HANSEN ALLEN & LUCE INC
ENGINEERS

MEMORANDUM

DATE:	August 25, 2017
TO:	Pat Sweeny
FROM:	Joseph Hawkes, M.S., P.E. Hansen, Allen, & Luce, Inc. 859 West So. Jordan Pkwy. Ste 200 South Jordan, UT 84095
SUBJECT:	MPE Treasure Project Hydrology Review
PROJECT NO.:	344.150.100

PROFESSIONAL ENGINEER
8-25-17
No. 8752113-2202
JOSEPH G. HAWKES
STATE OF UTAH

INTRODUCTION

MPE Inc. has employed Hansen, Allen, & Luce Inc. (HAL) to review the hydrology of their proposed Treasure Project. The study area is in and near Park City, Utah. The hydrologic review analyzed the tributary area that drains to the inlets on the west side of the intersection of 8th Street and Norfolk Avenue, both before and after the proposed development is completed.

SITE VISIT

On June 1st, 2017, Joseph Hawkes from HAL visited the study area with Patrick Sweeney and hiked through the proposed construction area and existing drainage basin. The purpose of the site visit was to determine the vegetation and drainage conditions of the basin. It was determined that the drainage basin is well vegetated and does not have a stream channel carved by runoff flows. Photographs of the site visit are included in this memorandum showing the condition of the drainage basin.

EXISTING HYDROLOGY

The drainage basin is comprised of mountainous terrain (approximately 54 acres) with some residential development (approximately 1.2 acres) at the lower elevations of the basin. The tributary area was delineated from contours derived from the 10 meter National Elevation Dataset available through the Utah Automated Geographic Reference Center (AGRC). Subbasin attributes were developed using Technical Report 55 Urban Hydrology for Small Watersheds (TR-55) (USDA, 1986) and from Lag Time Characteristics for Small Watersheds in the U.S. (Simas and Hawkins, 2002).

Precipitation

The precipitation events used in modeling the existing hydrology were generated from the National Oceanic and Atmospheric Administration's (NOAA's) Atlas 14 point precipitation for the approximate center of the study area. Multiple events were modeled as part of a sensitivity analysis to determine which duration of events created the peak runoff or most runoff volume. The precipitation depths for the corresponding events can be seen below in Table 1.

TABLE 1 – PRECIPITATION EVENTS AND DEPTHS

Recurrence Interval	1-Hour Duration	3-Hour Duration	6-Hour Duration	12-Hour Duration	24-Hour Duration
10-Year	0.88 inches	1.13 inches	1.42 inches	1.79 inches	2.25 inches
100-Year	1.74 inches	2.01 inches	2.24 inches	2.73 inches	3.24 inches

Storm distributions used in this study were derived from the Farmer–Fletcher (FF) distribution for 1, 3, and 6-hour storms and the Great Basin Experimental Area (GBEA) distribution for 12 and 24-hour storms.

Thirteen separate gauging stations in the Great Basin Experimental Area, ranging in elevation from 5,500 feet to over 10,000 feet, were maintained for varying periods of time from 1919 to 1965. Fifteen gauging stations were maintained in the Davis County Experimental Watershed (ranging in elevation from 4,350 feet to 9,000 feet) for varying periods of time between 1939 and 1968. After analyzing the data, Farmer and Fletcher (1971) found that "more than 50 percent of the storm rainfall depth occurs in 25 percent of the storm periods" and that "usually more than half of the total depth of rain is delivered as burst rainfall." Farmer and Fletcher developed design storm distributions which have been accepted by governmental entities including Salt Lake County and Davis County as the characteristic distributions for storms in Utah of short duration (generally 6-hour or less).

The work of Farmer and Fletcher was expanded by HAL in 1985 to develop a longer-duration rainfall distribution from the GBEA data. For the derivation of the design 24-hour rainfall event, a storm was defined "as a period of continuous or intermittent precipitation delivering at least 0.1 inches of rainfall during which time dry periods without rainfall did not exceed four hours." Storms having durations between 20 and 28 hours were accepted to be representative of a 24-hour storm duration. The 24-hour storms were screened to include only storms which contained rainfall meeting the burst criteria of having over 50% of the precipitation occurring in less than 25% of the time. Storms meeting the burst criteria were further categorized in accordance with which quartile of the storm the burst had occurred (i.e. the first, second, third, or fourth quarter of the storm period). Identified storms were used to develop a 24-hour design storm distribution for use in Utah. A sensitivity analysis for all storm distributions developed shows the 3rd quartile storm distribution to produce the higher runoff peaks. The GBEA 3rd quartile storm distribution includes a burst of rainfall with an approximate 10% of the 24-hour total falling within a 30 min period. Because the distribution is based on local data, the GBEA distribution is believed to be the best available storm distribution for Utah storms lasting between 6 and 24 hours. The distributions can be seen on Figure 1.

Land Use/Cover

Land use and vegetation drastically alter runoff. For example, impervious areas such as roadways convey nearly all precipitation directly to storm drain facilities, while homes and backyards experience less runoff and heavily vegetated areas experience very little comparative runoff. The study area comprises a ski run (Creole run), a pine forest, a mix of aspen and scrub oak woods, and residential areas at the bottom of the tributary area. The drainage basin is vegetated and was determined to have excellent cover. The open ski run area is well vegetated with natural grasses. Figure 2 shows the vegetated cover from the top of the Creole run looking down the drainage basin. Additional photos showing the typical vegetation cover of the subbasin can be seen in Exhibit A.

