Report

Teanaway Solar Reserve Hydrologic Analysis Kittitas County, Washington

Prepared for

Teanaway Solar Reserve, LLC

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Prepared by

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1.0 Introduction

At the request of Teanaway Solar Reserve, LLC (TSR) a hydrologic analysis for the proposed project site has been completed and is described in this memorandum. Background information was collected on the existing site conditions and used to create a pre-development model using the U.S. Army Corps of Engineers HEC-HMS 3.1.0 software. A model was also created to simulate the proposed site conditions. The models were then used to determine pre- and post-development peak rainfall runoff rates and volumes for 2-, 10-, and 100-year 6-hour storm events and a 10-year, 24-hour storm event. The runoff rates were then compared to determine the hydrologic impact of the development.

2.0 Background

The proposed 982-acre project site is located approximately 4 miles northeast of Cle Elum, Washington, in Township 20N, Range 16E, within Sections 22, 23, and 27 (see Figure 1 in Appendix A for the site location). This site is located on the eastern slopes of the Cascade Mountains on Cle Elum Ridge, which runs generally east to west at elevations ranging from approximately 2,200 to 2,600 feet. The Teanaway River is approximately 1 mile to the northeast of Cle Elum Ridge. The site is accessed from Highway 970 by way of county roads such as Red Bridge Road, private roads such as Loping Lane, and Wiehl Road, which is a dedicated public road that is maintained privately and not by the county. A description of the existing conditions is provided below.

2.1 Major Watersheds

Rainfall runoff from the proposed project site flows down the ridge through unnamed streams and eventually discharges to the Teanaway River. The Teanaway River is located in the Yakima River Basin and flows to the Yakima River. At its confluence with the Yakima River, the Teanaway River has a drainage area of 207 square miles. The peak 100-year flow as listed in the Flood Insurance Study (FIS) produced by the Federal Emergency Management Agency (FEMA) in 1981 is 7,350 cubic feet per second (cfs) at its confluence with the Yakima River.

Flood Insurance Rate Maps (FIRMs) from FEMA were used to determine the areas of special flood hazard near the proposed project site. The most recent available mapping comes from the 1981 FIS (map numbers 5300950254B, 5300950258B, 5300950262B, and 5300950266B). The data provided by the FIRMs only show the extent of the 100-year floodplain of the Teanaway River. The Teanaway River floodplain is located just downstream of the proposed site. See Figure 2 in Appendix A for a map of the 100-year floodplain in the vicinity of the project.

2.1.1 January 2009 Flooding Event

A major flood event occurred in January 2009 downstream of the proposed project site when heavy rain in the mountains and unseasonably warm temperatures turned the deep snow pack into flood waters. The flooding caused landslides and affected several landowners at the base of the ridge in the Teanaway River Valley. This event raised public and agency concerns pertaining to the potential hydrologic impacts associated with the development of the proposed Teanaway Solar Reserve Project. A letter written by GeoEngineers, Inc. on October 5, 2009, suggested there is some evidence that the cause of this flood event may have been more related to anthropogenic causes rather than hydrologic issues on the proposed project site (see Appendix B).

Drainages from the project site have been characterized as ephemeral, vegetated swales. A field reconnaissance completed by a professional hydrologist from GeoEngineers after the flooding event showed the drainages that emanate from the project site were in stable condition. No excessive erosion, lateral shifting or incision was evident in the drainages around the project site. The vegetation in the drainages helps reduce the velocity and erosional forces of the water as it runs off hill slopes and flows into concentrated areas.

Interviews with local residents were also conducted as a part of the field reconnaissance. One resident, a Mr. Jesse Geiger, a homeowner in the area, told GeoEngineers personnel that another area resident had used excavating equipment to trench into and disturb the streambed of an unnamed small drainage in an effort to reroute flows into irrigation pipes and ultimately into an existing delivery system. According to Mr. Geiger, the channel was never armored or re-vegetated after the soil disturbance and channel realignment. As a result, high flows in January 2009 destabilized the unprotected channel and breached the weak soil dam that had been erected adjacent to Red Bridge Road. The condition of the channel upstream of the disturbed area was not subject to erosion or damage; rather, only the disturbed reach was destabilized, causing a debris torrent to spill into the road and the subsequent flooding and damage to the road. Field observations of the drainage correlate with the description of events recounted by area residents, as evidenced by comparing the condition of this drainage to the drainage adjacent to Wiehl Road.

2.2 Site-Specific Drainage Basins

There are two major drainage basins on the proposed project site. These drainage basins will be referred to as the South drainage basin and the North drainage basin for the purposes of this report. Figure 3 in Appendix A is a map showing the location of the drainage basins on the proposed project site. Multiple drainage paths leave the site. Flow rates are comparative, but don’t provide detail of flow distribution by sub-basin. Drainage basins were delineated for this analysis to assess the impact the project is expected to have on major receiving waters. A more detailed analysis of the small, natural drainage basins on the site will be completed during the design phase of the project.

The South drainage basin has an area of 723 acres and covers a majority of the proposed site. Rainfall runoff from this drainage basin generally flows south to the base of the ridge, where it then flows east along the north side of Red Bridge Road eventually discharging to the Teanaway River.

The North drainage basin has an area of 259 acres and is located in the northeast corner of the proposed project site with a few small areas along the northern border of the project site. Rainfall runoff from the North drainage basin flows to the north from the site and eventually discharges into the Teanaway River.

3.0 Model Methodology

The selected methodology chosen for this analysis is based on the Natural Resources Conservation Service (NRCS) Technical Release-55 (TR-55), which presents procedures to calculate stormwater runoff volumes and peak rates of discharge. To determine runoff from storm rainfall, this methodology uses a runoff curve number (CN) method. Determination of the CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, and hydrologic condition.

The following subsections describe the existing and proposed conditions for the site that were used to create a model of the drainage basins.

3.1 Existing Conditions

3.1.1 Impervious Cover

Currently, no impervious area exists on the project site. The area is undeveloped ponderosa pine forest with dirt roadways.

3.1.2 Rain-on-Snow Events

A rain-on-snow event is an occurrence when rain falls onto frozen or saturated ground with a pre-existing snow pack. The rain can cause the snow to melt, and with the frozen or saturated ground acting like an impervious surface, large volumes of runoff are generated. Rain-on-snow events pose a significant flood hazard, such as occurred in 2009.

The magnitude of runoff from a rain-on-snow event is not expected to significantly increase as a result of the construction of the project. Due to limited infiltration capacity during a rain-on-snow event, the site would be expected to generate a similar volume of runoff at build-out as would be generated with the current site conditions.

3.1.3 Soil Infiltration and Drainage Characteristics

Soil types for the project site were determined using the NRCS web soil survey application. There are four types of soil located at the proposed project site: Nard ashy loam, 5 to 25 percent slopes; Nard ashy loam, 25 to 45 percent slopes; Teanaway loam, 3 to 10 percent slopes; and Teanaway loam, 25 to 50 percent slopes. All four soil types are in hydrologic soil group C. Soils in hydrologic soil group C have slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission, thus producing a moderate amount of rainfall runoff.

