The below write-up identifies accepted guidelines for spacing of multiple cooling towers on a single site as well as other criteria normally considered when locating cooling towers. As indicated below these guidelines and criteria were used during the JUOTC Phase I Study to identify the best technical location without regard to cost to site cooling towers for the closed cycle cooling options. As a result of public comment, the southern site identified in other studies was revisited and the results are provided below.

COOLING TOWER LOCATION CRITERIA

Cooling Tower Spacing Requirements for Multiple Tower Sites

When there are several cooling towers located on one site, the proper placement of the towers in relation to each other is an extremely important consideration. The reason is to minimize the occurrence of interference, where the hot, humid exhaust air from one cooling tower is entrained into the air inlet of an adjacent tower which raises the inlet wet bulb temperature of the impacted tower and results in decreased thermal performance (increased hot water temperature). If there is not adequate space provided between cooling towers they will not perform as designed. There are published industry reports and guidelines based on testing results and tower manufacturer expertise that define minimum distances that cooling towers should be situated from each other in order to minimize the occurrence of interference. Two examples of these industry publications are the Cooling Tower Institute Technical Sub-Committee #2 Report on the Study of Recirculation (PFM-110) and Cooling Tower Fundamentals published by SPX Cooling Technologies, Inc. Excerpts from each are attached (Attachment 1 and 2). Both publications offer similar guidance with regard to orientation and spacing of towers related to the prevailing wind direction.

The Cooling Tower Fundamentals also includes the following cautions

> *"Obviously, there are no rules of thumb which will cover every conceivable situation. Nor are the indicated guidelines intended to take the place of direct contact and discussion with a reputable cooling tower manufacturer. Considering that the location and orientation of the tower can impact the entering wet-bulb temperature from as little as 0.5°F, to as much as 3°F to 5°F, the user would be wise to invite as much expert assistance as possible."*

For this reason, Bechtel consulted with the cooling tower manufacturers that provided the designs for the towers proposed in the DCPP report and obtained the recommended minimum spacing required between the towers, specific to each tower type. The proposed layouts in the Phase II report reflect the requirements of the before mentioned publications as well as manufacturer recommendations.

In addition it should be noted that the above guidelines assume that the multiple towers are located at the same relative locations. If the adjacent towers are not at the same relative elevations spacing requirements will tend to increase in order for the tower performance to be guaranteed.

Other Cooling Tower Siting Considerations

Location of the cooling tower on site is also a consideration when developing a plant site. Efforts are taken to minimize the effects that drift (circulating water lost from the tower as water droplets entrained in the exhaust air stream) on plant equipment and plant and community roads. Drift can leave deposits on surrounding equipment and structures that may adversely affect the equipment. It also can be "seen" as fog that can create visibility or icing hazards on nearby roads. The drift will result in the need for additional maintenance on equipment and structures in the surrounding area of the towers. Once the location was selected and the Phase 1 report was approved by the Review Committee Bechtel proceeded with the preliminary design at the northern location.

DCPP Cooling Tower Recommended Locations

The Phase I Study considered the following criteria in siting the cooling towers for the closed cooling water option:

- Proper spacing to obtain the best performance using good engineering practices
- Minimizing the effects on existing plant infrastructure and operations

The feasibility of locating the towers in the southern location was reviewed early in Phase 1 of this effort. Based on the review it was found that it is likely feasible to utilize this area for the cooling towers but significant additional excavation (approximately 75% of the excavation quantity required for the northern location) would be required to accommodate the foot print need for properly spaced towers. Routing piping between the proposed cooling towers and the turbine building would also prove challenging. There are critical plant structures at the southern location that could not be relocated and are in the corridor through which the circulating water return ducts/pipes would have to pass. There may not be sufficient space to accommodate the ducts/pipes without removal of the critical plant structures. Based on the significant excavation required for the towers, combined with the pipe routing complexities and fact that the current main access route and plant facilities are all located south of the plant it becomes evident that the southern area is not the optimum location for the towers and the Phase I study concluded that the north location would be the more acceptable solution.