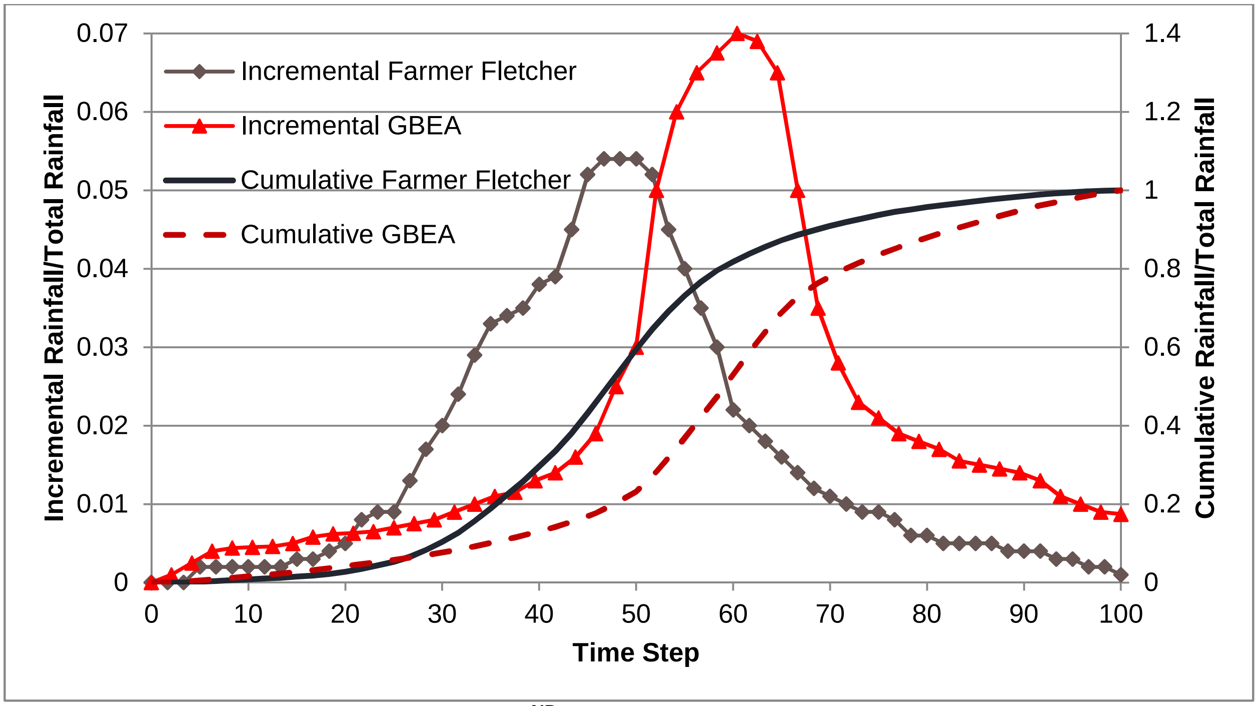
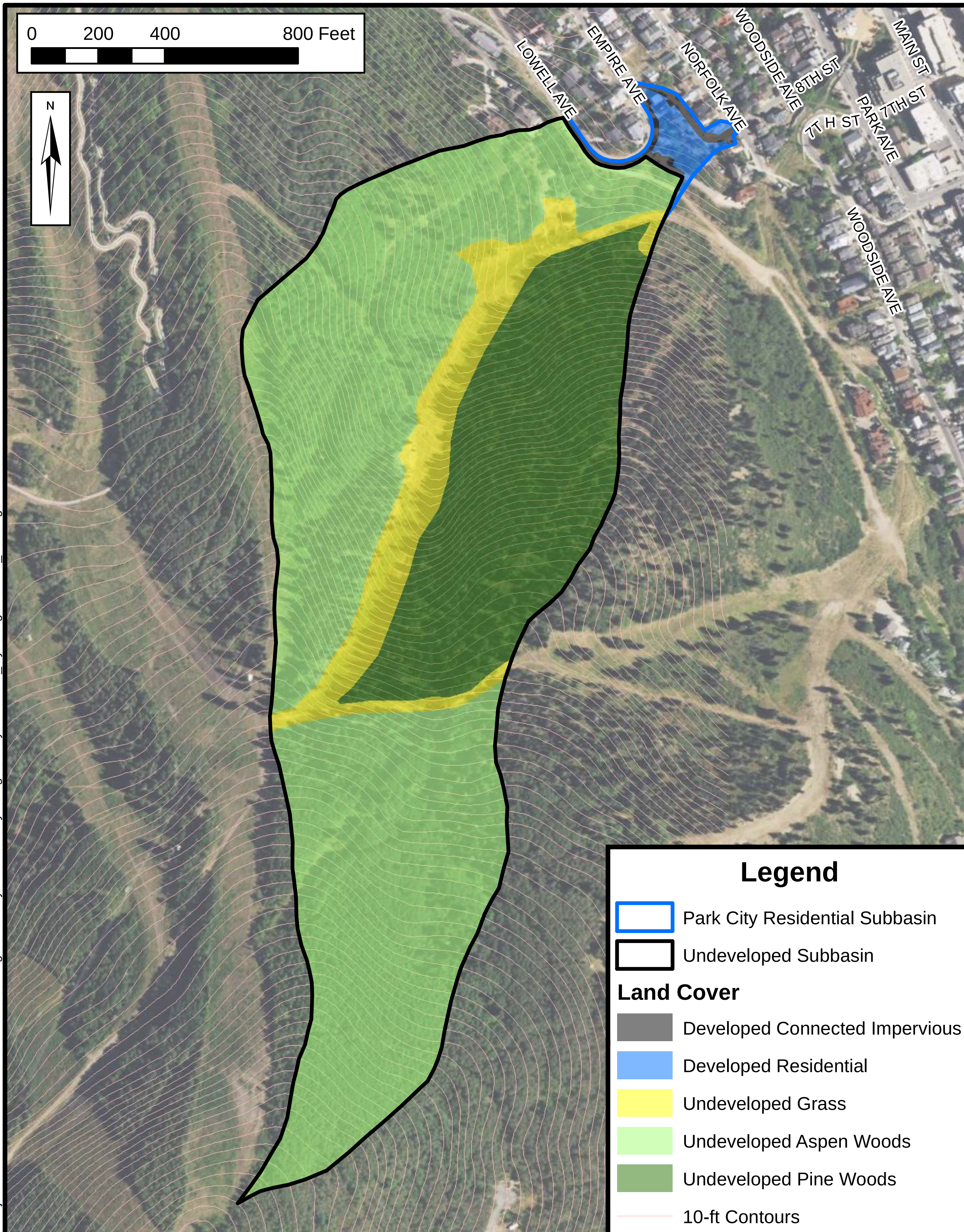


