Horning Geosciences

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Chad Sweet, City Administrator
City of Gearhart
PO Box 2510
Gearhart, OR 97138

RE: Geologic Hazard Reconnaissance of Potential New Fire Station Sites; nine sites in the greater Gearhart vicinity, Clatsop County, Oregon

Dear Chad:

At your request, Horning Geosciences has reviewed nine possible sites for a future fire station in the Gearhart area for geologic hazards with likely mitigation solutions for the hazards. The sites have been scored in the table below to assist comparison. The hazards include: 1) uneven settlement of loose soils and fill; 2) liquefaction of water-saturated soils and fill from earthquake shaking; 3) seismic shaking amplification due to thick, low-seismic-velocity soils or fill; 4) tsunami inundation (L-1 Large model); 5) co-seismic subsidence high standing water; and 6) seismically triggered landslide. The assessment of hazards is based on our understanding of geologic processes, based on more than 20 years of consulting in the area, plus a review of geologic maps, LIDAR imagery, and modeling scenarios by the Oregon Department of Geology and Mineral Industries. This study is based on tsunami run-up elevations of the L-1 Large tsunami. Relevant maps and figures are attached to this summary to assist in the findings.

LOCATION	Gearhart Park	Current Site	Trails End	Palmberg	Meadow Ct	Gearhart By The Sea	Highlands Lane	Fraser Property	Somewhere in the Hills*
Settlement/Fill	1	2	1	2	2	2	1	1	1
Liquefaction	0	1	1	3	2	0	0	0	0
Shaking Ampl.	2	2	2	2	2	2	2	2	1
Tsunami	2	3	3	4	3	0	0	0	0
Coseismic Flood	0	0	0	2	1	0	0	0	0
Landslide	0	0	0	0	0	0	0	0	1
TOTAL	5	8	7	13	10	4	3	3	3

Low totals are better than higher. *Water tank site, inside the fencing; other, better, sites may be available on stable ground.

Gearhart Park Location

Gearhart Park dune sand probably has been disturbed, but it is likely to be relatively limited, requiring only reconnaissance testing and improvement, as needed. Liquefaction hazard is limited to nil, given that the site is more than 20 ft above expected groundwater tables during wet winters. Seismic shaking amplification, like almost all other sites in the dunes, will occur, but can be mitigated by good design and construction. Tsunami run-up is projected to range up to 10 ft. Erosional retreat of the ocean beach, caused by co-seismic subsidence will approach the west slope of the dune but will not disturb this site. Overall, not a bad site, except for tsunami.

Rebuild in Current Location

Up to 10 ft of fill underlies the existing building. It poses a probable settling and liquefaction hazard that can be mitigated by digging out the fill and installing it back in compacted lifts, or instead with pit-run quarry rock or other suitable fill. Mat foundations or pilings may be necessary if deeper underlying sand is at risk of seismic liquefaction during rainy winters and high groundwater tables, to be determined. Shaking amplification due to thick alluvium can be mitigated by good design and construction. Tsunami inundation may be up to 10 ft, provided the site is at road grade. Tsunami inundation is s problem.

Trails End Park Location

The site is underlain by dune sand and will need to be filled with about 10 to 12 ft of sand or pit-run quarry rock to bring it up to the grade of Pacific Way. The fill will need to be installed and compacted in lifts to ensure appropriate densification standards. During rainy winters, the underlying sand may be susceptible to possible liquefaction from shallow groundwater tables; to be determined. Compaction of the deeper sand needs to be addressed prior to filling to determine its relative density; possibly it may need to be excavated and laid back in compacted lifts, or deep piling foundations or mat foundations may be needed to offset the expected liquefaction. Seismic shaking will be amplified for the site due to the thick alluvium; a minor problem that can be offset by appropriate design and construction. The site will be inundated by the L-1 Large tsunami to a depth of up to 10 ft, once the fill brings the site up to road level. Otherwise, the flooding will be as much as 20 ft over the existing field. Tsunami inundation is a problem.

