ENGINEERING STANDARDS,

CONSTRUCTION SPECIFICATIONS

AND

DESIGN STANDARDS

TOWN OF HUDSON, COLORADO

Revised 1999

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I. INTRODUCTION

The Engineering Standards, Construction Specifications and Design Standards regulate both public improvements and private work which will either be dedicated to or accepted by the Town. In addition, all work within the public right-of-way is governed by these regulations. They are intended to provide for coordinated modern development with adequate facilities to serve and protect the users.

They are meant to apply to new developments which are not constrained by already existing improvements. However, since infill development in an urban area is often constrained when matching existing improvements, to the extent deemed possible by the Town Engineer, infill developments shall match these Engineering Standards. The Town Engineer may allow modification of these standards when necessary to allow private and public construction which is compatible with surrounding in-place improvements.

These standards may also be used in conjunction with the Town's zoning regulations and subdivision ordinances for site development work on private property.

The design standards, included in Chapter VII, must be used on all public improvement projects and private work which will either be dedicated to or accepted by the Town.

II. ENGINEERING PLAN/REPORT SUBMITTALS

A. GENERAL INFORMATION

The Town of Hudson has responsibility for the health, safety, and welfare of the public within the Town right-of-way. Therefore, the Engineering Department has established and the Board of Trustees has adopted construction standards and engineering reviews for proposed developments.

With the establishment of engineering reviews for proposed developments, developers are required to submit plans/reports for review. The developer is encouraged to have his engineer meet with the Engineering Department so that the project's technical aspects can be discussed prior to submitting plans. The submittals which may be required and their intent are as follows:

SUBDIVISION IMPROVEMENT AGREEMENT (S.I.A.) - This is a contract between the Town and a property owner/developer which sets forth the terms and conditions for right-of-way dedications and the improvements required within the public right-of-way or easements. An estimate of quantities, costs and bond required for the improvements is included.

GRADING PLANS - This submittal details the overlot grading proposed for the site and should include significant features such as retaining walls and grades matching to adjacent properties. These are typically done with the drainage plans unless a separate overlot grading permit is desired.

PHASE I DRAINAGE REPORT - This report identifies and defines drainage problems and conceptually addresses the proposed drainage system including storm detention requirements and impacts on adjacent properties.

PHASE II DRAINAGE REPORT - This report contains construction documentation of the approved conceptual drainage system including engineering calculations and impacted adjacent property owner approvals if required by the Town.

PHASE III DRAINAGE REPORT - This report updates the concepts and presents design details for the drainage facilities discussed in the Phase II Drainage Report.

PRELIMINARY CONSTRUCTION PLANS - These are construction documents for the public improvements on the project. They include public and private street plans and drainage elements within easements or the public right-of-way. They also may include signing, pavement marking, water system, sanitary system, and traffic signal plans.
PAVEMENT DESIGN REPORT - This documents the soil conditions and

proposed pavement installation with the structural cross sections for both parking lots and streets.

GEOLOGIC AND MINING HAZARDS REPORT - This report documents geologic conditions and investigations into mining hazards potential anticipated at the site and their compatibility with the proposed development.

RETAINING WALL DESIGN REPORT - This report provides construction documents with all supporting engineering calculations necessary for retaining wall installations that are 30" or more above finished grade.

These submittals are reviewed by the Engineering Department in conjunction with other Town department staffs to insure conformance with Town standards. All submittals are to be prepared by a Professional Engineer registered in the State of Colorado.

B. NUMBER OF SUBMITTALS

Three (3) sets of plans/reports are required on each initial submittal except for street construction plans, where ten (10) sets are required. If additional sets are needed for agency referral reviews, the applicant will be contacted by the Engineering Department.

Upon approval, a mylar sepia and/or additional copies of the submittal may be required. The applicant will be contacted by the Engineering Department regarding this.

A transmittal letter should accompany each submittal, giving pertinent information such as review desired and contact person.

C. APPROVED PLANS/REPORTS

Plans and/or reports must be approved prior to initiation of any construction activities. Approved plans and/or reports will be valid for two years from the date of approval.

Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities or safety during construction.

D. DRAFTING/REPORT STANDARDS

All reports submitted for review must be typewritten and legible. All drawings submitted for review shall meet the Colorado Department of Transportation Drafting Standards, and be on 24" x 36" plan sheets.

Final drawings submitted for approvals shall be three mil mylar sepia copies of originals.

E. STATE HIGHWAYS

Whenever a project is proposed on or adjacent to a state highway, the Town of Hudson coordinates the review of the project with the Colorado Department of Transportation. The Town also is responsible for submitting all access permits to the Department once final construction plans have been approved by the Town Engineer.

Construction activities on state highways will be governed by the Colorado Department of Transportation regulations and inspection will be undertaken by the Department's forces.

State highways within the Town of Hudson currently include: Colorado 52 and I-76.

F. OTHER AGENCIES

Depending on the project's location, the Town may also refer the plans for review and comments to other agencies. Those agencies include: Army Corps of Engineers, State Engineer's Office, Weld County, Public Utility Companies, and Fire Protection Districts. The proposed project's location and improvement plans will determine which agencies receive referrals.