FIGURE 1 FARMER FLETCHER 2ND QUARTILE DIMENSIONLESS DISTRIBUTION

FIGURE 2 – VEGETATION FROM THE TOP OF THE CREOLE SKI RUN.

The delineated drainage area with the tributary areas defined by type of cover can be seen on Figure 3. Areas determined as Undeveloped Aspen Woods were conservatively assigned the same higher curve number as the Undeveloped Pine Woods to account for mixed vegetation cover.



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MPE Inc. Treasure Project
Existing Tributary Area and Land Cover

FIGURE 3

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Hydrogeology

Soil data for the study area was obtained from the Web Soil Survey (WSS) provided by the Natural Resources Conservation Service (NRCS). Soil types were determined to be mainly group B soils which are defined as silt loam or loam in TR-55. Group B soils are moderately well draining and transmit water between 0.15 and 0.30 inches per hour.

It was also noted during the field visit that the tributary area is on a highly fractured mountainside. Natural and manmade drains (in the form of sinkholes and abandoned mine shafts) were common throughout the area and likely provide additional paths for some runoff to enter the groundwater system instead of flowing down the mountainside. Figure 4 shows the soil groups which make up the study area.

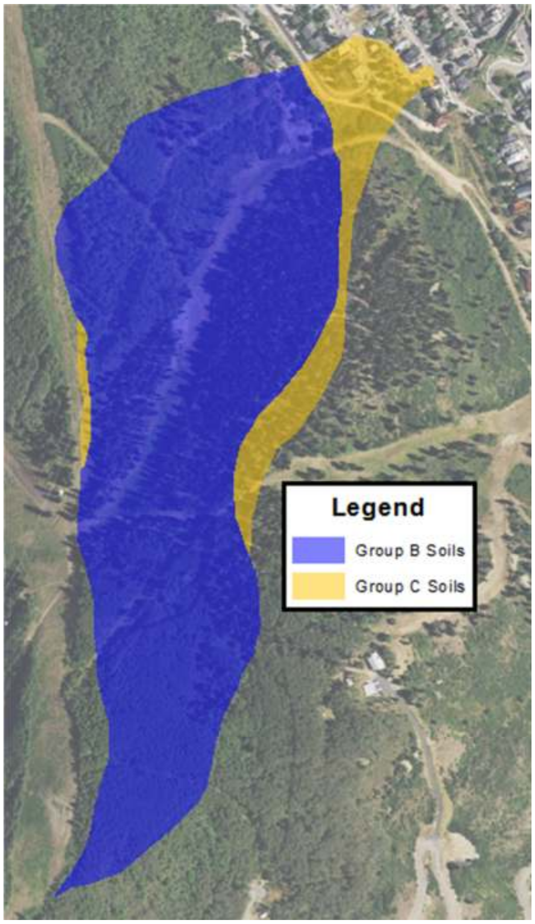


FIGURE 4 – SOIL TYPES

Model Methodology

The existing drainage area was split into an undeveloped subbasin and a much smaller developed subbasin during modeling efforts.

According to Water-Resources Engineering (Linsley and Franzini, 1979) the rational method of determining peak runoff “should be limited to very small, impervious areas.” Therefore, it was determined that the NRCS (formerly the SCS) method would instead best estimate the runoff from the subbasin. The modeling software used in this study is AutoCAD’s Storm and Sanitary Analysis. The software uses the EPA’s SWMM model as an engine, but has additional options for hydrology methods, including the HEC-1 method, which was used in this study. Subbasin attributes required with this methodology include the subbasin area, the curve number for the subbasin, the initial abstraction (can be calculated within the model), the percentage of directly connected impervious area in the subbasin, and the lag time.

