1. EXECUTIVE SUMMARY

This report was prepared by Geosyntec Consultants Inc. (Geosyntec) for the City of Klamath Falls (City) to summarize the results of hydrogeological review of the City's water supply and geothermal wells. The hydrogeological review was conducted to 1) better understand the technical justification for an Oregon Water Resources Department (OWRD) request to shutoff two City water supply wells in the summer of 2014, and 2) assess the long-term sustainability of their water supply and geothermal wells. The OWRD requested shut-off of two City wells: KLAM 53015 (Fremont, City well 11) and KLAM 10146 (Wocus, City well 1) was *"due to insufficient stream flow for senior water users downstream"* in a letter dated 6 June 2014 (OWRD, 2014a).

The hydrogeological review consisted of the following:

- A review of geology and hydrogeology, including a US Geological Survey (USGS) regional groundwater model,
- An evaluation of City well logs for the Wocus, Fremont, Conger well field, and geothermal wells,
- A review of water levels and pumping data for these wells,
- A review of the OWRD model used as the basis for the shut-off notice, and
- Model testing using the OWRD model and an alternative model to evaluate groundwater-surface water interaction.

The geology in the vicinity of the City's wells generally consists of fine-grained lake/river deposits near the ground surface, which are underlain by interbedded basaltic lava flows (volcanic units) and mudstone (sedimentary) units up to the maximum depth of the City's wells. The City's wells typically obtain water from both the volcanic and sedimentary units, and the aquifer properties, including horizontal and vertical hydraulic conductivity, are significantly different between these units.

The USGS developed a regional (i.e. large) scale groundwater model which was reviewed to compare aquifer properties at and in the vicinity of the City's wells and surface water bodies. Other data obtained for the Klamath Basin included precipitation data, and surface water flow and water levels for Klamath Lake and the Link River, which are in close proximity to the City's wells. The data was used as alternative input values in the OWRD model and an alternative model to represent more site-specific conditions.

The City pumping data and water levels were also evaluated and used as input values in the OWRD model and an alternative model. The City water level data were also

reviewed to evaluate long term trends. The findings from review of the OWRD model were as follows:

- The OWRD used the Hunt analytical model for hypothetical stream depletion to calculate depletion of surface water by pumping from the City's production wells.
- Unrealistic and overly conservative model input values included:
  - Use of permitted water rights for pumped water volumes,
  - A constant irrigation pumping timeframes (i.e. 180 days), and
  - Too high vertical hydraulic conductivity.
- The OWRD model assumed the aquifer is solely supplied through the connection with the surface water, which is not the case in this aquifer system where water also is supplied from underlying hydrogeologic formations.
- Changing any one of the model input values noted above results in drastically lower stream depletion rates.
- Use of actual City well pumping rates in the OWRD model for the Wocus and Fremont wells does not result in stream depletion above the threshold of 0.1 cfs after a 90-day recovery period (draft proposed OARs).

An alternative model was used to evaluate potential surface water depletion from pumping from the Wocus and Fremont wells and the Conger well field, using geologic and hydrogeologic and actual City pumping data. The modeling results were as follows:

- The Wocus and Fremont wells do not show stream depletion above the estimated threshold in the draft proposed OARs (i.e. 0.1 cfs after 90-days recovery).

- The Conger well field (five wells analyzed together) model results indicate:
  - A potential impact to surface water (Link River);
  - Essentially complete recovery of surface water depletion would occur in a few days using a time-dependent model; and
  - A residual depletion of surface water 90-days after pumping ceases would be less than the OWRD threshold of 0.1 cfs.
  - Future analyses could use less-conservative assumptions to further refine the model to demonstrate individual well performance and enable the City to be more strategic with the timing of when wells are pumped.

A review of water levels in geothermal wells indicate:

- A slight decline over the time period reviewed.

- Relatively stable conditions at the current pumping and reinjection rates.
- Additional and expanded well monitoring to provide a more consistent dataset, broaden the study area, and improve the quality of the data collected.

Conclusions

- The OWRD model is flawed for municipal use for several reasons (e.g. unrealistic hydraulic properties and pumping schedules). Using the modified input values, the OWRD model reveals considerably less impacts, but is still flawed (assumed the aquifer is solely supplied by the surface water).
- An alternate model was used because it more accurately represents the natural aquifer conditions. The model results indicate that potential surface water depletion by the City's well fields is negligible relative to average rate of at which water is released from Klamath Lake to the Link River.
- The calculations for stream depletion are below the threshold OWRD criteria of with the exception of the Conger well field.
- Numerical modeling (MODFLOW) is not recommended at this time because:
    - it isn't needed to find flaws in the OWRD model; and
    - it would also include many assumptions and wouldn't provide more certainty when compared to less expensive alternatives (e.g. additional monitoring)
- The stability of water levels in the City wells indicates the production from the wells is sustainable.
- It was recommended to continue monitoring water levels from the City's and other private water supply and geothermal wells to show the water levels are or are not systematically decreasing.