affect the resident animals and any potential habitat?
- Would the penstock affect the movement of herps? How can this be avoided or mitigated?

Forestry

- What forestry operations (such as timber harvest, thinning, road construction and reconstruction) are allowed or anticipated in the affected area of the watershed?
- Would the project, including the intake works, penstock, powerhouse, and transmission lines affect forestry operations? How can this be avoided or mitigated?
- How many trees would need to removed or modified to accommodate project construction, operation, and maintenance?

Botany

- Do rare plants occur or are suspected to occur in the areas expected to be disturbed by project construction, operation, or maintenance?
- What surveys for rare plants have been conducted. What surveys may be needed?

Geomorphology

Landslide hazards assessment

- Are the areas proposed for development suitably stable?
- Are there areas along the penstock location that are prone to landsliding or serious surface erosion that could disrupt or destroy the penstock?

The stability of slopes is an important element of site analysis. A geotechnical analysis of the areas that would be disturbed, especially the penstock location, is needed to ensure that the proposed sites are suitably stable for development. See detailed description for landslide assessment that follows on Page 67.

Social and Cultural

Recreation use

- What are the current and potential recreation uses of the area to be developed?
- With the development affect the recreational values or access?

Native American significance

- Do the areas be to be developed as a significance for Native American use or historical value?

Visual quality

- Do the areas to be developed have visual qualities and values?
- If there are visual qualities and values to be protected, what measures are

Public acceptance

- Are public objections to the project likely?
- How can public acceptance be promoted?

Environmental Justice

- Are there environmental justice issues inherent in the project? How can these issues be addressed?

Archaeological resources and surveys

- What archaeological resources could be affected by the project?
- Have any archaeological surveys been conducted. Are new surveys needed?
-