Palmberg Property Location

Site of a former rock crushing operation that exploited local round-rock deposits, Palmberg has disturbed ground that might require earth-work excavation, laying back in compacted lifts the disturbed deposits of sand and rock. The water table is very close to the surface, making liquefaction a major problem, most likely to be dealt with by using piling foundations to carry loads to depth. Shaking amplification will be high, very much like most of Gearhart, although it can be mitigated by proper design and construction. Tsunami inundation will be on the order of 15 to 30 ft; a serious challenge. Co-seismic subsidence will cause a permanent rise of the water table of as much as 5 ft, making this site a possible future wetland, or seasonally flooded site. Because of landscape features in Gearhart and Seaside, this site will not drain well soon after the tsunami and will be impassable for at least several days due to standing salt water. Swamps and marshes in the area will become open lakes because of subsidence of the land. Roads may be permanently flooded. This is a poor site.

Meadow Court Location

Dune sand will require sand compaction, as needed. Low site elevation means the water table is near the surface, which raises the liquefaction hazard. Shaking amplification is significant but can be mitigated by design and construction. The site will be inundated by 10 to 20 ft of water in the L-1 Large tsunami mode. Co-seismic subsidence of up to 5 ft will raise the water table, possibly causing long-term flooding. Tsunami inundation is a problem.

Gearhart by the Sea Location

This dune site is above expected tsunami run-up. Shallow sand may be disturbed from past construction and may require excavation and laying back in lifts with proper compaction. Liquefaction hazard is nil, as saturated sand is more than 20 ft beneath the surface. The site will experience seismic shaking amplification, as will nearly all other sites, and this can be mitigated with good design and construction. Co-seismic beachfront erosion will not reach beyond the west slope of the high dune on which this site is located. (Land north or south of McMennamin's, east of Marion Drive, could be the site of the project, close enough to condo-blocked views not to cause significant

community objection. The structure could be built on fill or on the native slope with engineered foundations, resulting in a new fire station at street level, equipment storage below, possibly with a second story City Hall, and a third-story vertical tsunami evacuation platform. The site could be west of Marion, as well.) There is a limited possibility that the tsunami could be higher than the L-1 scenario, although this is exceedingly unlikely. This is an excellent site. *Comment 2*: The tall condos were constructed in the early 1970's and are highly susceptible to collapse from the earthquake, posing a large possible death toll. They should be hardened or replaced; perhaps with a layout that incorporates the new fire station; perhaps in a collaborative process.

Highlands Lane Location

Located outside of tsunami inundation, this site is underlain by undisturbed dune sand and is at least 20 ft above the local water table, minimizing liquefaction risk. The dune sand may need to be compacted some to resist settlement during shaking, but likely very little. Shaking amplification will be like all other sites in the dunes and can be mitigated by proper design and construction. It is a good site.

Fraser Property Location

Even higher in elevation (40-60 ft) than the Highlands Lane site (40-50 ft) and located outside of tsunami inundation, the Fraser property is underlain by undisturbed dune sand and is at least 20 ft above the local water table, minimizing liquefaction risk. The dune sand may need to be compacted some to resist settlement during shaking, but likely very little. Shaking amplification will be like all other sites in the dunes and can be mitigated by proper design and construction. It is a good site.

Somewhere in the Hills Location

Located above the end of Salminen Road, the nominal site is underlain by both basalt and mudstone bedrock. The water tank rests on deeply weathered, but highly stable basalt. Faults are mapped running near and through the vicinity of the tank, posing uncertain limited shaking amplification hazard. They appear to have weakened the mudstone to the point that it has experienced landslide movements in the past, as shown in Figure 4. The landslide does not reach the tank site, ensuring survival of resources inside the fence, but the road, buried water main, and proposed station site may be compromised. Other hillside sites do not have as much landslide hazard as this one, particularly the lane at the south end of Salminen Road (Figure 4; Figure 2- Evacuation Trail). Hillside sites are generally free of liquefaction, tsunami inundation, and significant shaking amplification. Roads crossing the marsh at the base of the hill should be elevated 5 ft above existing grades to be above the new post-earthquake/tsunami water table to ensure access to the fire station. Options include using fill with numerous culverts and hardening to resist erosion by strong tsunami currents, or the construction of a long bridge.