3.1.4 Slopes

Slopes in the South drainage basin were estimated to range between 3 and 26 percent. Slopes in the North drainage basin were estimated to range between 3 and 31 percent. Topographic maps were used to calculate the time of concentration for each basin. Time of concentration calculations are provided in Appendix C.

3.1.5 Vegetated Cover

Per Kittitas County zoning, the site is currently zoned Forest and Range (F&R). Since the early 1900s, this site has been repeatedly selectively logged. Harvests have occurred in the 1920s, 1950s, 1980s, and 2000s. Pre-commercial thinning occurred in the decades between logging. Prior to 1900, the site had a fire frequency of 9 to 12 years, indicating that a healthy understory and small trees did not exist, creating a park-like stand of larger trees that were fire resistant to low-intensity, periodic fires. The site was most recently selectively logged in 2001, and existing site vegetation consists of low grasses, shrubs, and trees. Shrubs and riparian communities are predominantly snowberry and rose bushes. Herbaceous plant communities are predominantly lupine, yarrow, arrowleaf balsamroot, and various grass species. Wetland plant communities are dominated by rushes sedges, wild onion, and various other grass species.

Table 1 is a summary of CNs based on hydrologic soil group and vegetative cover type from *Technical Release 55: Urban Hydrology for Small Watersheds* (NRCS, 1986). The woods-grass combination was used to determine the existing curve number for the site. The existing site's CN of 72 was computed for an area with 50 percent woods and 50 percent grass (pasture) cover in good condition.

TABLE 1
Runoff Curve Numbers (TR-55)

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range-continuous forage for grazing [a]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Woods- grass combination (orchard or tree farm) [b]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods [c]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[d]	55	70	77

[a] Poor: <50% ground cover
Fair: 50 to 75% ground cover
Good: >75% ground cover

[b] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[c] Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

[d] Actual curve number is less than 30; use CN=30 for runoff computations.

3.2 Proposed Conditions

The purpose of the proposed project is to generate up to 75 direct current megawatts (MWdc) of photovoltaic (PV) solar energy for distribution to utilities and communities seeking to optimize their renewable and sustainable energy sources. The proposed project area consists of 982 acres. Based on site surveys, the project will utilize approximately 477 acres within the proposed project area. Solar arrays will be placed on approximately 399 acres. The remaining acres are currently undeveloped open space, which will be preserved as part of the wildlife mitigation plan for the project. The proposed project will consist of the following key components:

- Solar modules
- Power inverter enclosures
- Power transformers
- Underground electrical conductors
- Electrical substation and switchyard
- Operations and maintenance (O&M) building supervisory control and data acquisition (SCADA) system
- Overhead interconnection transmission line
- Access and maintenance roads

3.2.1 Impervious Cover

An increase in impervious area on the proposed project site is expected to be generated by the following: solar modules, power inverter enclosures, and the O&M facility. Other project components that include maintenance and access roads, a 6-acre graveled substation, etc. are accounted for in the change in CN. A conceptual site plan and corresponding areas were provided to CH2M HILL by Studio GREENE. These areas were used to determine the impervious area for the site. Impervious surfaces and their corresponding areas are shown in Table 2.

TABLE 2
Project Impervious Surfaces and Areas

Impervious Surface		Area (SF)	Area (ac)
Array Fields			
	Solar Modules	12,665	0.291
	Field Inverters	6,400	0.147
	Field Transformers	3,840	0.088
BPA Substation			
	Concrete Pads	23,000	0.528
	BPA Control House	1,800	0.041
	Tower and Transmission Pole	100	0.002
	BPA Switchgear Building	1,080	0.025
Operations and Maintenance Building		1,000	0.023
Transmission Structure		1,000	0.023

Notes:
SF = square feet
ac = acres

An assumption for calculating the impervious area created by solar panels was used for this analysis. The impervious area created by a solar panel was considered to be the area of the foundation of the panels, not the panels themselves. While solar panels do generate concentrated runoff on the panel surfaces, the panels are considered a disconnected impervious surface because the infiltration capability of the soil is only affected by the foundation. Flow spreaders can be used to distribute the concentrated flow from the panels evenly over the ground surface.

Because impervious area from the site is disconnected, the resulting impacts calculated in this analysis are conservative. A more detailed analysis of the small, natural drainage basins on the site that will be completed during the design phase of the project may reveal lesser impacts. The detailed analysis completed during design will be used to select the appropriate stormwater Best Management Practice (BMP) that is best-suited to protect each drainageway and minimize the impacts of the project to the maximum extent practicable.

3.2.2 Vegetated Cover

The construction of the proposed solar reserve would result in a reduction of the ponderosa pine forest canopy. Project elements that will affect the vegetated cover are shown in Table 3. The CN for the solar array field is based on a CN for grassland in fair condition. Areas were based on a conceptual site plan and corresponding areas that were provided to CH2M HILL by Studio GREENE.

TABLE 3
Project Elements Creating a Change in Vegetated Cover

Project Element	Area (SF)	Area (ac)	Curve Number Used
Roads (Graveled)			
Existing Road Improvements	450,200	10.3	89
New Roads	301,200	6.91	89
BPA Substation			
Graveled Area	90,0000	2.07	89
Roads	35,000	0.803	89
Array Fields			
Solar Array Field	17,380,440	399	79

4.0 Climate

The NRCS classifies storms in the project vicinity as being Type 1A. Total precipitation amounts in the vicinity of the project were taken from National Oceanic and Atmospheric Administration (NOAA) Atlas 2 and increased by 16 percent per guidance provided by the Eastern Washington Stormwater Management Manual. The storm depths used in the analysis are described in Table 4.

TABLE 4
Total Precipitation Storm Events

Storm Event	Precipitation (inches)
2-year, 6-hour	1.04
10-year, 6-hour	1.51
10-year, 24-hour	2.90
100-year, 6-hour	2.03

Data gathered from the NRCS Temperature and Precipitation Summary (TAPS) station WA1504 show the climate in Cle Elum consists of mild summers and cold winters. Temperatures range from an average January minimum of 21.2 degrees Fahrenheit (ºF) to an average August maximum of 80.0ºF. The average annual precipitation is 23.09 inches, with the majority occurring from November through March. Table 5 presents average monthly precipitation and snowfall data for Cle Elum.

TABLE 5
Average Annual Precipitation, Cle Elum, Washington (1971 - 2000)

Month	Average Precipitation (in)	Average Total Snowfall (in)
January	3.80	24.6
February	2.51	14.7
March	1.67	6.2
April	1.16	0.8
May	0.93	0.2
June	0.96	0.0
July	0.46	0.0
August	0.58	0.0
September	0.93	0.0
October	1.76	0.5
November	3.90	12.6
December	4.43	27.0
Annual Average	**23.09**	**86.5**

5.0 Drainage Basin Modeling

The background information described above was used to create basin models using the U.S. Army Corps of Engineers Hydrologic Modeling System HEC-HMS 3.1.0. This software was used to determine the pre- and post- development runoff rates and volumes from the project site for the 2-, 10-, and 100-year, 6-hour storm events to determine the impacts the development will have on hydrology of the two drainage basins on the site and the surrounding area. A 10-year, 24-hour storm was also used to illustrate the effect of a longer duration storm event.