The subbasin area and directly connected area were determined from the manual delineation of the subbasin boundaries and the aerial imagery showing roadway, driveways, or other directly connected impervious areas.

The curve numbers for the subbasins were determined from Tables 2-2 (a, b, c, and d) in TR-55. Curve numbers used in the study were for C type soils for ¼ acre residential areas (after removing the impervious percentage), for B and C type soils defined as “meadows,” and for B and C type soils defined as “woods” in good hydrologic conditions. Although some areas of the drainage could be classified as oak-aspen cover it was determined that they would be conservatively defined as “Woods” due to the mix of pine vegetation on the entire mountainside.

The lag time for the residential developed area was determined using the TR-55 method, and the lag time for the undeveloped area was determined using the Simas and Hawkins method (Simas and Hawkins, 2002) which adjusts the lag time based on the curve number, watershed width (area/length), and slope along the longest flow path.

Existing Hydrology Results

The modeling results showed that little predicted runoff comes off of the undeveloped subbasin. The peak predicted runoff flow rates and the total predicted runoff volume of the existing subbasins can be seen in Table 2.

TABLE 2 – EXISTING SUBBASIN HYDROLOGIC RESULTS

Subbasin	10-Year Event		100-Year Event	
	Predicted Peak Flow	Predicted Runoff Volume	Predicted Peak Flow	Predicted Runoff Volume
Undeveloped Subbasin	0.47 cfs *24-hour storm*	0.28 ac-ft *24-hour storm*	2.90 cfs *24-hour storm*	1.40 ac-ft *24-hour storm*
Park City Residential Subbasin	1.27 cfs *1-hour storm*	0.13 ac-ft *1-hour storm*	2.86 cfs *24-hour storm*	0.20 ac-ft *24-hour storm*

As seen above, the 10-year predicted runoff from the undeveloped area is relatively small considering the 54 acres that contribute to the runoff. This is approximately 0.009 cfs/acre. The field visit suggested that the subbasin does not experience channelized flow as noted by the lack of any defined channel and there was very little erosive rutting in the access road which follows the ski run. The field visit and modeling suggest that the subbasin only experiences runoff in events larger than the 10-year 6-hour storm. The full modeling results can be seen in Exhibit B. Figure 5 shows the lower portion of the undeveloped subbasin where a defined channel would be expected to exist if the subbasin experienced frequent runoff events.

FUTURE HYDROLOGY

The Treasure Project is a collection of high rise resort lodgings proposed to be located at the downstream end of the study area. The proposed development will require significant excavation for the construction of the resort buildings and includes a planned placement of the excavated materials near the top of the Creole ski run. The analysis of the future development is mainly conceptual and is not based on a final design of the project. The analysis is provided to provide a perspective of the runoff flow rates and volumes from a development with similar impervious areas.

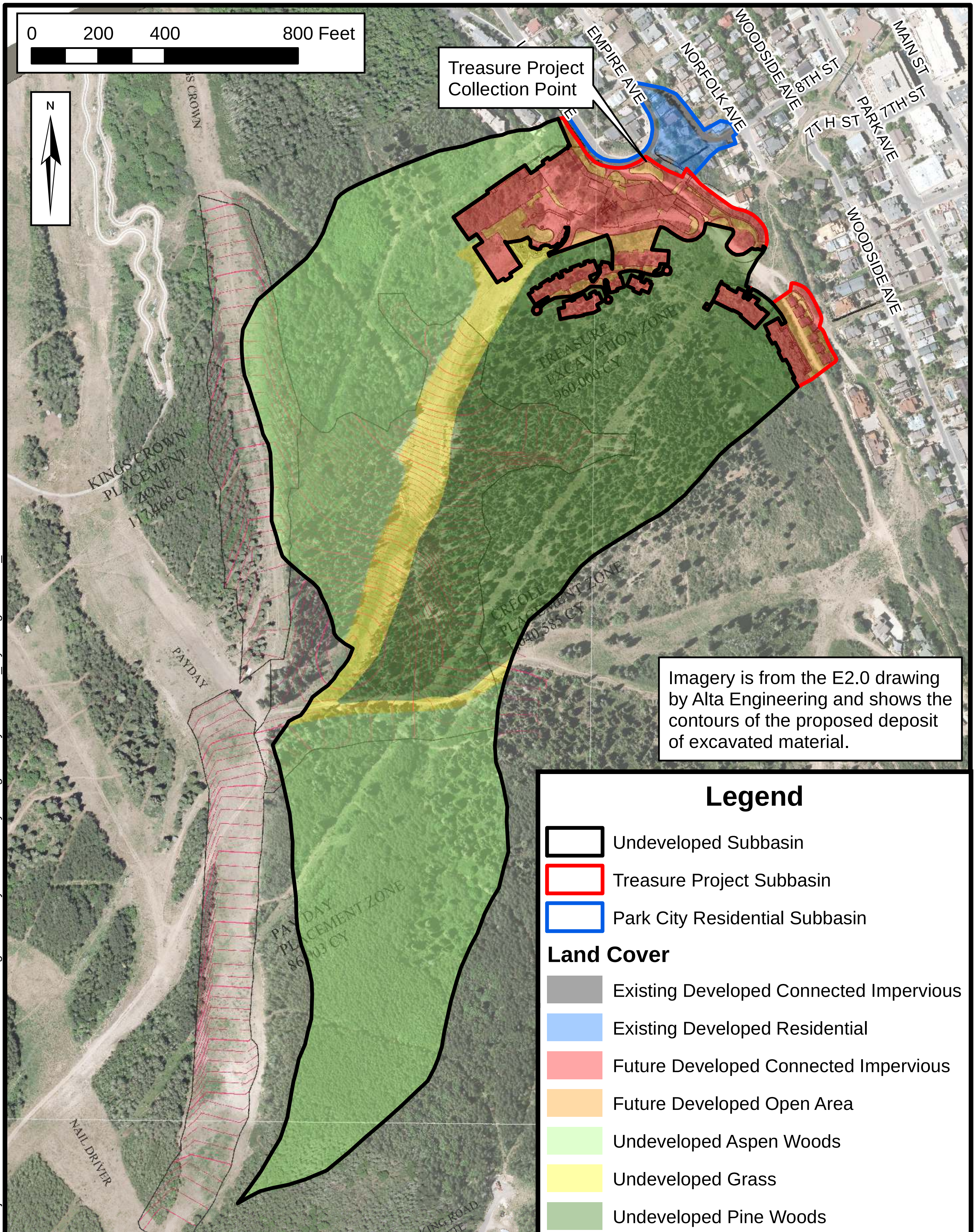
FIGURE 5 – LOWER PORTION OF SUBBASIN WITH NO DEFINED CHANNEL