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Expires: 7/1/17

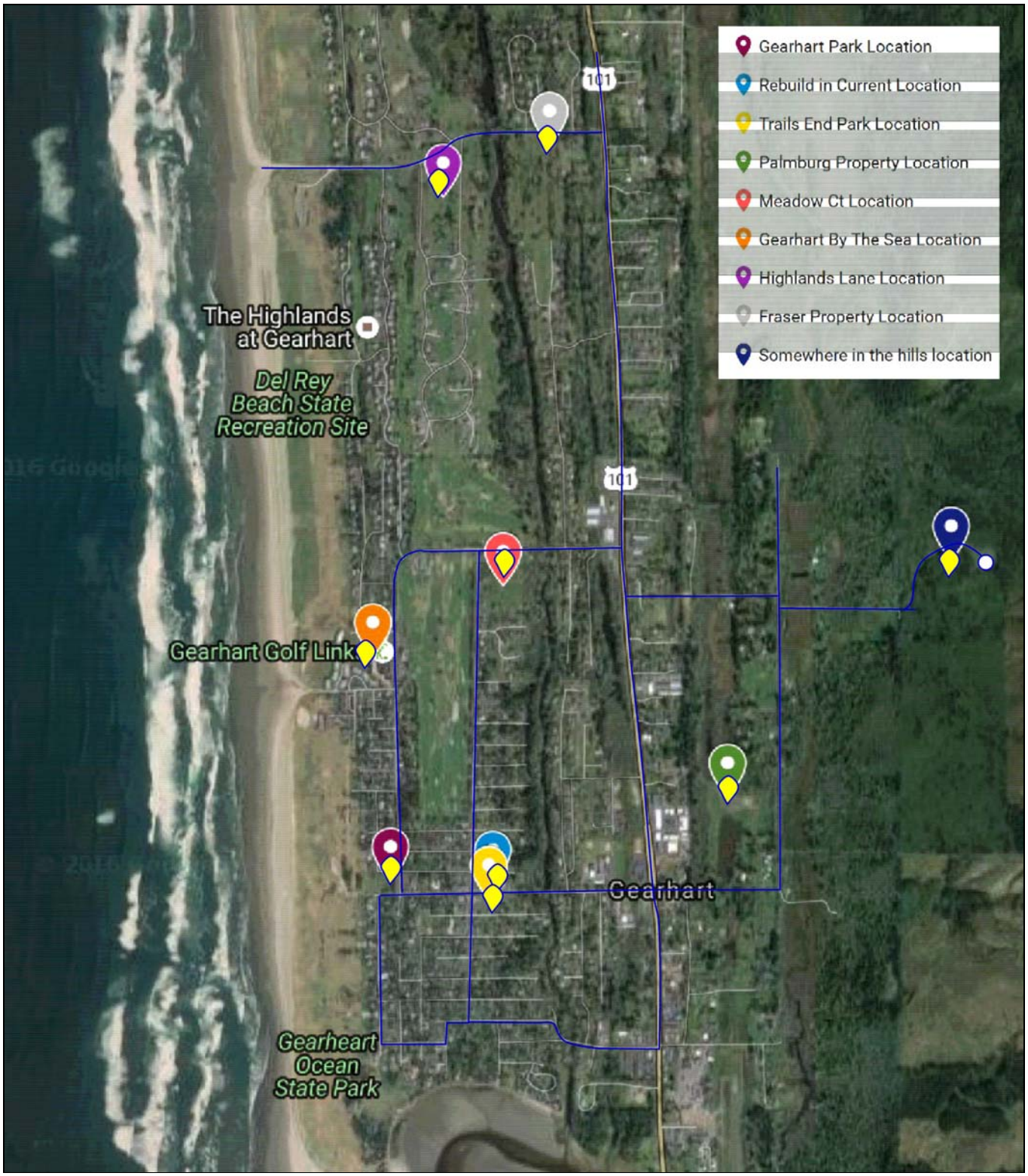

Figure 1: Aerial photo of the greater Gearhart area with nine possible sites for a new fire station. The smaller yellow symbols are reproduced and overlain on the following geologic maps of the area. Map provided by Dan Jesse, City Councilor.