The 2-, 10-, and 100-year, 6-hour storm events were used with the NRCS storm distribution Type 1A to calculate the runoff from the drainage basins for the existing and proposed conditions in the North and South drainage basins. A 10-year, 24-hour storm was also used to illustrate the effect of a longer duration storm event. A summary of the areas and curve numbers used in the model are shown in Table 6. The peak rainfall runoff rates and volumes for the existing and proposed conditions are shown in Tables 7 and 8, respectively.

TABLE 6
Areas and Curve Numbers used in the HEC-HMS Model

Conditions	Drainage Basin	Impervious Area (ac)	Impervious Area Curve Number	Pervious Area (ac)	Pervious Area Curve Number [a]
Existing Conditions					
	North	0	98	259	72
	South	0	98	723	72
Proposed Conditions					
	North	0.06	98	258.94	73
	South	1.11	98	721.89	76

[a] Values of proposed conditions are weighted per values shown in Table 3.

TABLE 7
Existing Site Rainfall Runoff and Volume Calculations from HEC-HMS Model

Drainage Basin	Storm	Peak Discharge (cfs)	Total Runoff Volume (cf)
North Drainage Basin	2-year, 6-hour Storm	0.60	18,803
	10-year, 6-hour Storm	2.50	103,419
	10-year, 24-hour Storm	21.80	695,726
	100-year, 6-hour Storm	5.40	282,051
South Drainage Basin	2-year, 6-hour Storm	1.70	52,490
	10-year, 6-hour Storm	6.90	288,694
	10-year, 24-hour Storm	56.00	1,915,878
	100-year, 6-hour Storm	15.00	787,347

TABLE 8
Proposed Site Rainfall Runoff and Volume Calculations from HEC-HMS Model

Drainage Basin	Storm	Peak Discharge (cfs)	Total Runoff Volume (cf)
North Drainage Basin	2-year, 6-hour Storm	0.80	18,803
	10-year, 6-hour Storm	2.70	122,222
	10-year, 24-hour Storm	24.80	742,734
	100-year, 6-hour Storm	5.70	310,256
South Drainage Basin	2-year, 6-hour Storm	3.30	131,225
	10-year, 6-hour Storm	9.80	498,653
	10-year, 24-hour Storm	89.60	2,440,776
	100-year, 6-hour Storm	24.90	1,102,286

The existing site rainfall runoff and volume calculations were used as a baseline for determining the increase in rainfall runoff and volume expected as a result of the construction of the proposed project.

Rainfall runoff and volume are expected to increase in both the North and South drainage basins. Due to the small amount of construction in the North drainage basin, peak rainfall runoff rates and volumes are expected to increase on a much smaller scale when compared to the increases in the South drainage basin. See Table 9 for a summary of the increase by drainage basin.

TABLE 9
Summary of Peak Discharge and Volume Increases by Basin

Drainage Basin	Storm	Increase in Peak Discharge (cfs)	Increase in Total Runoff Volume (cf)
North Drainage Basin	2-year, 6-hour Storm	0.20	0
	10-year, 6-hour Storm	0.20	18,803
	10-year, 24-hour Storm	3.00	47,009
	100-year, 6-hour Storm	0.30	28,205
South Drainage Basin	2-year, 6-hour Storm	1.60	78,735
	10-year, 6-hour Storm	2.90	209,959
	10-year, 24-hour Storm	33.60	524,898
	100-year, 6-hour Storm	9.90	314,939

The largest increase in peak discharge for the 6-hour storm events occurred during the 100-year storm in the South drainage basin (9.90 cfs). At the point of discharge to the Teanaway River, the total contributing drainage basin area is 195 square miles. Using a direct proportion of drainage basin area to flow (FEMA data reports recorded the total size of the drainage basin to be 207 square miles and have a 100-year discharge of 7,350 cfs), the flow in the Teanaway River at the discharge point is expected to be approximately 6,924 cfs during a 100-year storm event. An increase of 9.90 cfs results in a 0.14 percent increase in flow during the 100-year storm event. From a flooding standpoint, this increase is determined to be negligible when compared to the contribution of the entire watershed at the point of discharge from the project site.

For the 10-year, 24-hour duration storm, the largest increase in peak discharge occurred in the South drainage basin (33.60 cfs). Again, using a direct proportion of drainage basin area to flow (FEMA data reports recorded the total size of the drainage basin to be 207 square miles and have a 10-year discharge of 5,300 cfs), the flow in the Teanaway River at the discharge point is expected to be approximately 4,993 cfs during a 10-year storm event. An increase of 33.60 cfs results in a 0.67 percent increase in flow during the 10-year storm event. From a flooding standpoint, this increase is determined to be negligible when compared to the contribution of the entire watershed at the point of discharge from the project site.

Increases in rainfall runoff rates and volumes experienced by the onsite natural drainages will be managed using infiltration to the maximum extent practicable and stormwater BMPs will also be implemented if necessary.

5.1 Stormwater BMPs

Stormwater BMPs will be chosen based on site-specific conditions during design and on their ability to function with and protect the natural watershed. Specific BMPs will be outlined in the National Pollutant Discharge Elimination System (NPDES) permit and the Stormwater Pollution Prevention Plan (SWPPP) that will be submitted to the Washington State Department of Ecology prior to construction of the project.

There are three basic types of stormwater BMPs: source control, water quality treatment, and flow control. Source control BMPs are measures that are directed toward pollutant-generating activities that will help prevent pollution or other adverse effects of stormwater. Water quality treatment BMPs remove pollutants from stormwater by filtration, biological uptake, adsorption, and gravity settling. The need for water quality BMPs is based on the types of pollutants generated by a project and the vulnerability of the receiving waters to the pollutants of concern. Flow control BMPs control the rate, frequency, and/or flow duration of stormwater runoff through infiltration, evaporation, or detention facilities with infiltration being the preferred method wherever possible. The concept of detention is to collect runoff from a developed area and release it at a slower rate than it would typically run off the site.

Stormwater management involves careful application of source controls, site design principles, and construction techniques in order to protect a watershed. Some potential stormwater BMPs for the site include, but are not limited to, infiltration ponds; infiltration trenches; infiltration swales; large, extended-detention wet ponds; and extended-detention wetlands. Facilities will be designed in accordance with the standards outlined in the Eastern Washington Stormwater Management Manual in order to protect water quality in the receiving waters and reduce the impacts of development on the watershed. Guidance on stormwater BMPs and Low Impact Development (LID) were provided by the Washington Department of Ecology; however, they were not included in the list of facilities above. Stormwater BMPs provided in the Eastern Washington Stormwater Management Manual were more applicable to the rural setting of the project and also account for location and climate in the project area.

6.0 Construction- and Operation- Related Stormwater Impacts

This section addresses specific concerns related to the stormwater impacts from construction and operation of the Teanaway Solar Reserve facility.