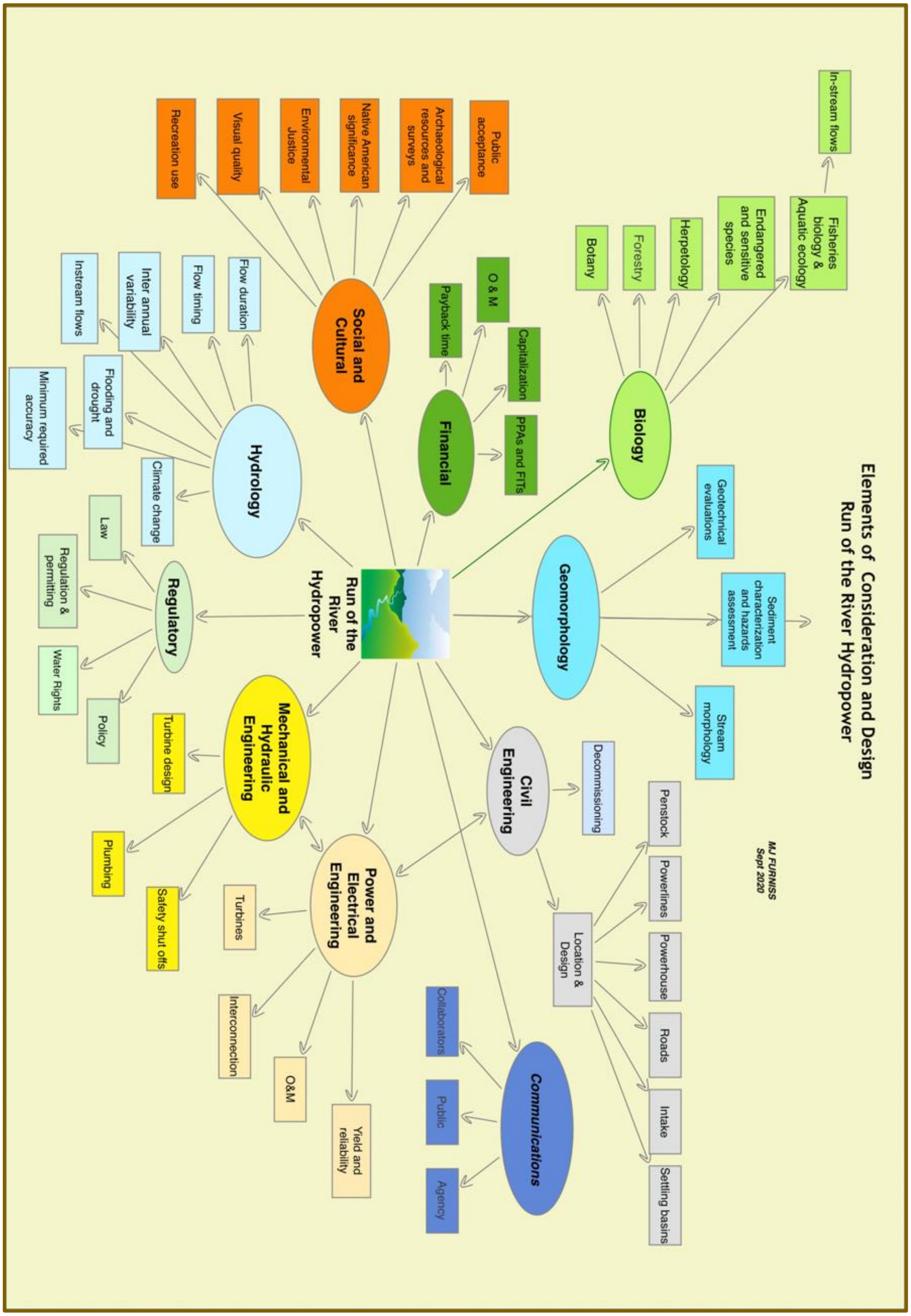


Figure 68. Elements of consideration and design in small run-of-the-river hydropower establishment.

Information gathering

For the purposes of assessing the potential for ROTR hydropower and its attendant impacts, risks, and benefits, two types of analysis are most critical: landslide potential and stream channel conditions. Detailed procedures for these two elements are therefore presented here:

Gathering information to address key questions and conducting watershed analysis

This crucial step consists of the compilation of information that is needed for the analysis. A wealth of data exists for most areas, but it usually is held in a variety of places and requires some effort to identify and acquire.

NOTE: This step will occur at various times, before, during and after the analysis. Although many information needs are guided by the issues and key questions, some basic information resources, such as aerial photos, can be anticipated prior to starting.

Information should be collected early on, if possible so that analysis is not unnecessarily delayed for data acquisition. With an early assembly of information, analytical opportunities presented by unusual data sets can be recognized soon enough to be useful. Previous steps might also require data compilation or collection, particularly stratification. The analysis can be expedited by gathering and organizing basic information well in advance of analysis.

Minimum Information Needs

Humboldt County lands tend to be relatively rich in data, and data acquisition and management are important components of modern federal land management. Within the next decade, most inventory information is now organized in computer-based geographic information systems (GIS), and such coverage is already available for most public and private lands.

Many analysis watersheds will encompass large tracts of private land for which basic data might not be available. Even on public land, existing coverage may be out of date or incomplete. Some types of missing information can be obtained rather easily, while other types require substantial work. When time is limited, desired data standards or coverage often must be compromised. Three strategies are commonly used in such a case:

- Complete coverage of the area is attained at a lower precision than ordinarily desired;
- Complete coverage of the area is attained for a subset of the usual attributes; or
- Representative subareas or strata are sampled and the data extrapolated.

Which approach is most useful depends on how the information is to be used. In some cases, data needs become apparent only during analysis, and rapid data acquisition techniques can also be applied at this point.

Rapid data acquisition often is carried out by stratifying the landscape into areas expected to have uniform distributions of the variable in question. Sampling within subareas can then be used to characterize each subarea with respect to the variable. This approach produces a generalized description of subareas rather than an inventory-style map, but this is sufficient for many Watershed Analysis applications.

Analysis of stereo aerial photography is central to many aspects of Watershed Analysis, and complete recent coverage of the watershed is very desirable. The photographic scale should be appropriate to the analysis being conducted. Often the most useful evidence for historic watershed conditions is aerial photographs, so the oldest available imagery should also be procured. Existing imagery is described in a catalog maintained by the U.S. Geological Survey Earth Science Information Center (ESIC) and available on microfiche at many university libraries and USGS offices. The primary source of USDA aerial photo products. The USDA-ASCS-APFO unit in Salt Lake City holds all the negative and flightline maps for Forest Resource Photography taken since 1950. They also hold negatives for some of the recent high-altitude photography. Aerial Photography that predates 1950 can, in some cases, be obtained through the National Archives in Alexandria, Virginia. Other sources of information include the Forest Service historic photographs collection held by the National Agriculture Library in Beltsville, Maryland.