The future directly connected impervious areas were derived from the E2.0 Drawing titled Treasure Excavation Management Plan Material Placement Zones by Alta Engineering. Based on the drawing, approximately 5 acres of directly connected impervious area were delineated for the model, with an additional 1.5 acres of landscaping on imported Group C topsoil and unconnected impervious areas. These areas are estimates and could vary with the implementation of Low Impact Development (LID) designs or modifications to the final design, but are a reasonable representation of projected future conditions. The proposed future tributary area and land cover can be seen on Figure 6.

Modified Delineation

The placement of excavated material at the top of the Creole run is expected to adjust the tributary area to the storm drain inlets in 8^{th} Street. Approximately 1.7 acres are expected to be removed from the drainage, with runoff from that area directed down the King's Crown run.

A portion to the east of the existing drainage was added to the tributary area to represent area that will drain onto the proposed development. This area normally would flow onto the back of lots along Woodside Avenue but the proposed development will likely intercept the runoff with the development's storm drain system.



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HANSEN ALLEN & LUCE INC ENGINEERS

MPE Inc. Treasure Project
Future Tributary Area and Land Cover

FIGURE 6

Modified Soil Types

Portions of the placement of the excavated material at the top of the Creole run were adjusted to conservatively reflect curve numbers representative of the Group C soils which are more prevalent at the bottom of the drainage. The curve numbers were adjusted for 6 acres of the fill area with the understanding that the development will be able to retain the drainage conditions of some of the placement material.

Future Hydrology Results

The future peak predicted runoff flow rates and the total predicted runoff volume of the future subbasins can be seen in Table 3.

TABLE 3 – EXISTING SUBBASIN HYDROLOGIC RESULTS

Subbasin	10-Year Event		100-Year Event	
	Predicted Peak Flow	Predicted Runoff Volume	Predicted Peak Flow	Predicted Runoff Volume
Undeveloped Subbasin	0.75 cfs *24-hour storm*	0.47 ac-ft *24-hour storm*	4.02 cfs *24-hour storm*	1.86 ac-ft *24-hour storm*
Treasure Project Subbasin	12.91 cfs *1-hour storm*	0.98 ac-ft *24-hour storm*	26.18 cfs *1-hour storm*	1.46 ac-ft *24-hour storm*
Park City Residential Subbasin	1.26 cfs *1-hour storm*	0.12 ac-ft *24-hour storm*	2.81 cfs *1-hour storm*	0.20 ac-ft *24-hour storm*

Increases in the projected runoff from the undeveloped area are explained by the expansion of the subbasin area to the east as well as conservative modifications to the soil groups on the excavation deposit area. As expected, predicted runoff from the existing residential area remains the same. The potential Future Developed area may have significant runoff peaks, as well as volumes if runoff is not detained or reduced through LID designs. The full modeling results can be seen in Exhibit B.

CONCLUSION

The existing drainage experiences little to no channelized flows from the undeveloped mountainside even during relatively large (10-year 1 through 6 hour) events. The proposed development will slightly affect the natural topography of the drainage, and care should be taken to maintain the well-drained condition of the soils when placing excavated materials on the hillside.

The proposed project will affect flow rates from the Undeveloped Subbasin and the Treasure Project Subbasin (currently undeveloped). Peak flows from the Undeveloped Subbasin and the Treasure Project Subbasin are collected together at the "Treasure Project Collection Point." To compare how the proposed project could affect runoff rates, the flows are compared in Table 4 below.