6.1 Teanaway River Total Maximum Daily Loads

Section 303(d) of the federal Clean Water Act requires states to periodically prepare a list of all surface waters in the state whose beneficial uses are impaired by pollutants. Waters placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs). TMDLs are used to set and implement standards to clean up the polluted waters. TMDLs identify the maximum amount of a pollutant allowed to be released into a waterbody so as not to impair uses of the water, and allocate that amount among various sources.

The Teanaway River has a TMDL for temperature. From July through September stream temperatures in the Teanaway River basin often exceed Washington State water quality standards. Temperature increases in streams can occur for a variety of reasons. Some examples include the loss of vegetation along streams that used to shade the water, impervious area that causes rainfall to increase in temperature before it runs off into a stream, and sediment transport that results in reduced channel width-to-depth ratios.

The Teanaway River is also included in the Upper Yakima Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL. Suspended sediments and turbidity are caused by erosion of earthen roads and stream banks, and by the discharge of agricultural return flows to the river that are full of sediment. Organochlorine pesticides are also transported by suspended sediment.

In accordance with the standards outlined in the Teanaway Temperature TMDL and Upper Yakima Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL and the stormwater requirements for Eastern Washington, BMPs will be implemented to prevent soil erosion and any downstream turbidity during construction and operation of the Teanaway Solar Reserve facilities. These BMPs will be outlined in the National Pollutant Discharge Elimination System (NPDES) permit and the Stormwater Pollution Prevention Plan (SWPPP) that will be submitted to the Washington State Department of Ecology prior to construction of the project. The project is highly unlikely to increase temperature in the Teanaway River due to the disconnected nature of impervious area, flow paths on the site, and distance from the project site to its discharge into the Teanaway River.

6.2 Vegetation Management

Routine vegetation management will be required to ensure vegetation growth does not interfere with the operation of any equipment on the Teanaway Solar Reserve project site. Woody vegetation removal and ongoing management will be necessary to prevent interference with solar arrays. Measures will be implemented to protect herbaceous plant cover on site, including under solar arrays. These measures include ongoing vegetation removal that will be limited to woody vegetation that could potentially interfere with safe and effective project operations and preventing non-native plant invasion into the project area.

For a list of BMPs that will be implemented during construction and operation of the Teanaway Solar Reserve, please refer to Attachment G, *Vegetation Management Plan*. The use of herbicides in accordance with the BMPs and requirements of the local, state, and federal jurisdictions is not expected to affect stormwater quality in the project area.

6.3 Improvements to Loping Lane and Wiehl Road

The Teanaway Solar Reserve site will be accessed via Kittitas County and private roads that interconnect with Highway 970. Loping Lane, a private road, and Wiehl Road, a privately maintained public road, will be used to access the site during construction and operation of the project. Currently, Loping Lane and Wiehl Road generally consist of gravel and dirt; the portions of Loping Lane and Wiehl Road that will be used during construction and operation will need to be improved pursuant to County requirements.

With several drainages in close proximity to the roads, stormwater drainage infrastructure will be necessary if Loping Lane and Wiehl Road are improved. All drainage improvements will be designed and constructed in accordance with the Eastern Washington Stormwater Management Manual and the requirements of local, state, and federal jurisdictions. BMPs will also be implemented to prevent soil erosion and any downstream turbidity during construction and operation.

7.0 Summary

Background information was collected on the existing and proposed site conditions for the Teanaway Solar Reserve Project and used to create models of the existing and proposed conditions for the two drainage basins on the project site. The NRCS *Technical Release 55* (*TR-55*) methodology was the selected method for the analysis to determine the increase in rainfall runoff and volume from the project site. To determine runoff from storm rainfall, this methodology uses a runoff CN method. Determination of the CN depends on the watershed's soil and cover conditions, which the model represents as hydrologic soil group, cover type, and hydrologic condition.

Once all of the inputs were determined for the existing and proposed conditions in each drainage basin, models were built using the U.S. Army Corps of Engineers HEC-HMS 3.1.0 software. The models were then used to determine pre- and post-development peak rainfall runoff rates and volumes for 2-, 10-, and 100-year 6-hour and 10-year, 24-hour storm events. Peak runoff rates and volumes are expected to increase minimally as a result of the development of the site. The increases are negligible when compared to the contribution of the entire watershed at the point of discharge to the Teanaway River. Mitigation of the hydrologic impacts from the increased runoff rates and volumes for local drainages will be mitigated through infiltration to the maximum extent practicable and stormwater BMPs will be implemented if necessary. These measures will be designed and constructed in compliance with the Eastern Washington Stormwater Management Manual.

Rain-on-snow events pose a significant flood hazard, however the magnitude of runoff from a rain-on-snow event is not expected to significantly increase as a result of the construction of the project. Specific concerns related to the stormwater impacts from construction and operation of the Teanaway Solar Reserve facility were addressed in regards to the Teanaway Temperature and Upper Yakima Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDLs and the improvements to Loping Lane and Wiehl Road. Vegetation management through the use of Department of Ecology-approved herbicides is not expected to affect stormwater quality. All stormwater drainage improvements associated with the Teanaway Solar Reserve project will be designed and constructed in accordance with the Eastern Washington Stormwater Management Manual and the requirements of local, state, and federal jurisdictions to reduce the impacts of the project to the maximum extent practicable.