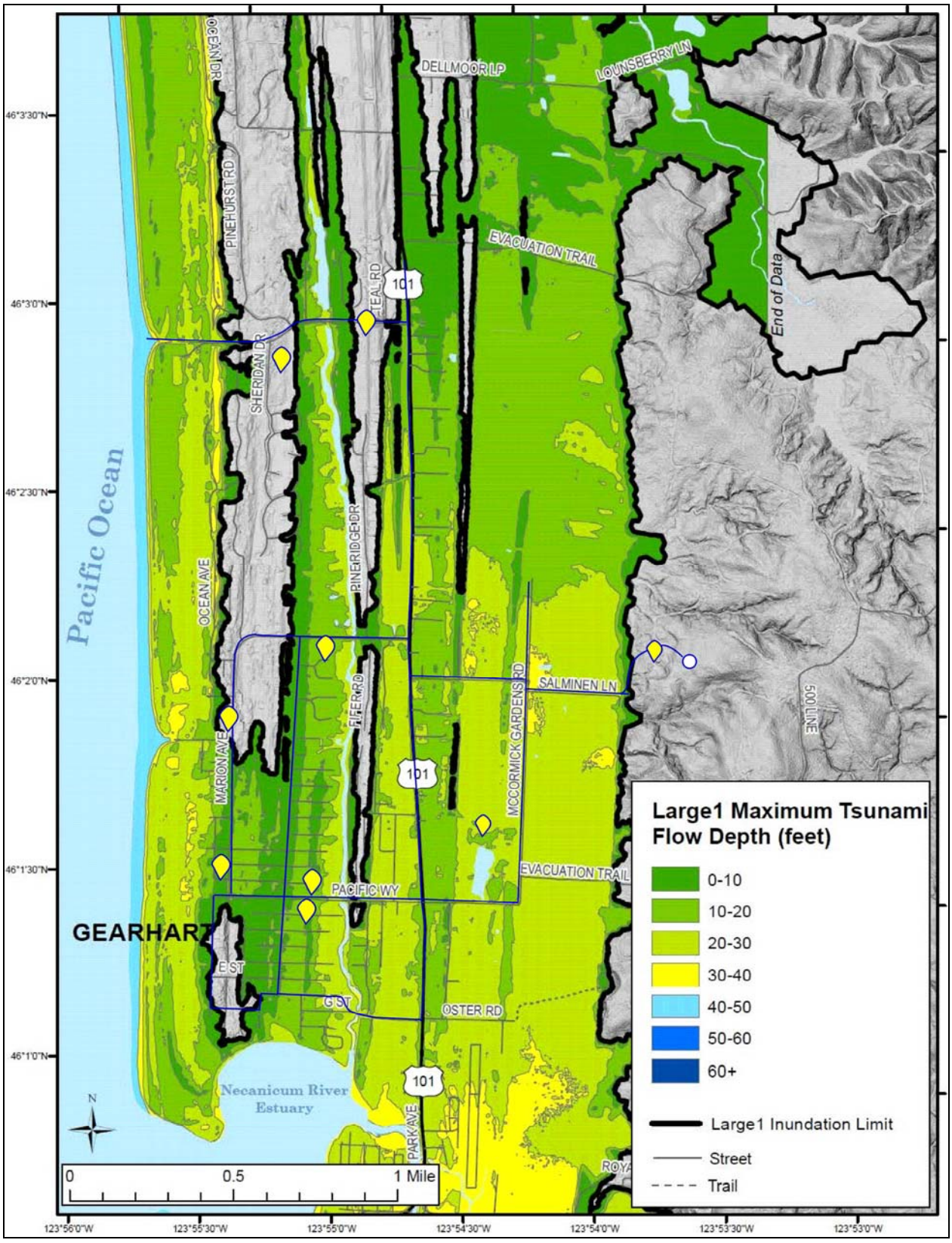

Figure 2: Maximum tsunami water flow depth map for the Gearhart area; water depth is color coded. This portrays run-up for a Large scenario wave, as shown in Figure 3. Uncolored areas are above tsunami run-up.