Identifying Existing Information Sources

In addition to searching for specific types of information, it is often useful to ask likely sources what types of information they have. Ranger districts, Work Centers, and functional branches often have files or archives of relevant data. Regional universities should be contacted to identify relevant research in the area. Many academic departments maintain lists that show the location of past research projects carried out by their students and faculty. Many Tribes, state agencies, and large private landowners have monitoring programs that may produce relevant information.

Information from nearby watersheds can also be useful and should be identified. For example, stream-gauging records are more likely to be available for a nearby watershed than for the one being analyzed, but if geology, topography, and climate are similar, these records can be used to estimate the hydrologic characteristics of the analysis watershed.

In other cases, data from even further afield can be useful. For example, sedimentation records for reservoirs in the region may indicate characteristic magnitudes of erosion, and data from a national park or wilderness area may provide indication of process distribution or magnitude for low land-use intensities.

Detailed Landslide Analysis: Recommended Procedure.

Goals:

- Identify distribution patterns of landslides in the watershed.
- Identify land-use activities with which landslides are associated.

Strategy

Use aerial photographs to identify factors controlling debris flow distribution, and stratify the watershed according to the distribution of those factors. Use the air photos to assess the relative frequency of landslides in each stratification unit.

Procedure:

- Scan any existing landslide maps to observe the general pattern of debris flow distribution in the watershed. Read any existing reports on landsliding in the area.
- Scan a set of 1:12,000 (or similar scale) aerial photographs that post-date a major storm to observe the association of debris flows with topography, land-use activities: geology, vegetation, and channel order. Note the locations of exceptionally high debris flow densities and particularly large t1ows.
- Talk to geomorphologists and road maintenance personnel working in the area to get their view of debris flow distribution and their causes and the types of storms and antecedent conditions that generate them.
- Use the observed associations between debris flow occurrence and land characteristics to identify two or three characteristics that seem to most closely control debris flow distribution. These are likely to be topography, geology, channel order and land use, but they may include vegetation, elevation, or other characteristics.
- Stratify the watershed or channel network according to the identified characteristics. Land use is usually treated as a subdivision within a stratification unit since it often varies over relatively small distances and times. If the network itself is stratified then a stratification based on geology and channel order may be useful. Ideally ,there will be 3 to 5 different stratification units.
- Landslides are usually uncommon and evident enough after a major storm that their distribution over an entire watershed can be quickly mapped. If there are too many to conveniently map the entire population, select random areas within each stratum for sampling.
- Map and number the landslides in the sample area.
- For each cataloged debris flow tabulate the length. The topographic setting of the source slide, planar slope, inner gorge), association with land use (e.g., clearcut, road fill, grazing), topographic setting of the terminal deposit (right-angle confluence. acute-angle confluence, mid-reach), and perceived cause if evident (e.g., undercutting, road drainage).

- Measure the area of each land-use type and vegetation type in each sampled area and the length of roads present. If this information is not available from a GIS, linear features can be measured using methods such as that presented by Mark (1974), and areas by using point counts (Van der Plas and Tobi 1965).
- Landslides portrayed on existing landside maps can be tabulated by stratum similarly where appropriate data are available.
- Use the tabulated results to describe the association of landslides of various types with land-use activities or vegetation in each stratum.

Data needs:

1. Topographic maps (1:24,000)
2. A recent set of aerial photos (Ideal: 1:12,000 color or false-color IR)
3. Geologic map
4. Vegetation map
5. Rainfall map
6. Land-use map
7. Maps of landslide distribution, if available
8. Any existing analyses of landsliding in the area

Products:

- A map (1:24000) of stratification units is used to characterize landslides and the cataloged debris flow locations. Units can be portrayed as having high, medium, or low debris flow incidence.
- A tabulation of debris flow characteristics within each stratification unit, including size, the relative frequency for the period sampled, and association with topography, land use, vegetation, and cause.
- If analysis showed a relation between flow length and confluence geometry, indicate the portions of the watershed that are particularly likely to generate large landslides

Stream Channel Assessment: Recommended Procedure

Assumptions:

This qualitative analysis is done using office tools and information only, primarily aerial photographs, agency records, maps of soils, vegetation., and geology, and project response. An adequate set of aerial photographs (I: 12,000 or greater) and topographic maps (1:24,000) are available.