8.0 References

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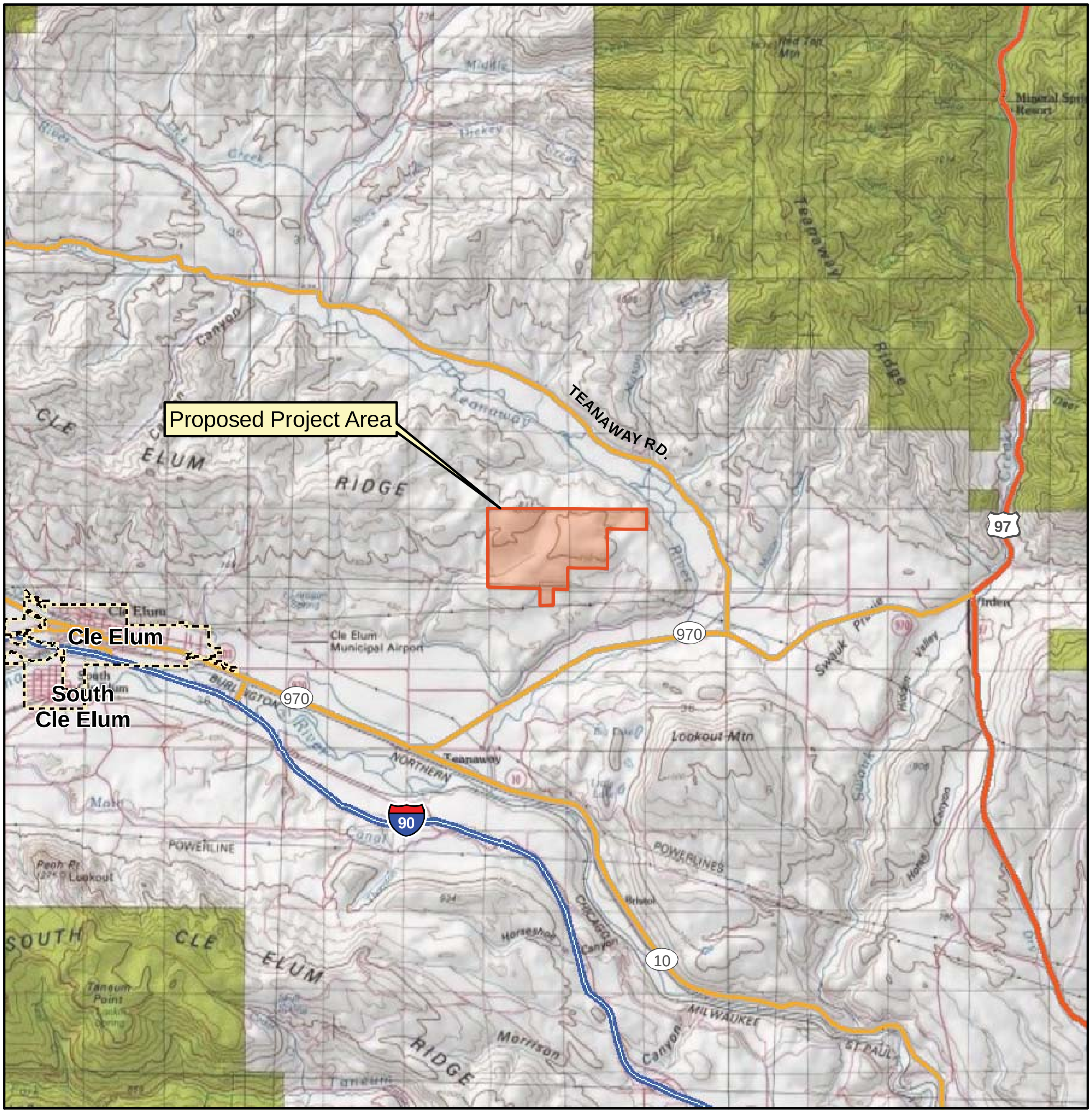
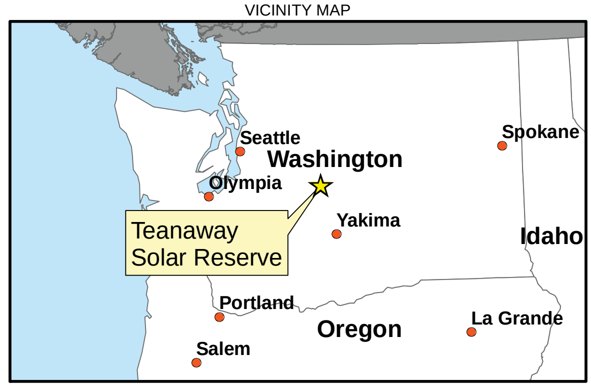
APPENDIX A

Figures



LEGEND
Proposed Project Area
City Boundary
Interstate
Highway
Major Road

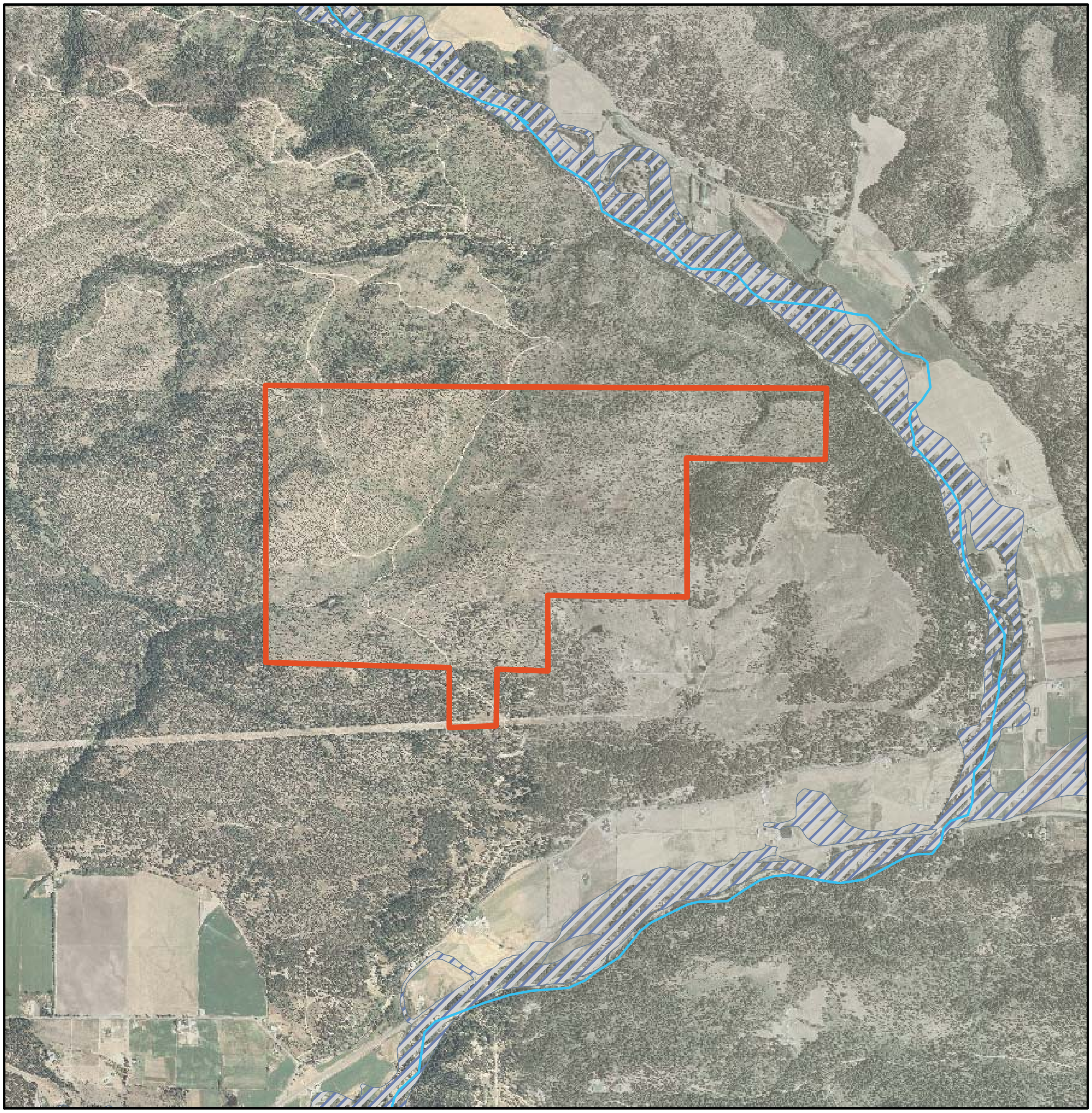
VICINITY MAP



Note:
1. USGS 100K Quadrangle: Wenatchee.