As a result of the public comments on the JUOTC Phase II Study, the area south of the turbine building was again revisited. Tower arrangements using the Cooling Tower Institute Report, the SPX publication and recommendations received from recognized cooling tower suppliers as guidance where superimposed over the area. Only the tower arrangement that is representative of the wet mechanical and hybrid towers are included here as these take the least amount of space. Refer to Figure 1. In all cases, significantly plant area is required to be excavated in order to install the towers. Much of the existing structures and infrastructure in the area south of the turbine building would have to be removed and replaced at some other location. Circular hybrid towers were recommended by the cooling tower supplier as these are less sensitive to recirculation and require less plot area than the traditional hybrid towers. Tower spacing shown was based on input supplied by the tower manufacturer. Other proven hybrid towers in the size needed for this plant are single line towers with heating coils installed near the outlet. A back-to-back arrangement is only available using SPX Clear SkyTM cooling tower. Unfortunately there is little operating experience with these towers and none available in the size that would be required at Diablo Canyon.

Attachment 1

Excerpt from Cooling Tower Institute Technical Sub-Committee #2 Report on the Study of Recirculation (PFM-110)

Tower Orientation

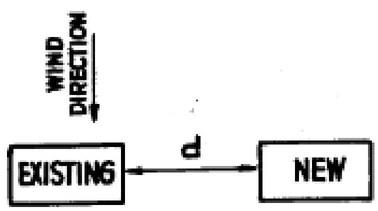
Wind direction was found to have no effect on the correlation given in Figure 2, where only the maximum recirculation test for each tower was considered. However, an examination of the 6 tests on individual towers revealed that less recirculation occurs on short cooling towers when the wind direction is parallel to the longitudinal axis. Subsequent tests and additional data on cooling tower recirculation indicate that regardless of tower size, type or configuration, the tower should be oriented so that the longitudinal axis of the tower should be parallel to the wind direction for minimum recirculation.

a. Towers less than approximately 250 ft long should be aligned with the prevailing summer wind direction.

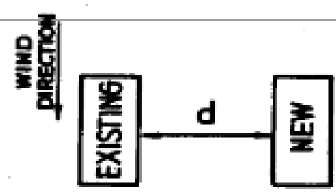
b. Towers longer than 250 ft should be placed perpendicular to the prevailing summer wind direction.

For orientation of a new cooling tower to be installed near an existing tower, the following recommendations apply:

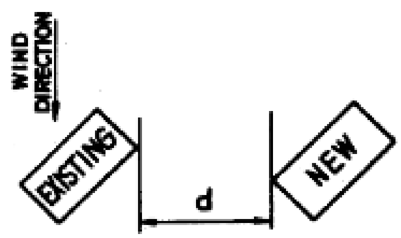
1. *Where the long axis of the existing tower is perpendicular to the prevailing summer wind direction,* the influence of the old tower on the new is minimized if the distance between the towers is greater than their average length ("d"). The new tower's long axis will be in line with the old tower's long axis.



2. *Where the long axis of the existing tower is parallel to the wind direction,* the influence of the old tower on the new is minimized if the distance between the towers is greater than their average length.



3. *Where the long axis of the existing tower is at a 45° angle to the wind direction,* the influence of the old tower on the new is minimized if the distance between the towers measured normal to the wind direction is greater than their average length. The ends of the old tower and the new tower should be in line so that an offset of at least one tower length exists.



Conclusion

The recommendations submitted in this paper offer a satisfactory direct method for making allowance for recirculation in cooling tower design.

Notation

- acfm — actual air volume; cu ft per minute
- d — distance between two cooling towers; ft
- G — mass air flow; lb dry air per hr
- gpm — circulating water flow rate; gallons per minute
- h — enthalpy of air-water vapor mixture; Btu per lb dry air
  - h_1 — enthalpy of exhaust air
  - h_a — enthalpy of ambient air
  - h_2 — enthalpy of average entering air
  - h_w — enthalpy of air on windward side
- L — mass water flow; lb per hr
- L/G — liquid-to-gas ratio; lb water per lb dry air
- R — cooling range; F
- R_e — per cent recirculation; per cent of total entering air quantity (lb) which is exhaust air

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1. Lichtenstein, J., Performance and Selection of Mechanical-Draft Cooling Towers, *Transactions* of The American Society of Mechanical Engineers, Vol. 65, No. 7, October 1943, pp. 779-787

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3. Smith, L. G. and Williamson, G. J., The Development of a Mechanical-Draught Water-Cooling Tower, *Proceedings* of Institution of Mechanical Engineers, Vol. 170, 1956, pp. 1-20; and *Proceedings* of Institution of Civil Engineers, Vol. 5, No. 2, Part I, March 1956, pp. 86-117