Not all channel reaches can be evaluated, so we focus on those that are most sensitive to watershed disturbance.

We need to focus on channel conditions that we can evaluate with the available data and methods, are sensitive to watershed disturbance and land use, and are important to beneficial uses.

The steps listed below comprise a general strategy. Each location has its own familiar methods of data analysis and interpretation and channel and landform classifications that can apply to specific steps.

Goals:

- Characterize channel forms and geomorphic processes directly affecting channels in the watershed.
- Identify reaches that would be sensitive to large variations in runoff, sediment supply, and large woody debris.
- Catalog historical disturbances, e.g., climatic events, wildfires, land use. flow diversions, stream cleaning that might have affected channels.
- Evaluate what effects these have had on sensitive reaches and how long it takes sensitive reaches to recover from disturbances.
- Evaluate effects of past land use on channels.

Procedure:

Compile background information and data:

- Obtain base map including channel network from Background Data/Topography module. • • -
- Review beneficial uses in channels and likely mechanisms for their impairment. Obtain initial indications of which watershed products (water. sediment, large woody debris, hear, nutrients toxics) are involved in processes that propagate disturbances in channels or are involved in direct effects (for example., dams and diversions).
- Map (or obtain from other analyses) hillslope and valley features (e.g., floodplains, terraces, estuaries, alluvial fans, streamside slides, earthflows. and debris-t1ow termini, lakes. dams. and terminal and recessional moraines) and background variables (for example, geology, soils. precipitation patterns, vegetative cover) that influence processes that affect channels.

Identify sensitive reaches:

- Using the largest-scale aerial photographs available, identify and map channel reaches of second-order or greater (depending on photo scale and canopy cover) with alluvial valley bottoms (floodplains and terraces). If no alluvial bottoms are apparent, map reaches with bars or those associated with stands of riparian-dependent species. Map and/or tabulate valley-bottom morphology and extent and channel pattern (for example, braided, meandering, bar-pool. plane-bed). Note the limits of your mapping that is obscured by riparian vegetation. (Locate access routes for field inspection.) If too many channels are obscured by vegetation or photo coverage is poor, conduct an overflight or use a drone to identify channel- and valley-bottom characteristics and be prepared to make observations on channel conditions that will be needed for later steps.
- Decide if you have time to evaluate the condition and causal factors for all sensitive channels. If you do, proceed immediately with the subsequent steps. If not, devise a scheme to stratify sensitive channels according to sub-basin characteristics, stream order, channel type, or other factors that strongly influence channel condition, select representative channels from each strata, and proceed with the following steps. Alternatively, stratify by sub-basin and conduct the analysis on sensitive reaches in each selected sub-basin. This may be advantageous if compiling data for hillslope characteristics and land use is overly time-consuming.

Evaluate past disturbances:

- Reconstruct flood history from nearby gaging stations and precipitation gages. (Evaluate relative peak flow magnitude for last runoff season.)
- From information obtained from hydrology, sediment, and vegetation analyses, map locations and annotate delivery of sediment to channels from landslides, wildfires, roads, cutting units, and other sources, relative magnitudes of changes in peak flow, and large woody debris loading.
- From other assessments, obtain evaluations of effects of land use on watershed processes that affect important disturbance mechanisms of channels.
- Review agency records and interview locals about direct human intervention in channels and riparian areas, grazing, splash dams, diversions, mining, stream cleaning, channelization, and so on. Enter this information on the base map and annotate.

Evaluate channel condition and relate to beneficial uses and land use:

- Identify sensitive reaches and examine their condition in an undisturbed sub-basin of the target watershed or in an undisturbed watershed of similar background characteristics nearby. Be aware that most types of disturbance (for example, wildfire, debris torrents, and landslides) are "natural," and their absence in the historic past does not necessarily typify a "natural" condition.
- From sequential air photos, evaluate changes in sensitive reaches (and in more resilient reaches, if evident).· In most cases, changes that would be

observable (depending on relative scales of channels and photos) would include channel widening, braiding, migration, formation and breakup of large debris jams, and removal of riparian vegetation. Document obvious cause/effect relationships.