0 1 2
Miles
N

FIGURE 1
Vicinity Map
Hydrologic Analysis
Teanaway Solar Reserve
Kittitas County, Washington



LEGEND

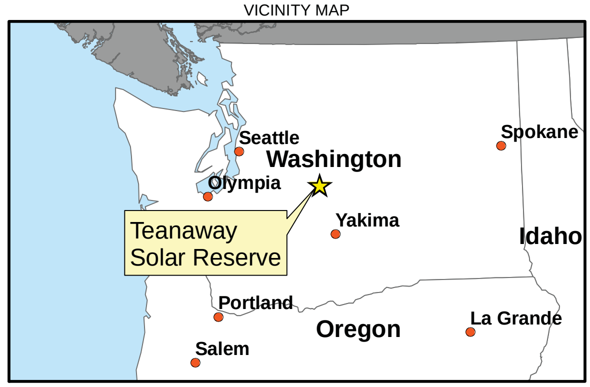
Shoreline Management Act Stream
(450 feet from proposed project area)

FEMA 100-year Flood Zone

Proposed Project Area

Notes:
1. Flood Data: Federal Emergency Management Agency Flood Insurance Rate Map.
2. Stream Data: Washington Department of Ecology.
3. Aerial Imagery: 2006 1m NAIP.

VICINITY MAP

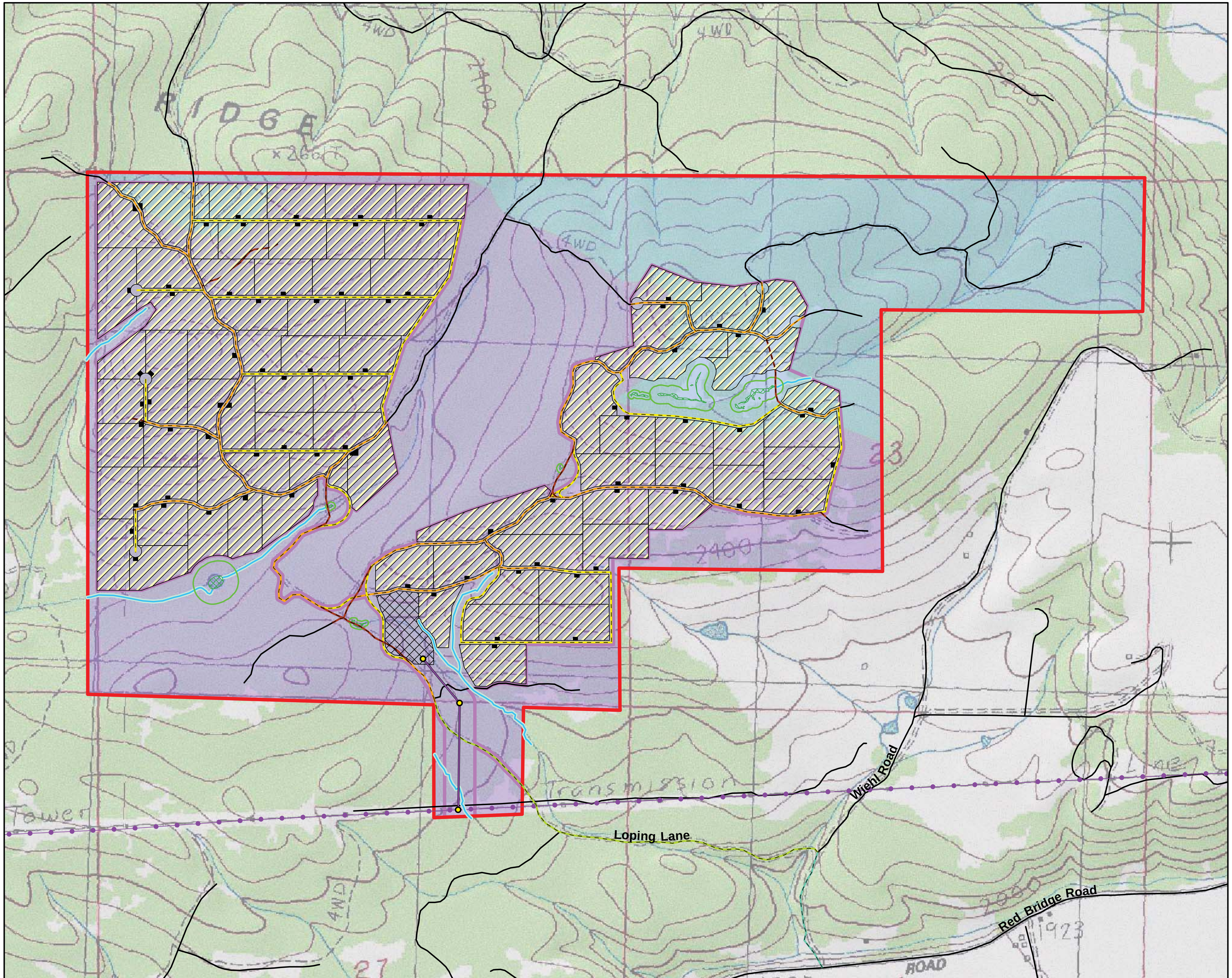


0 1,500 3,000
Feet

N

FIGURE 2
100-year Floodplain Map
Hydrologic Analysis
Teanaway Solar Reserve
Kittitas County, Washington

CH2MHILL



LEGEND

Proposed Project Features

- Proposed Project Area (982 Acres)
- Proposed Project Site (477 acres)
- Proposed PV Array Block
- Proposed Field Inverter and Field Transformer
- Proposed Substation/O&M Facility
- Proposed Transmission Line
- Proposed Transmission Structure
- Proposed Maintenance Road
- Proposed Improved Maintenance Road
- Existing Maintenance Road (Planned Decommissioning)
- Proposed Improved County Access Road
- Proposed Improved Private Access Road

Existing Features

- Existing BPA Transmission Line and ROW
- Existing Road
- Stream
- Stream Buffer
- Wetland
- Wetland Buffer
- South Drainage Basin
- North Drainage Basin

N

0 1,000
Feet

1 inch = 1,000 feet

FIGURE 3
Proposed Site Layout with Drainage Basins

Hydrologic Analysis
Teanaway Solar Reserve
Kittitas County, Washington

APPENDIX B

GeoEngineers Letter (October 2009)

GeoEngineers
Plaza 600 Building
600 Stewart Street, Suite 1700
Seattle, Washington 98101
206.728.2674

February 19, 2010

Teanaway Solar Reserve, LLC
218 East First Street, Suite B
Cle Elum, Washington 98922

Attention: Mr. Howard Trott

Subject: Hydrologic Evaluation
(CU-09-00005)
Hydrologic Services
Teanaway Solar Reserve
Kittitas County
File No. 17700-001-01

INTRODUCTION

Teanaway Solar Reserve, LLC (TSR) proposes to construct and operate the project on approximately 982 acres of private land within the Forest and Range (F&R) zoning district in an unincorporated area of Kittitas County, Washington. TSR submitted a Conditional Use Permit (CUP) and State Environmental Policy Act (SEPA) Checklist for the proposed project to Kittitas County on August 18, 2009. The application was deemed complete by the County on September 3, 2009. The public comment period on the CUP/SEPA ended on October 5, 2009. Comments were received from various state agencies and interested local parties.