4. Willa, J. L. and CTI TSC #2, Instrumenting a Field Study of Industrial Water-Cooling Tower Performance, *Transactions* of The American Society of Mechanical Engineers, Vol. 79, No. 7, October 1957, pp. 1679-1684

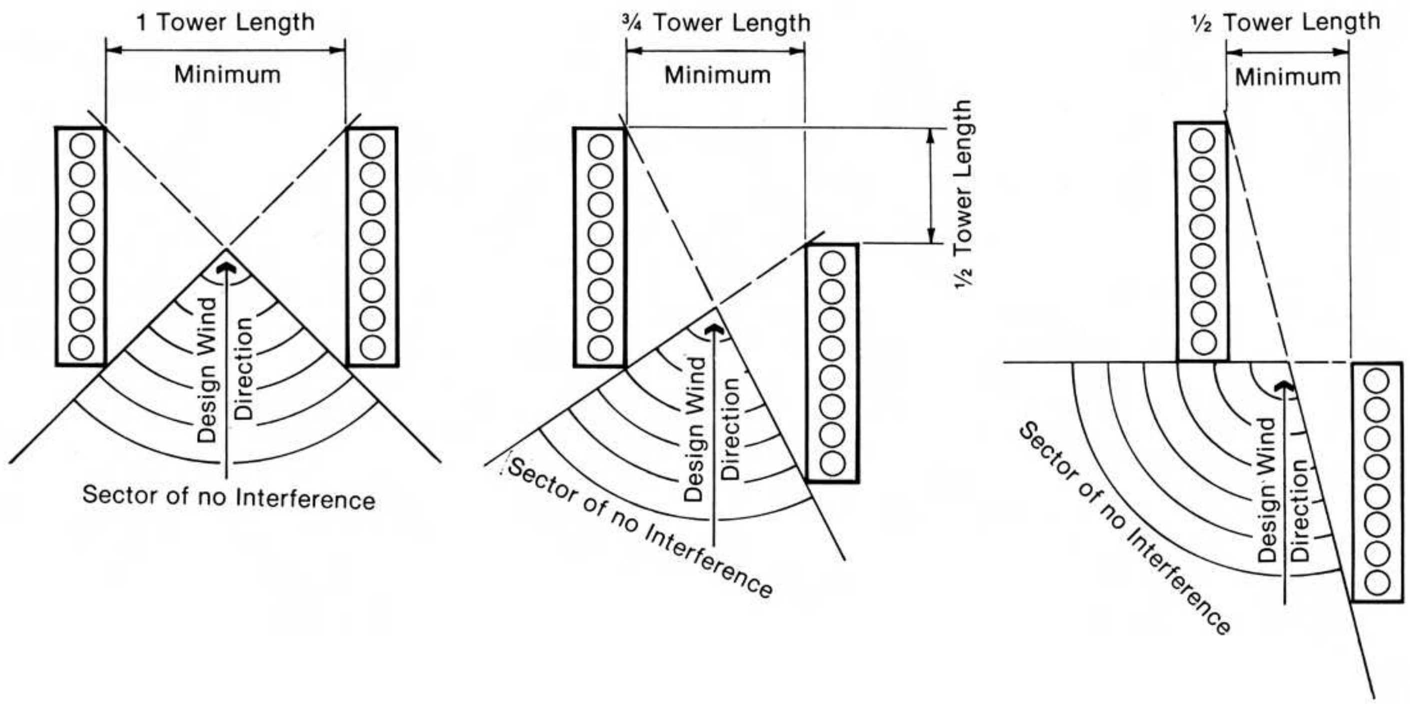


Figure 37 — Proper orientation of towers in a prevailing longitudinal wind. (Requires relatively minimal tower size adjustment to compensate for recirculation and interference effects.)