- Compile existing on-the-ground information about sensitive reaches (e.g., stream surveys, habitat classifications, project-levee data), compare with aerial surveys, and refine interpretations of channel conditions.
- Interview locals about historic channel changes. (*Pay particular attention to features not observable from air photos, e.g., pool depth and frequency, substrate particle size, aggradation/degradation.)
- For each sensitive reach, tabulate information on channel and valley form, past and present condition (especially those that are critical to beneficial uses, direct disturbances, and type, proximity, timing, and severity of disturbances propagated from upstream. Note the resolution of channel change obscured by riparian vegetation. Locate access routes for field inspection. If too many channels are obscured by vegetation or photo coverage is poor, conduct an overflight or use a drone to identify channel- and valley-bottom characteristics and be prepared to make observations on channel condition that will be needed for later steps.
- Decide if you have time to evaluate the condition and causal factors for all sensitive channels. If you do, proceed immediately with the subsequent steps. If not, devise a scheme to stratify sensitive channels according to sub-basin characteristics. stream order, channel type, or other factors that strongly influence channel condition, select representative channels from each strata, and proceed with the following steps. Alternatively. stratify by sub-basin and conduct the analysis on sensitive reaches in each selected sub-basin. This may be advantageous if compiling data for hillslope characteristics and land use is very time-consuming..

Evaluate channel condition and relate to beneficial uses and land use:

- Identify sensitive reaches and examine their condition in an undisturbed sub-basin of the target watershed or in an undisturbed watershed of similar background characteristics nearby. Be aware that most types of disturbance (e.g., wildfire, debris torrents, and landslides) are "natural," and their absence in the historical past does not necessarily typify a "natural" condition.
- Compile existing on-the-ground information about sensitive reaches (e.g., stream surveys, habitat classifications, project-levee data), compare with aerial surveys, and refine interpretations of channel conditions.
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- For each sensitive reach, tabulate information on channel and valley form, past and present condition · (especially those that are critical to beneficial uses, direct disturbances. and type, proximity, timing, and severity of disturbances propagated from upstream. Note the resolution of channel change.

Watershed Power Profile for Small Hydropower Assessment:

Watershed Information Checklist, Template, and Data Dictionary

Primary Screen Data

- Available: - Land designation
- Capable: - Has power potential. Yes or No
- Suitable: - Can connect to grid, Has low environmental effects, no special case stoppers

Physical

- Watershed Name
- Lat. Long
- Area. Acres
- Shape/perimeter: Shape category and meters
- Relief/Steepness: Full elevation range in meters
- Confluence with: Name of adjacent watersheds of note
- Major roadways: Description of primary access roads
- Important adjacency: Description of notable adjacent features
- Other context: Description of other relevant context
- Images
- Primary contact
    a. Name(s) (
    b. Contact phone: Phone number with area code and dashes
    c. Contact email

Crucial missing data checklist

Ownership

- Federal: Image of land ownership
- State: Image of land ownership
- Private: Image of land ownership
- Ownership mix description: General description

Biological

- Anadromy: Presence of anadromous species, species list

- Upstream Limit: Distance from mouth to upstream limit
- Species: Species present if known
- Resident fish: Presence and species
- Aquatic organisms other than fish: Presence of non-fish aquatic organisms and species list
- Stream survey availability: Stream survey available
- Significant Riparian areas: Valley bottoms description
- Terrestrial organisms: Mammals, Herps, Plants. Listing of known organism presence
- Listed Species: Listed species, present or suspected
- Restoration opportunities: Description

Hydrologic

- Mean Annual Precipitation: Mean Annual Precipitation in inches
- Flow Duration Curve: Flow duration curve
- Average annual hydrograph: Average hydrograph
- Soils hydrologic functioning interpretation of soils data: Description, texture, permeability, infiltration capacity
- Temperature monitoring: Description and contact
- Streamflow Gaging: Nearest gage with >10-year record. Data tables
- Water pollution: Other impairment(s): Description. Pollutants present or suspected
- Listed for water quality: Tributary to listed waterbody? Listed or tributary to listed

Socio-Cultural

- Native significance: Description
- Native use: Description
- Recreation use: Description
- Residential occupancy: Description
- Archaeological resources: Description
- Visual qualities and risks: Description
- Environmental justice analysis: Description
- Public acceptance markers: Description

Water Rights

- Type of right: Appropriative or Riparian
- Holder of right: Who holds the water right