This letter has been prepared on behalf of Teanaway Solar Reserve, LLC (TSR) in response to the September 16, 2009 comment letter prepared by Mark Teske of the Washington Department of Fish and Wildlife (WDFW) regarding the Teanaway Solar Reserve located in Kittitas County, Washington. The letter raised questions regarding the solar reserve's impact, if any, on flooding and erosional hazards in the vicinity of tributary streams to the Teanaway River. To address issues raised in the WDFW letter, a professional hydrologist from GeoEngineers visited the site of the proposed solar reserve, the surrounding watershed, and the drainages that emanate from the project area. The information presented in this letter is based on a review of Solar Reserve design information, a review of area topographic maps, a field reconnaissance and interviews with local residents familiar with the history of flooding issues along Red Bridge Road. This response is organized according to the topics outlined in the September 16th WDFW letter.

PROJECT DESCRIPTION

Teanaway Solar Reserve, LLC (TSR) proposes to construct and operate the project on approximately 982 acres of private land within the Forest and Range (F&R) zoning district in an unincorporated area of Kittitas County, Washington. The project will generate up to 75 direct current megawatts (MWdc) of photovoltaic (PV) solar energy utilizing approximately 477 acres of land within the proposed project area. The project location was chosen for its south-facing slopes of moderate steepness, which are required for the effectiveness of the solar facilities. Studio Greene Architects has completed the initial site layout work on the project and Quanta Services, Inc. will manage site development and construction. GeoEngineers was provided layout and foundation information by CH2M HILL Inc.

Several module mounting types will be considered to best address the slope of land and soil stability at the project site. For example, large land areas with a slope toward the south are excellent for single-axis tracking systems. Land areas that are sloped to the east, southeast, west, or southwest will not as easily accommodate single-axis tracking systems, and are better suited to a fixed-tilt mounting structure.

The foundations securing the solar modules will be designed to withstand high winds and snow loads. The site may have multiple foundation types to match the ground conditions and type of mounting structures used. The mounting-system support structures could consist of embedded posts, poles, or structural steel angle. The embedment could be completed via a vibratory drill or similar installation method to depths of approximately 8 feet. Pending final design, the solar module foundations will require site work and potential boring.

The posts will not be anchored unless a patch of bedrock is encountered during installation. After the posts are installed, they are held in place by friction from the surrounding soil, without the use of concrete. Driven piles develop their strength by utilizing a definable skin friction between the pile and the soil. As the pile is forced into the ground, the displaced material compresses and that, in turn, creates the friction at the pile/soil interface. Piles are typically driven to a depth that prevents seasonal and temporary changes from affecting their strength. A geotechnical engineer will determine the parameters to be used in the structural design. No concrete will be used when installing the foundations for the modules.

METHOLODOLGY

A professional hydrologist from GeoEngineers visited the site of the proposed solar reserve, the surrounding watershed, and the drainages that emanate from the project area. The information presented in this technical memorandum is based on a review of Conceptual Site Layout as presented in the CUP/SEPA application materials, topographic maps, a field reconnaissance, and interviews with local residents familiar with the history of flooding issues along Red Bridge Road.

RESULTS

A summary of the potential impacts related to the development of the solar reserve is presented below. The public comment letter from the Washington Department of Fish and Wildlife (WDFW) outlined the following concerns: impervious surfaces, January 2009 flooding, and the 303(d) listing of the Teanaway River.

Impervious Surfaces

Concern was raised by the public comments that impervious surfaces from the proposed project will intercept rain and snow.

Permanent impacts resulting from installation of the solar reserve may result from the removal of ponderosa pine trees, road construction, and placement of the panels. In terms of permanent land conversion and modification of the hydrology of the watershed, the impacts are significantly less than a typical development which typically consists of paved roadways, impervious structures and supporting facilities. The roads at TSR will be maintained as dirt or gravel, and no large-scale clearing or grading beyond tree removal is required for the reserve. After construction, native grasses will be restored to the disturbed areas.

Although the solar reserve panels are impervious, due to their angled orientation above the ground surface, they will not function as an impervious surface such as a roadway or flat surface at ground level. Therefore, rainwater or snow intercepted by the panels will run off the elevated surface and flow to the native soil and grasses, which will continue to serve the same drainage function that approximates the current condition. The primary effect of runoff from the solar panels will be to concentrate the natural rainfall that would naturally have fallen over a 17.5-square-foot area (individual panel dimensions are 3.5 feet by 5 feet) into a linear corridor with a length that may vary from 3.5 feet to 8.5 feet, depending on the orientation and angle of the panel at the time of a storm event. The likely impact that may result from construction of the individual solar panels would be a minor concentration of runoff at the base of each panel that could result in rilling or small-scale gully formation in extreme rainfall cases.

JANUARY 2009 FLOODING

The January 2009 flooding that occurred adjacent to the proposed project area, specifically along Red Bridge and Wiehl Roads was the result of a significant rain-on-snow event and was possibly the flood of record for the small drainages that emanate from the project area. These drainages can be characterized as ephemeral, vegetated swales. A field visit to the project area shows that the drainages that drain the project area are in stable condition. No excessive erosion, lateral shifting or incision was evident in the drainages around the project site. The vegetation in the drainages acts to reduce velocity and erosional forces of water as it runs off hillslopes into concentrated areas.

The proposed project area is situated within two basins, one of which (east tract) drains to the Red Bridge Road via Weihl Road. The condition of the channel that drains Wiehl Road shows that the channel was not significantly altered as a result of the extreme flood events in January 2009. Drainage from the west tract is routed through a stock pond, which effectively removes any peak flow from major flood events, and runs southwest into a drainage that is captured for irrigation along Masterson Road. Observations of the channel upstream and downstream of the stock pond show that the extreme flooding in January 2009 did not significantly impact the channel stability.

One of the major sources of flooding and the main source of debris onto Red Bridge Road during the January 2009 event was a small drainage that does not emanate from the project area and will not be affected by the proposed solar reserve. The unnamed drainage is not located within the proposed project area and is hydrologically and topographically disconnected from the project area. The drainage receives flow from the hillside above and directs the runoff down a short, steep section that runs into an irrigation ditch parallel to Red Bridge Road.

According to Jesse Geiger, the homeowner across the street from the unnamed drainage, the flooding and debris flow from this drainage were a result of recent disturbance to the stream channel caused by another local valley resident. Mr. Geiger told us that another area resident had used excavating equipment to trench into and disturb the streambed of the unnamed small drainage in an effort to reroute flows into irrigation pipes and ultimately into an existing delivery system. According to Mr. Geiger, the channel was never armored or revegetated after the soil disturbance and channel realignment. As a result, high flows in January 2009 destabilized the unprotected channel and breached the weak soil dam that had been erected adjacent to Red Bridge Road. The condition of the channel upstream of the disturbed area was not subject to erosion or damage; rather, only the disturbed reach was destabilized, causing a debris torrent to spill into the road and the subsequent flooding and damage to the road. Field observations of the drainage correlate with the description of events recounted by area residents, as evidenced by comparing the condition of this drainage to the drainage adjacent to Wiehl Road.