TABLE 4 – TREASURE PROJECT COLLECTION POINT FLOWS

Subbasin	10-Year Predicted Peak Flow		100-Year Predicted Peak Flow	
	Existing	Future	Existing	Future
Undeveloped Subbasin	0.47 cfs	0.75 cfs	2.90 cfs	4.02 cfs
Treasure Project Subbasin	NA*	12.91 cfs	NA*	26.18 cfs
Treasure Project Collection Point	**0.47 cfs**	**12.91 cfs**	**2.90**	**26.18 cfs**

*Not Applicable

Storm Water Management Alternatives

According to Park City Code 15-7.3-5, onsite detention of developments is generally required as well as mitigation of downstream storm drain facilities. The impact to downstream storm drain facilities can be significantly reduced through the implementation of Low Impact Development (LID) designs in the development as well as use of detention ponds. LID designs may include use of bioretention (grassy swales and vegetated depressions), green roofs, or permeable pavers. Maintaining the general soil conditions of the area will also facilitate increased infiltration of runoff into the groundwater system, matching current conditions.

Park City is classified as a Small Municipal Separate Storm Sewer System (MS4) as defined by the Utah State Department of Environmental Quality. The City is therefore regulated by the Utah Pollutant Discharge Elimination System (UPDES) modified permit which became effective on December 1, 2016. The permit requires that by March 1st, 2019, development that disturbs more than 1 acre of land must prevent the off-site discharge of runoff from precipitation events less than or equal to the 90th percentile rainfall event unless it can be shown that retention of the runoff is “technically unfeasible.” This is not currently required but is expected to be enforced by March 1st, 2019.

There are several options MPE Inc. may pursue in managing storm water from the proposed development:

- All runoff can be conveyed, without detention, from the development into the City’s system. Park City’s Code 15-7.3-5 does not state if developments must design for a specific storm in developing their storm drainage system. Generally, the controlling 10-year storm is used to size pipe systems while detention areas and overflow channels are designed for the 100-year storm. If this is the case for the Treasure Project, a 24-inch pipe would be required to convey the peak 10-year flows from the project and would need to increase in diameter to accommodate downstream runoff in the City before outfalling to Silver Creek.

- Runoff can be retained (no runoff) from the development by using retention ponds, infiltration methods, and LID design.
  Retention of the runoff from the Treasure Project Subbasin would require a 1.5 acre-foot retention pond to capture the 100-year 24-hour storm. The retention could be broken into different portions throughout the project making use of available open space without having to designate a larger site for the total runoff volume. This option would have the least impact on storm water quality and on downstream storm drainage facilities. Additional storm drain facilities would be required to convey any runoff from the undeveloped subbasin to City’s storm drain system.

- Runoff can be detained and reduced through LID design before being conveyed from the development into the City’s system.
  Implementation of detention and LID designs would reduce the peak runoff from the project while not requiring the full 1.5 acre-feet of retention volume. It is recommended that runoff from the design storm be reduced to a point where the 24-inch pipe outfalling to Silver Creek has adequate capacity. In conjunction with Park City, the design storm should be defined and a more detailed hydrologic and hydraulic analysis of the development footprint should be completed for the final design of the project.