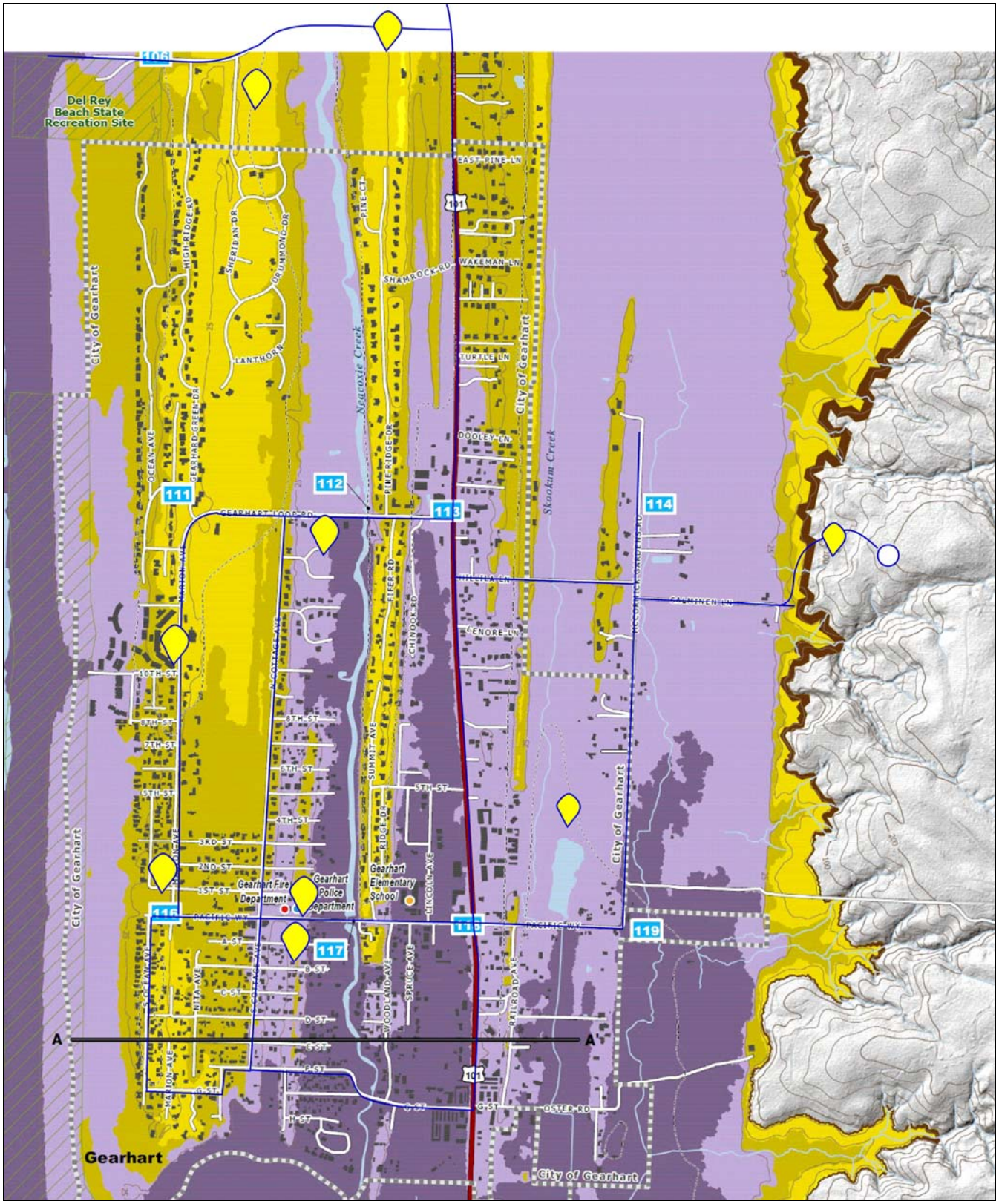

Figure 3: Tsunami inundation scenarios for Gearhart. Five wave height scenarios are color-coded: Small (dark purple), Medium (light purple), Large (dark mustard), Extra Large (yellow), and Extra-Extra Large (bright canary yellow). Extracted from the DOGAMI Gearhart TIM map.