G. PERMITS

The owner/developer is reminded of its responsibility to obtain all permits related to the design, approval, and construction of the development. Permits may be required from the following agencies:

1) Army Corps of Engineers (Nationwide, 404)
2) Colorado Department of Health
3) Federal Emergency Management Agency

Final approval and signature of the engineering plans by the Town of Hudson, US West, local cable company and any other public utility, shall be required prior to commencement of any construction on the development. Final signatures on the plans shall be deemed "permit approval". A minimum of ten (10) sets of plans shall be submitted for final signatures. The developer's contractor must have an approved set of plans on the project site at all times during construction.

H. INSPECTION

Contractors shall be responsible for notifying the Town at least 48 hours prior to the

start of any construction. If work is suspended for any period of time after initial start-up, Contractors must notify the Town 48 hours prior to restart.

Inspections will be performed on all development work by the Town Engineer or his/her designee as required to ensure all work is being constructed in accordance with the Town Standards. Contractors shall be responsible for organizing a pre-construction conference prior to the start of construction, at which shall attend, at least, the Town Staff, affected agencies, contractor's representatives, contractor's surveyors, and the owner/developer's engineers. The Town's costs for all inspections and meetings related to the owner/developer's project shall be charged back to the owner/developer.

I. TESTING

Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, as amended, and as amended by the Town of Hudson Design Standards, shall apply to roadway testing requirements.

All tests and inspection results performed by the testing firm in the employment of the owners/developers shall be submitted directly from the testing agency to the Town Engineer or his/her field representative at the time of field tests, and within ten (10) working days after the testing or retesting date of laboratory tests.

Any work performed inside Town of Hudson R.O.W. and associated easements shall be tested by an approved materials testing firm. Materials testing firms shall be approved by the Engineering Department on an annual basis and must employ a full time registered professional engineer who directly supervises work of the firm. The costs of testing and associated reporting will be paid by the owner/developer.

The testing of all materials and construction shall be in conformance with the appropriate AASHTO, ASTM and CDOT specifications. A partial list of approved testing methods includes:

TEST PROCEDURES	AASHTO	ASTM
Atterberg Limits (LL & PL)	T 89 & T 90	D 4318
Gradations Analysis (except hydrometer)	T 27	D 422
CBR (as modified in Section 5.2.4.1)	193	-
R-value (subgrade & base)	T 190	D 2844
Marshall Stability	T 245	D 1559
R_t Value	T 246	D 1560
Compaction Curve (standard)	T 99	D 698
Compaction Curve (modified)	T 180	D 1557
Compaction Curve (CTAB)	T 134	-
Field Density Tests (Sand Cone)	T 191	D 1556
Field Density Test (Nuclear)	T 238/T 239	D 2922/D 3017
Field Density Test (Balloon)	T 205	D 2167

Concrete Slump	T 119	C 143
Concrete Air Content	T 152	C 231
Concrete Compressive Strength	T 22	C 39
Concrete Sampling	T 141	C 172
Strength of Soil-Lime Mixtures	T 220	-
Asphalt Flow	T 245	D 1559
Air Voids	T 245	D 1559
Profil-o-graph	Colo. Procedure 64-85	

The design engineer is encouraged to discuss the project with the Engineering Department prior to the first submittal. This also has proven beneficial in reducing the Town review time for plan and report submittals.

1. Utility Trenches, Inlets, Manholes and Junction Boxes Backfilling

All utility trenches within the R.O.W. shall be placed and compacted in accordance with Roadway and Drainage design standard No.26.

Field moisture-density testing shall be performed during backfill operations beginning one (1) foot above the top of the pipe and extending to the finished subgrade elevation. A sufficient number of tests shall be taken at various depths to confirm backfill compaction and moisture content specifications are met. As a minimum, one test shall be taken within one (1) foot of manholes, water valves or other obstacles.

2. Curb, Gutter, Sidewalk, Crosspans, and Minor Drainage Structures

Subgrade shall be thoroughly compacted to the moisture and density specifications required for the material tested. The surface shall be smooth with no humps or depressions and to the final grade on which the concrete will be placed.

Testing frequency for the subgrade shall be a minimum of each six inch lift on replacement materials with one test for every 250 feet of structure with more tests taken if necessary for control.

These test results shall be submitted to the field representative of the Town Engineer for compliance review.

Concrete with air entrained, Class A, B, or D shall be used.

Curing methods shall conform to CDOT standard specifications.

Concrete placement shall include methods which will not reduce the strength or integrity of the final product.

The slump, air content and unit weight tests shall be carried out in the first truck of concrete for the daily placement and thereafter in conformance with the following table:

TESTING FREQUENCY

ITEM	TESTING FREQUENCY
Sidewalks, Crosspans, curb returns	1 set of 4 cylinders for every 1,000 square yards or fraction thereof of concrete placed.
Curbing and combination curb, gutter and walk	1 set of 4 cylinders for every 1,000 lineal feet or fraction thereof of curb and gutter placed.
Minor drainage structures	Each structure 1 set of 4

NOTE: The testing to include the slump (T 119), air entrainment (T 152), temperature of concrete at placement, yield and compressive strength of the cylinders (T 22).