BIBLIOGRAPHY

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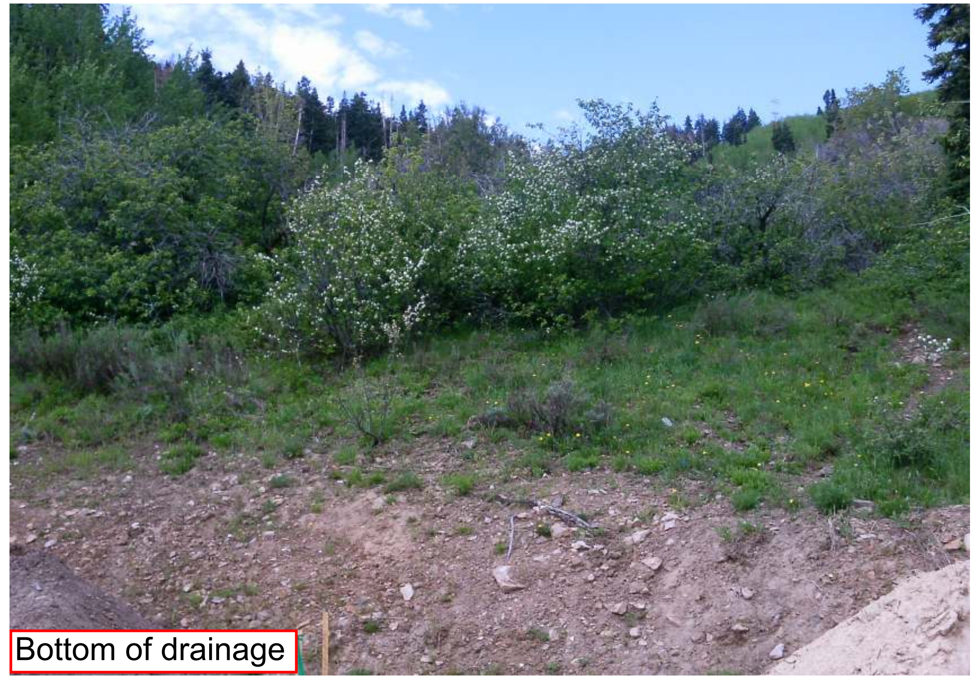
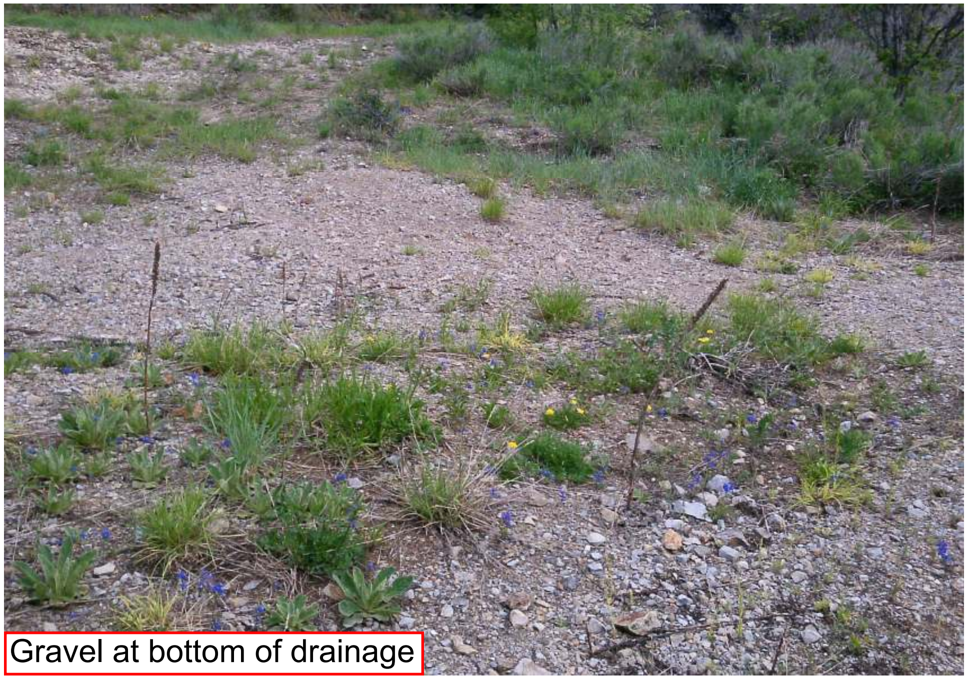
Exhibit A


