CHAPTER 4

SUMMARY AND RECOMMENDATIONS

4.1 SUMMARY

The report reviewed five low vibration techniques that have been used for ground improvement near existing structures. These five techniques are: compaction grouting, permeation grouting, jet grouting, *in situ* soil mixing, and drain pile. The factors which influence the effectiveness of each technique and thirteen available case studies of liquefaction remediation are reviewed in Chapter 2. Of these five techniques, only jet grouting and *in situ* soil mixing can treat all liquefiable soil types. Compaction grouting may be marginally effective in treating silts. Chemical grouts cannot permeate soils with more than about 25% fines (silt and clay). It seems that drains would be ineffective in ground with low permeability. Upon reviewing the available cases studies, one quickly becomes aware that very little has been reported on ground improvement near existing pipelines and other lifelines, let alone the actual seismic performance of sites treated by these techniques.

Six case studies of ground improvement near various lifelines are reviewed in Chapter 3. With great care and depending on their nature and condition, permeation and jet grouting could improve soil conditions immediately adjacent to lifelines. Compaction grouting could be applied beneath lifelines, but may not sufficiently compact soils immediately adjacent to them. The *in situ* soil mixing and drain pile techniques could possibly be effectively employed a short distance away (say 1 to 3 m). Other less expensive ground improvement techniques, such as vibro-replacement through pre-augered holes, could be used within about 1 m of many lifelines. A combination of techniques may provide the most cost-effective ground improvement solution.

4.2 RECOMMENDATIONS FOR FUTURE STUDY

The following recommendations are provided to identify areas that need further study.

1. Compile additional case studies of ground improvement near pipelines and other lifelines. These case studies should include detailed information about the condition of the lifeline, ground improvement procedures, verification techniques, and cost.

2. Compile additional case studies documenting the performance of improved ground during strong earthquake shaking.

3. Perform laboratory and field investigations to determine how much ground improvement is needed to protect pipelines and other lifelines.

4. Develop less expensive ground improvement techniques, since all the low vibration techniques reviewed are expensive to conduct.