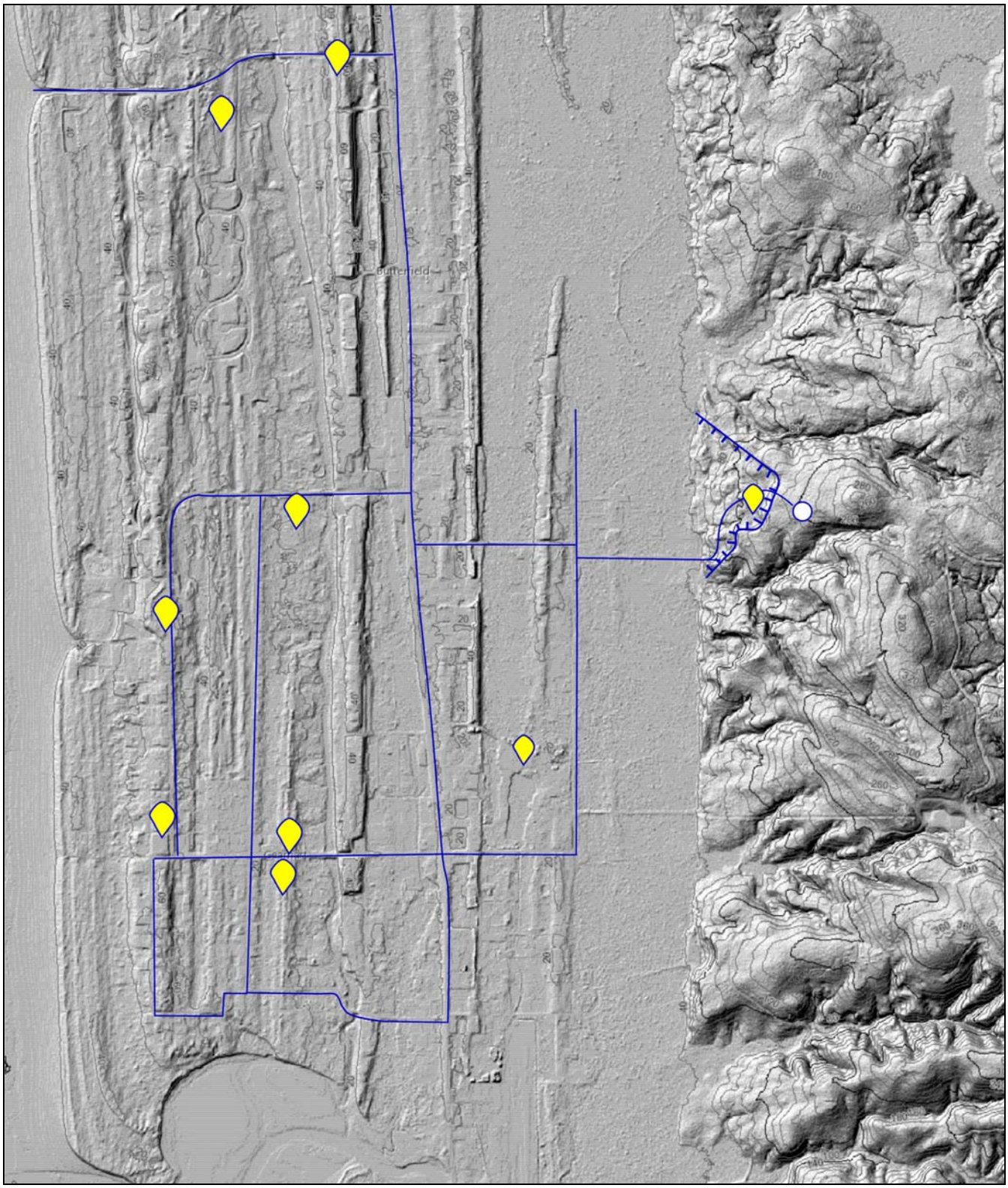

Figure 4: LIDAR map for the greater Gearhart area; blue hatched line denotes the boundary of a landslide at the east end of Salminen Road. The north side of the slide may be controlled by bedrock faults in mudstone, shown in Figure 5. The age of the slide is uncertain. It may have occurred in response to shoreline erosion 4500 years ago, or to seismic shaking during the ensuing period of time and 8 to 9 subduction zone earthquakes. Smooth hillslopes indicate areas free of landslide activity. Hills east of the south end of McCormick Garden Loop have limited landslide hazard. The swamp land will tend to flood and not drain after the earthquake.