Silver Creek


Bottom of drainage


Silver Creek


Bottom of drainage



Gravel at bottom of drainage

Detention/retention basin

Bottom of drainage

Footpath at bottom of drainage


Detention/retention pond


Access road at bottom of drainage


Detention/retention pond and ski run


Mine entrance


Access road up ski run


Typical vegetation


Access road down ski run


Ski run


Typical vegetation and fractured mountainside


Typical vegetation and fractured mountainside

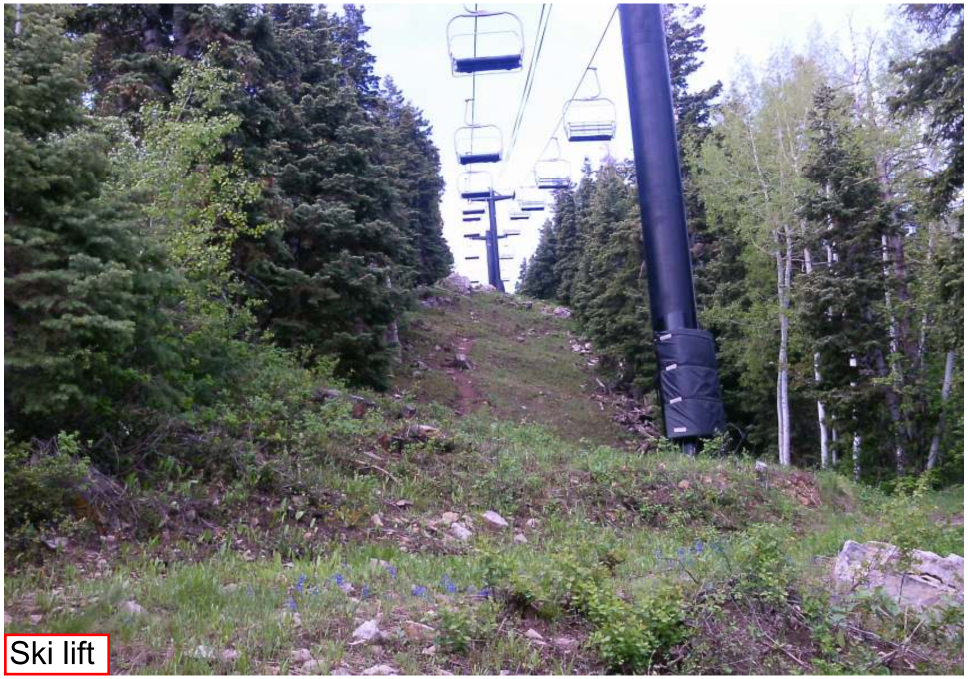

Typical vegetation


Fractured material and mine vent


Bike trail


Bike trail


Typical vegetation

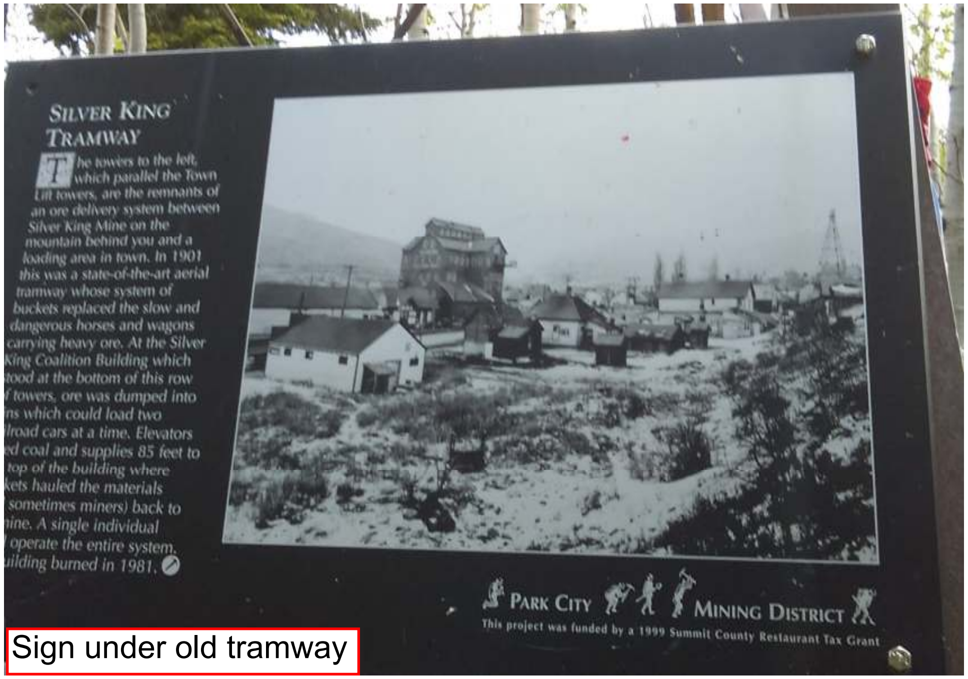

Ski lift


Mine vent/sinkhole


Mine tailings and typical vegetation


Ski lift and bike trail


Typical soils and vegetation



Sign under old tramway


Access road at top of ski run


Mine vent/sinkhole and bike trail


Vegetated ski run

MPE Inc.
Treasure Project Hydrology Review
Exhibit B - Flow Results

Existing Scenario

	Undeveloped Subbasin					
	10 yr			100 yr		
	Runoff		Volume	Runoff		Volume
Duration	cfs	inches	ac-ft	cfs	inches	ac-ft
1 hr	0	0	0.00	0.394	0.006	0.03
3 hr	0	0	0.00	1.245	0.028	0.13
6 hr	0	0	0.00	1.622	0.06	0.27
12 hr	0.212	0.009	0.04	2.296	0.163	0.73
24 hr	**0.467**	**0.062**	**0.28**	**2.897**	**0.313**	**1.40**

	Park City Residential Subbasin					
	10 yr			100 yr		
	Runoff		Volume	Runoff		Volume
Duration	cfs	inches	ac-ft	cfs	inches	ac-ft
1 hr	**1.266**	0.388	0.04	**2.861**	0.892	0.09
3 hr	0.63	0.518	0.05	1.395	1.077	0.11
6 hr	0.431	0.687	0.07	0.847	1.242	0.12
12 hr	0.318	0.926	0.09	0.587	1.612	0.16
24 hr	0.224	**1.25**	**0.13**	0.375	**2.02**	**0.20**

Future Scenario

	Undeveloped Subbasin					
	10 yr			100 yr		
	Runoff		Volume	Runoff		Volume
Duration	cfs	inches	ac-ft	cfs	inches	ac-ft
1 hr	0	0	0.00	1.366	0.02	0.09
3 hr	0	0	0.00	2.465	0.057	0.26
6 hr	0.026	0.001	0.00	2.817	0.101	0.46
12 hr	0.475	0.026	0.12	3.627	0.23	1.05
24 hr	**0.745**	**0.103**	**0.47**	**4.021**	**0.408**	**1.86**

	Park City Residential Subbasin					
	10 yr			100 yr		
	Runoff		Volume	Runoff		Volume
Duration	cfs	inches	ac-ft	cfs	inches	ac-ft
1 hr	**1.255**	0.403	0.04	**2.808**	0.917	0.09
3 hr	0.625	0.537	0.05	1.36	1.104	0.11
6 hr	0.424	0.709	0.07	0.823	1.27	0.12
12 hr	0.311	0.951	0.09	0.567	1.643	0.16
24 hr	0.218	**1.278**	**0.12**	0.361	**2.051**	**0.20**

	Treasure Project Subbasin					
	10 yr			100 yr		
	Runoff		Volume	Runoff		Volume
Duration	cfs	inches	ac-ft	cfs	inches	ac-ft
1 hr	**12.909**	0.69	0.36	**26.175**	1.413	0.74
3 hr	6.034	0.894	0.47	11.274	1.65	0.87
6 hr	3.866	1.138	0.60	6.439	1.855	0.98
12 hr	2.579	1.457	0.77	4.14	2.298	1.21
24 hr	1.67	**1.864**	**0.98**	2.513	**2.768**	**1.46**