TEANAWAY RIVER

The WDFW letter identifies that the Teanaway River is an impaired waterbody due to temperature and flow limitations as defined by the Washington State Department of Ecology (Ecology) Total Maximum Daily Load (TMDL) detailed implementation plan (DIP). According to the DIP, the sources of temperature and flow impairment in the Teanaway River are:

- Lack of streamside shade
- Increased channel width:depth ratio
- Instability of streambanks
- Lower instream flows during the summer

The proposed solar reserve will have negligible influence on any of the processes listed above. WDFW suggests that the proposed development will result in a flashier hydrograph in the drainage channels that emanate from the planned solar reserve project area and that this conversion will further impair conditions in the Teanaway River. We address issues raised by WDFW below:

Timing of Runoff

Historically, and in an undisturbed state, the ephemeral drainages emanating from the project area flow are naturally “flashy,” typically resulting from short, intense rainfall or rain-on-snow events. These events are likely to occur in autumn and early winter, when flows in the Teanaway River are naturally elevated and temperatures low.

It is also important to note that, the drainages flowing from the project area either are intercepted by irrigation ditches or cross over Red Bridge Road and spread out over the fields between Red Bridge Road and Highway 970. As such, there is no direct surface water connection to the Teanaway River from these drainages.

Sediment Transport

WDFW suggests that the proposed solar reserve project is expected to increase sediment load and impact salmonid egg incubation in the Teanaway River. Sediment transport from the project area to the Teanaway River is not expected to increase as a result of the detention facilities that will be put in place to offset any predicted increases in post-development sediment load. Additionally, irrigation diversions and the lack of a surface water connection limit any sediment movement to the Teanaway River except during periods of extreme flows and sediment concentrations, when the entire valley is flooding and overtopping Highway 970. Furthermore, field observations indicate that the channels routing water from the project area are in stable condition, while the major source of flooding and debris is from a drainage unaffected by the proposed project.

Hyporheic Zone

Hyporheic exchange between the Teanaway River and its floodplain can be an important source of cool water during periods of low flow. However, the historically ephemeral and flashy flow from the project area stream channels likely supplied little of the total water volume in the hyporheic zone. Most of the water that emanates from the project area and adjacent basins is captured for irrigation and therefore is regulated by the irrigation schedule and ultimately enters the Teanaway River as return flows. Flows that exceed the capacity of the irrigation system or that are routed past irrigation diversions have no open channel to pass water quickly to the Teanaway River; rather, the flows spread across the fields and infiltrate into the floodplain, slowly working their way towards the river as hyporheic flows. The processes that currently supply the hyporheic zone from the project area streams will not be altered, nor will the floodplain processes of the Teanaway River be modified as a result of the proposed project.

CONCLUSIONS

During final design of the project, and as part of the building permit application, more detailed hydrologic analyses will be completed to design stormwater management features. The applicant proposes to have no effect on the existing hydrology leaving the project site. Any calculated increase in runoff will be managed through the implementation of Best Management Practices. Runoff from the project area routes through two drainages, one of which currently has a stock pond that can be easily modified to collect and release runoff in a manner such that the post-development runoff matches the existing hydrology. When additional analyses are completed, the applicant will utilize a continuous hydrologic model such as MGS Flood or the Western Washington Hydrology Model to accurately model the effects of the development on basin hydrology.

There is no field evidence that the landslides/debris torrents referenced in the public comment letter received from the WDFW emanated from the proposed project area. Flooding of the drainages is a natural process that occurs during extreme events such as the rain-on-snow event that occurred in January 2009. The volume and timing of surface water runoff from the project area will not increase beyond the existing condition as a result of careful planning and application of stormwater management measures where necessary. The proposed solar reserve development will not result in hundreds of acres of impervious area, as suggested by the WDFW letter. The primary cause of landslides/debris torrents seen in the January 2009 event that impacted Red Bridge Road resulted from land disturbance in drainage that is neither within, nor affected by, the proposed project.

LIMITATIONS

GeoEngineers has prepared this letter report for the exclusive use of the Teanaway Solar Reserve, LLC and their authorized agents for Hydrologic Services for the Teanaway Solar Reserve located in Kittitas County, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with the generally accepted hydrologic science practices in this area at the time this report was prepared. The conclusions and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

Sincerely,
GeoEngineers, Inc.

Jonathan M. Ambrose
Senior Hydrologist

David A. Cook, LG
Principal

JMA:DAC:csv
SEAT:\17\17700001\01\Finals\1770000101_Hydrology_Letter_Revised.docx

APPENDIX C
Time of Concentration Calculations

Time of Concentration Worksheet

PROJECT:	Teanaway Solar Reserve Project
BASIN	Teanaway Drainage Basin
LOCATION:	Kittatas County, Washington

Parameters		**Units**			**Comments**
Total length of Flow	4895	ft			
Sheet Flow Segment					
Length	100	ft			
Slope of hydraulic Grid Line - S_o	0.11	ft/ft			
n_s - Sheet flow Manning' Effective roughness coeff.	0.4				*[HEC-HMS Technical Reference Manual]*
Travel time (sheet Flow Segment) T_1 = $0.42\ (n_sL)^{0.8}/((1.58*(S_o)^{0.4})$	12.3	min			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Shallow Concentrated Flow Segment					
Length	300	ft			
S_o	0.050	ft/ft			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Velocity V = $16.1345(S_o)$^0.5	3.61	ft/s			*[City of Portland Stormwater Management Manual 2004 page C-2]*
T_2 = L/(60*V)	1.4	min			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Pipe Flow Segment					
Length	4495	ft			Assume sheet flows empty into inlets connected to pipes.
T_3 = L/(60*V)	25.0	min			Assume pipe flow velocity of 3fps
T_c	38.7	min			

Time of Concentration Worksheet

PROJECT:	Teanaway Solar Reserve Project				
BASIN	South Drainage Basin				
LOCATION:	Kittatas County, Washington				

Parameters		**Units**			**Comments**
Total length of Flow	7738	ft			
Sheet Flow Segment					
Length	100	ft			
Slope of hydraulic Grid Line - S_o	0.11	ft/ft			
n_s - Sheet flow Manning' Effective roughness coeff.	0.25				*[City of Portland Stormwater Management Manual 2004 page 2-74]*
Travel time (sheet Flow Segment) $T_1 = 0.42\ (n_sL)^{0.8}/((1.58*(S_o)^{0.4})$	8.4	min			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Shallow Concentrated Flow Segment					
Length	300	ft			
S_o	0.070	ft/ft			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Velocity V = 16.1345(S_o)^0.5	4.27	ft/s			*[City of Portland Stormwater Management Manual 2004 page C-2]*
T_2 = L/(60*V)	1.2	min			*[City of Portland Stormwater Management Manual 2004 page C-2]*
Pipe Flow Segment					
Length	7338	ft			Assume sheet flows empty into inlets connected to pipes.
T_3 = L/(60*V)	40.8	min			Assume pipe flow velocity of 3fps
T_c	50.4	min			