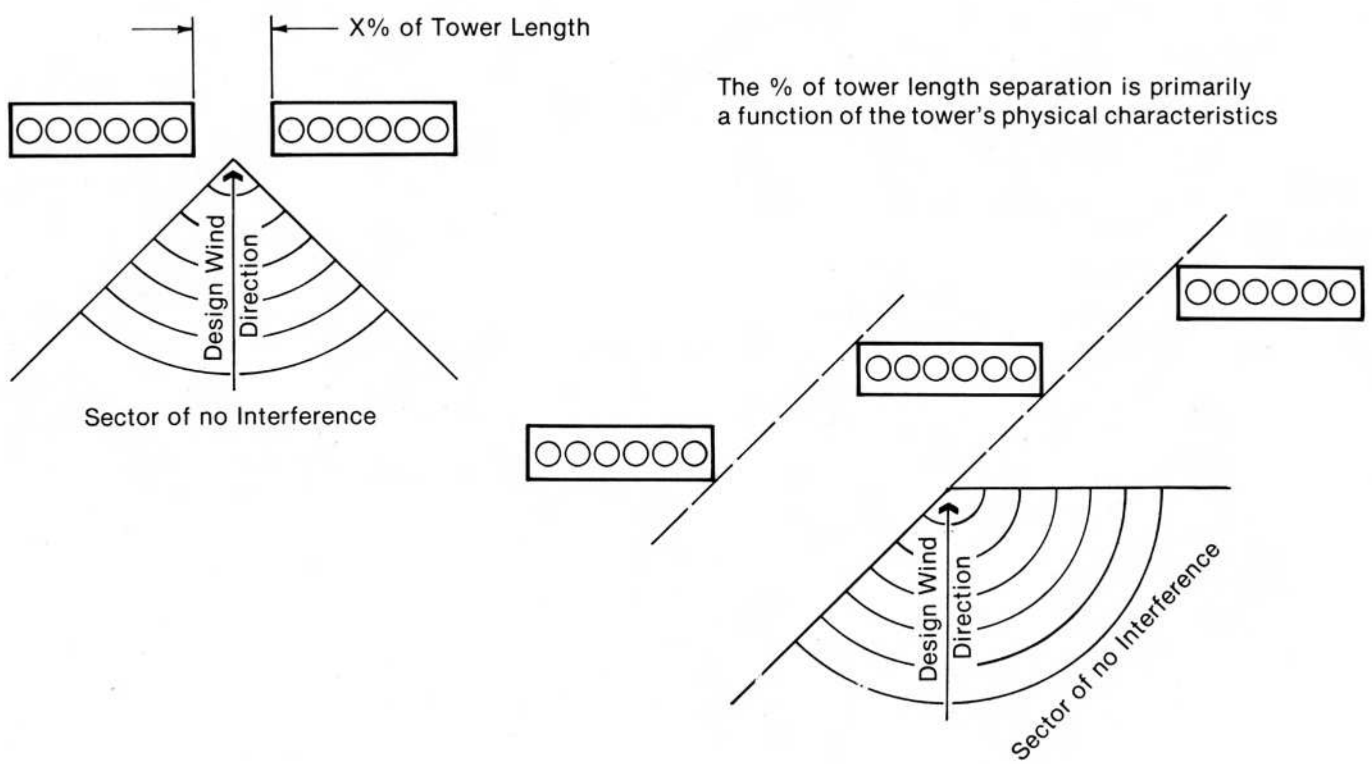


Figure 38 — Proper orientation of towers in a prevailing broadside wind. (Requires significantly greater tower size adjustment to compensate for recirculation and interference effects.)

the ends of the towers, the net amount of recirculatory effect may well have been halved.

c. ***Interference***: Similarly, multiple towers should not be situated such that any tower is within the downwind interference zone (lee) of another tower or extraneous heat source. If a tower is so located, then its design wet-bulb temperature should be adjusted appropriately.

Although the round tower indicated in Figure 32 suffers relatively little from recirculation, it is certainly not immune to interference from an upwind tower, nor will it hesitate to impact a downwind tower under certain atmospheric conditions.

d. ***Effect on Site Piping***: The need for proper siting and orientation is fundamental to a tower's ability to cool water dependably, and must take precedence over any concern as to the quantity or complexity of site piping required to accommodate the appropriate cooling tower layout. On relatively small installations, the extent of cooling tower relocation that may be required usually has an insignificant impact on total piping cost. Large multi-tower projects, however, typically require several hundred feet of pipe of appreciable diameter, representing a portion of the overall project cost that is anything but insignificant.