- Quantity: Quantity, in CFS by season
- Other extant rights upstream or on diverted reach + above 3

Administrative

- Forest Plan: Description and link to maps
- Closures: Description
- Statutory and Regulatory Requirements: Description
- Roads Analysis Process Conclusions: Description
- Timber management status: Description
- Special uses and other easements: Description

Hydropower opportunities

- Transmission line proximity: Distance to
- Transmission line capacity: MW unused
- Distribution line proximity: Distance to
- Distribution line proximity: Distance to
- Distribution line Loop or Terminal: Distribution line type
- Proximity to load: Approx. distance to primary loads
- Local non-grid-connected potentials: Description
- Go/No go/Not certain: Description and reasons
- Candidate for local NGC provision: Description
- Road proximities to diversion points: Description
- Possible diversion points: Description
- Possible powerplant locations: Description
- Penstock routing options: Description
- Site Hydrology: Average flow in DJFM
- Head (HEAD): Elevation difference in meters
- Penstock run length: Length in meters
- Power generation potential: Estimated MW in DJFM
- Costs
- Potential Revenue: Potential monthly gross revenue

Best Practices in Run-of-the-River Hydropower

1. A robust, interdisciplinary environmental assessment is conducted to predict impacts so they can be avoided or mitigated to the full extent possible. The regionally-specific assessment references all relevant documents, guidance, standards, and best practices (including Best Management Practices) for the area and activities under consideration.
2. The project is located where adding roads, power lines, human activity, and a river diversion does not significantly compromise existing refuge areas, species of concern, local Tribal and community priorities, established recreational opportunities, ecosystem services, or other values.
3. Cumulative effects are seriously considered, and the project does not create an unacceptable incremental impact, including effects cumulative to other power projects, water diversions, forestry, mining, agriculture, and so on.
4. Affected Tribal communities and other stakeholders are contacted early enough in the planning process to become well informed and are given ample opportunity to provide meaningful input to the project. Their input has been taken seriously and incorporated where appropriate.
5. Potential risks to species and ecosystems are identified. Appropriate surveys establish animal and plant status and potential threats, and impacts have been avoided or mitigated.
6. Adequate geotechnical evaluation is conducted in locating roads, penstock, powerhouse, and transmission lines. Hazards are mapped, and risks are assessed.
7. Conditions and criteria to mitigate impacts associated with ongoing operations are established, including low-flow thresholds in the diversion reach to support local fish populations and other aquatic organisms.
8. Input from agencies and stakeholders with responsibility for fish habitat and populations is sought, fully considered, and any concerns regarding minimum flows, aquatic habitat requirements, and mitigation have been addressed and incorporated.
9. The headpond, weir, and intake associated with the diversion, as well as the tailrace, are designed to minimize impacts, including those affecting fish migration, sediment movement, and flooding. Intakes are configured to exclude fish and other organisms from the diverted streamflows.
10. In siting and planning roads and power lines , individual and cumulative impacts on wildlife habitat and plant and animal species of concern are considered and deemed acceptable or in need of mitigation . Road location, design, use, maintenance, and decommissioning are consistent with protecting water quality and soil health.
11. Post-construction monitoring occurs with an established frequency and reporting process and includes provisions for modifying plant operations when unacceptable risks or impacts are discovered.
12. Systems are effectively decommissioned when no longer used. Disturbed sites are restored and are stable and productive without maintenance.