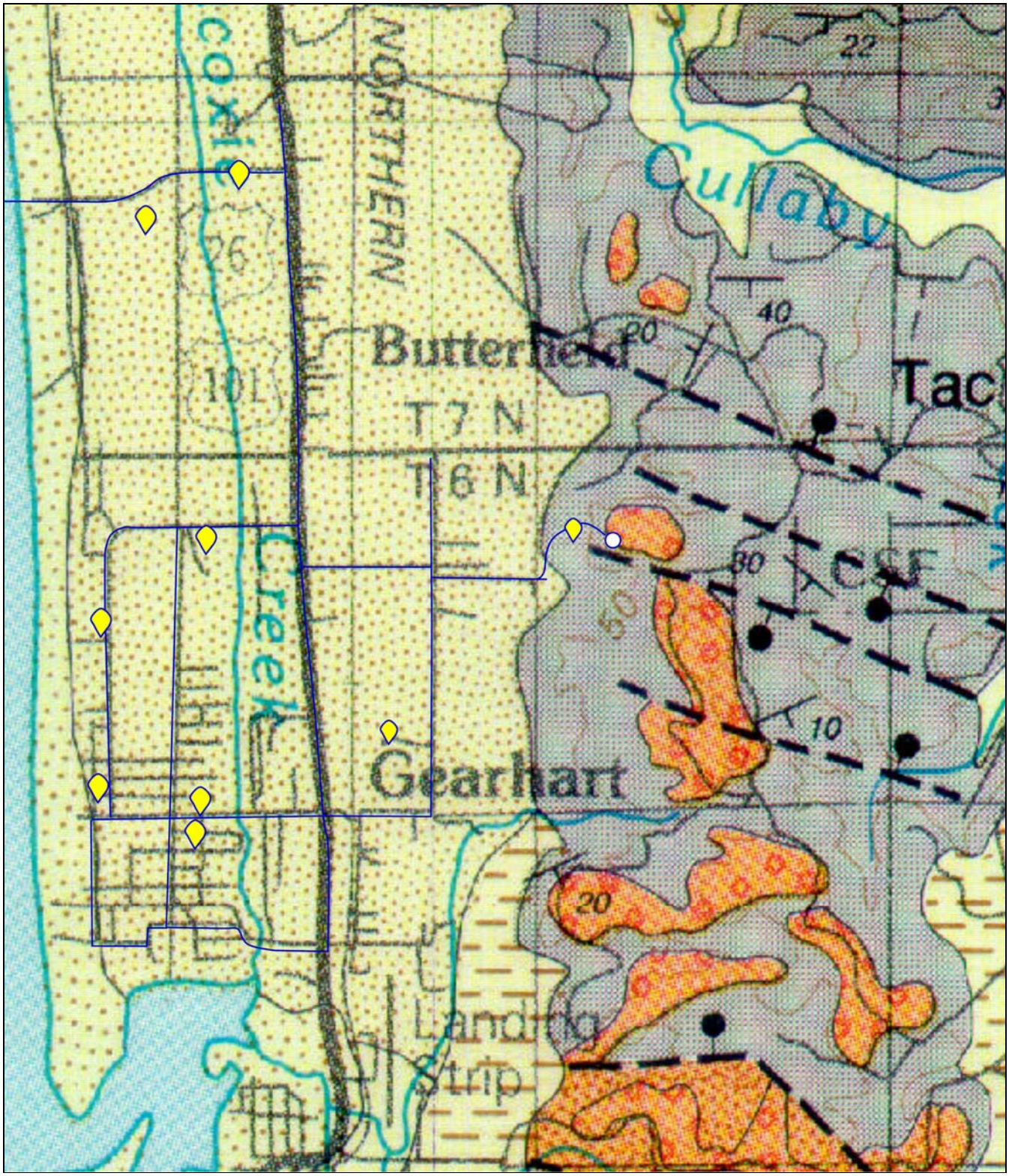

Figure 5: Geologic map for the Gearhart vicinity; after Niem and Niem (1985). Dune sand (straw-yellow stipple), laps against mudstone bedrock of the Cannon Beach member of the Miocene Astoria Formation (Tac), which is locally overlain or intruded by invasive pillow lavas of the 15-million-yr-old Frenchman Springs member of the Columbia River Basalt Group (orange, with circles). Minor deltaic sandstone (stippled orange) lies between the basalt and the mudstone in places. The water tank at Salminen Road lies on the edge of pillow lava bedrock, which will resist slope failure. The pipeline lying within weathered mudstone may be damaged by slope movements, based on interpreted landforms in Figure 4. Dark dashed lines are inferred faults; ball-on-stick denotes side of fault that has dropped.

References Cited

Niem, A. R., and Niem, W. A., 1985, Oil and Gas Investigation of the Astoria Basin, Clatsop and Northernmost Tillamook Counties, Northwest Oregon: OGI-14, State of Oregon, Department of Geology and Mineral Industries.

Priest, G.R., Stimely, L.L., Madin, I.P., and Watzig, R.J., 2015, Local tsunami evacuation analysis of Seaside and Gearhart, Clatsop County, Oregon; Open-File Report O-15-02; Oregon Department of Geology and Mineral Industries.