As will be seen in Section II-D, the multiplicity of water distribution system arrangements available on crossflow cooling tower designs coordinate to reduce the required site piping to a minimum for rectilinear tower layouts. As can be seen in Figure 39, however, most effective reductions in site piping requirements occur when either hyperbolic or round mechanical draft towers are chosen. This is because of their inherent tolerance to much closer spacing.

Obviously, there are no rules of thumb which will cover every conceivable situation. Nor are the indicated guidelines intended to take the place of direct contact and discussion with a reputable cooling tower manufacturer. Considering that the location and orientation of the tower can impact the entering wet-bulb temperature from as little as 0.5°F, to as much as 3°F to 5°F, the user would be wise to invite as much expert assistance as possible. On certain critical projects involving appreciable heat loads, it may well be advisable to consider site-modeling for wind tunnel study.

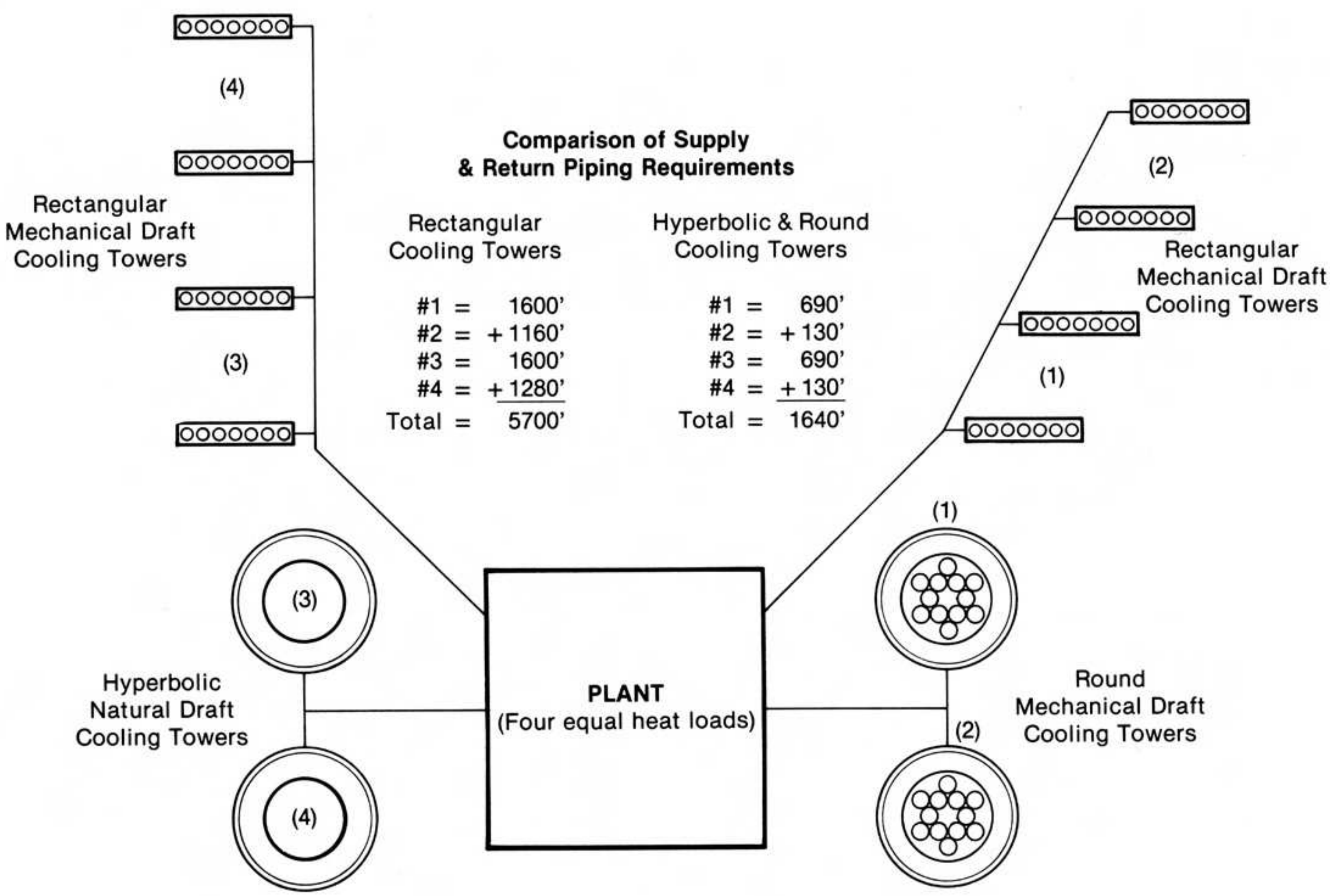
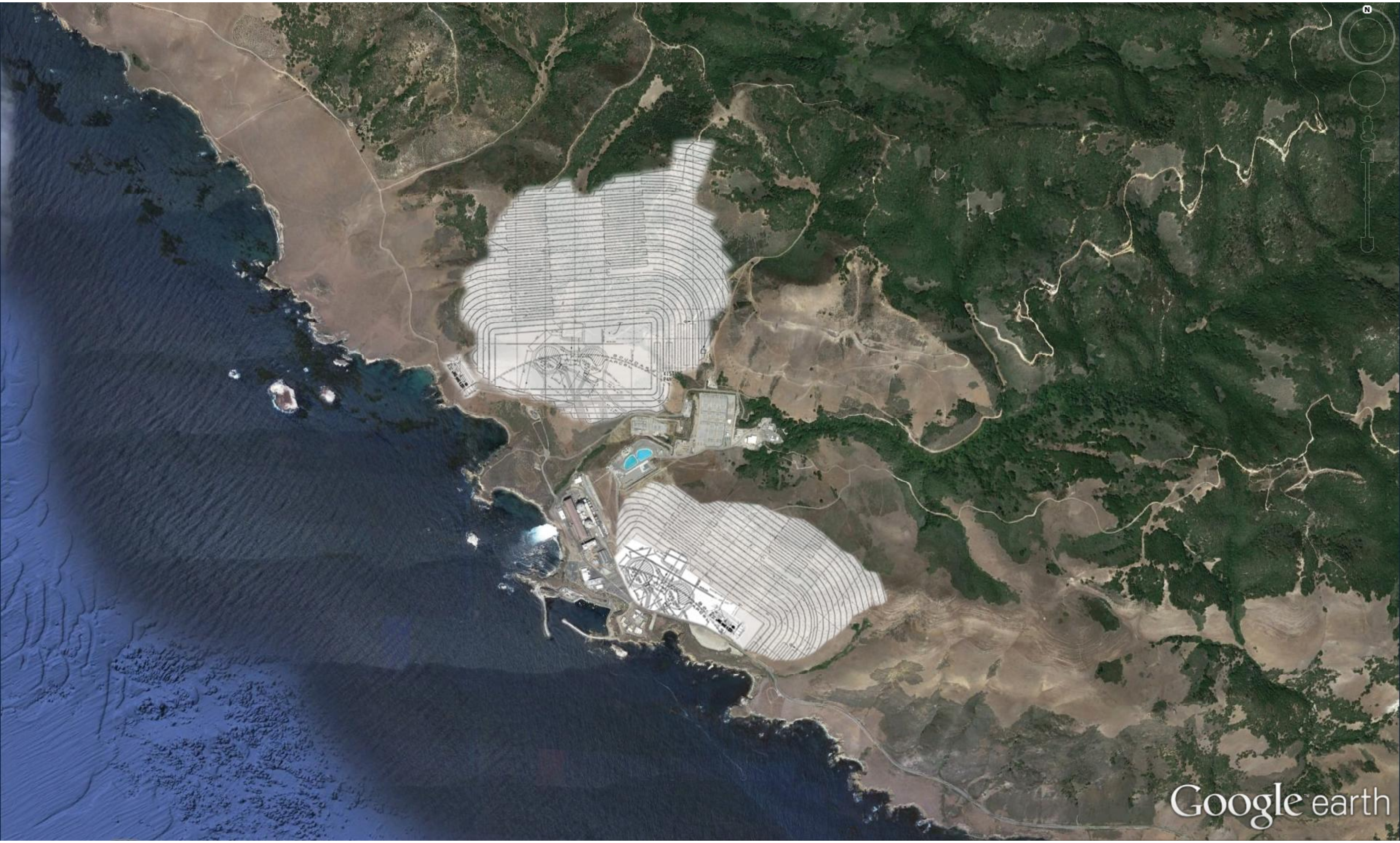


Figure 39 — Comparison of piping and ground use for both rectilinear towers and round towers. (Both types selected for equal performance.)


Google earth