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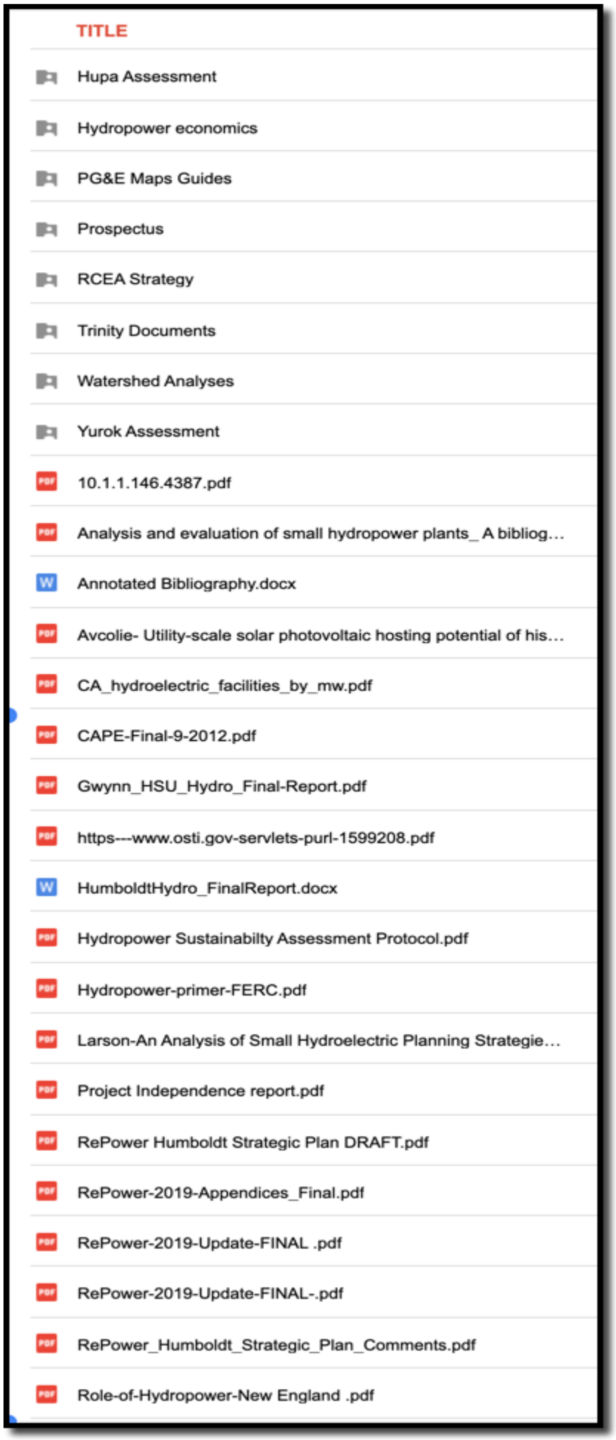
Information Archives

Online archive ➔ https://sites.google.com/view/smallhydro-team/home



Key Documents Archive

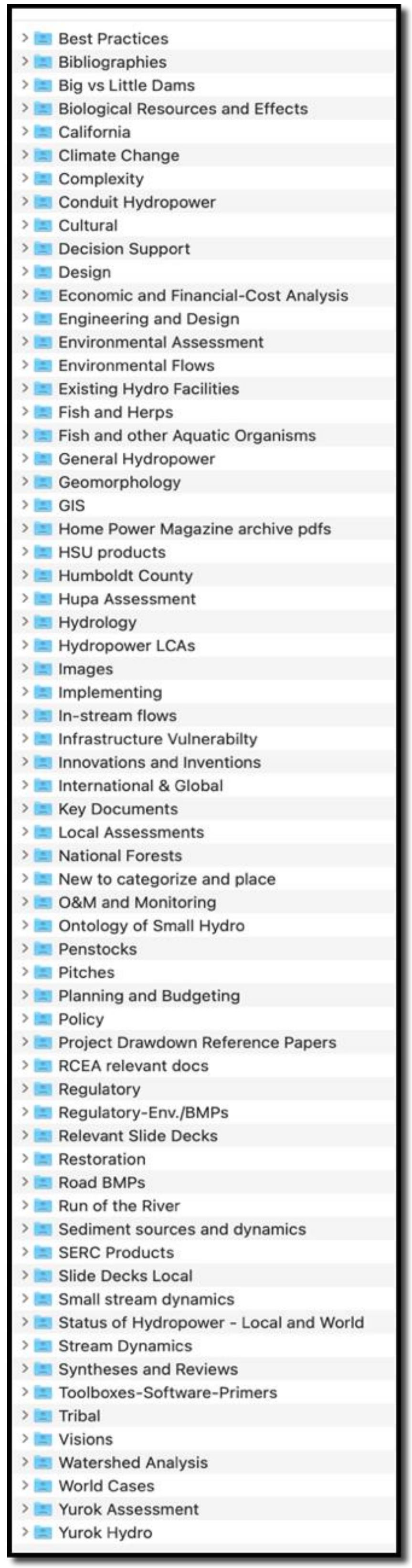


Figure 69. Information archive directories.

References archive directories