All work done by hand (non-extrusion) shall require a minimum of two (2) sets of tests per day.

These test results shall be submitted to the field representative of the Town Engineer for compliance review.

At the discretion of the Town Engineer, the contractor will provide core test results of concrete at random intervals, not averaging less than one test in 500 feet, to verify the specified thickness of concrete was installed. Testing costs shall be paid for by the owner/developer. If the Town Engineer has not been given the opportunity to inspect the subgrade and/or concrete forms prior to placement of the concrete, and at the discretion of the Town Engineer, the contractor will provide additional core tests.

3. Street Subgrade Preparation

The subgrade shall be free of organic material and shall be scarified to a depth of 12 inches, moisture treated to within ± 2 percent of optimum moisture content and compacted to 95% optimum density, AASHTO T-99.

Field moisture-density tests using acceptable methods will be required at random locations at the rate of one for each 500 lineal feet of paving for each travel lane.

After the subgrade has been compacted, tested and found to meet specifications, the entire subgrade shall be proof-rolled with a heavily loaded vehicle to ensure uniformity of the subgrade. The vehicle must have a loaded GVW of 50,000 pounds with a loaded single axle weight of at least 18,000 pounds and a tire pressure of 90 psi. Subgrade which is pumping or deforming must be reworked, replaced or otherwise modified to form a smooth, stable, non-yielding base for subsequent paving courses. The Engineering Department shall be notified at least 48 hours before final proof-rolling.

The results of field density tests and proof-rolling shall be submitted and reviewed by the Engineering Department. Provided all tests are acceptable, compaction will be approved for the placement of the next paving course. Should testing indicate unsatisfactory work, the necessary reworking, compaction or replacement will be required prior to continuation of the paving process. The approval is valid for 24 hours. Changes in weather such as freezing or precipitation will require re-approval of the subgrade.

4. Lime Treated Subgrade

Lime treated subgrade shall be used only where a mix design has been previously submitted and approved by the Engineering Department.

Construction of lime treated subgrade shall be in accordance with the requirements of the CDOT Standard Specifications.

Lime treated subgrade will be observed and tested on a full-time basis and paid for by the owner/developer. Field moisture-density tests shall be taken at the rate of one for each 500 lineal feet of travel lane for each lift. Compaction curves (AASHTO T 220) will be required for each soil type and field density shall be compared to the appropriate curve for percentage compaction determinations. Field compacted 7-day strength and lime content (AASHTO T 232) determinations shall be required for each 500 tons of subgrade treated, with a minimum of one per project.
The results of field density, lime content and strength tests shall be submitted and reviewed by the Engineering Department. Provided all tests are acceptable, the subgrade will be approved and the next paving course can be placed. Should these tests fail to meet project specifications, the strength reduction will be used to calculate increased pavement layer or overlay thickness required for the design section.

5. Aggregate Base Course

Aggregate Base Course materials must be from a currently approved source and conform to the requirements of the CDOT Standard Specifications. The

owner/developer shall, upon request, provide verification of material properties.

Materials shall be placed on an approved subgrade which has been proof-rolled within the past 24 hours and found to be stable and non-yielding. Should weather conditions change, such as freezing, precipitation, etc., aggregate base materials shall not be placed until the subgrade is reapproved.

Aggregate base materials shall be placed, moisture treated and compacted as outlined in the CDOT Standard Specifications.

At least one sample of aggregate base course for each 1000 tons of materials placed shall be tested to determine gradation and Atterberg Limits. Should these tests indicate the material does not meet specifications, the material shall be removed and replaced.

During placement and compaction, Compaction Curves will be required for each material used. Field moisture-density tests shall be taken of each lift of material at random locations at approximate intervals of 500 feet in each travel lane. At least 20 percent of the tests shall be taken within one (1) foot of manholes, valves, and curbs.

The results of field density tests shall be submitted to and reviewed by the Engineering Department. Provided all tests are acceptable, the aggregate base course materials, placement and compaction will be approved and the next paving course can be placed. Should testing indicate unsatisfactory work, the necessary reworking, compaction or replacement will be required prior to continuation of the paving process.

6. Cement Treated Aggregate Base Course

Aggregate and cement materials must be from a currently approved source and the mix design shall conform to the requirements of CDOT Standard Specifications. The owner/developer shall provide verification of material properties and an approved mix design.

Materials shall be placed on an approved subgrade which has been proof-rolled within the past 24 hours and found to be stable and non-yielding. Should weather conditions change, such as freezing, precipitation, etc., materials shall not be placed until the subgrade is reapproved.

Cement treated aggregate base shall be prepared per the mix design, and placed, moisture treated and compacted as outlined in the CDOT Standard Specifications.

At least one sample of cement treated aggregate base course for each 1000 tons of materials placed shall be tested to determine cement content, gradation and Atterberg Limits. Six field-prepared proctor mold samples shall be taken for each 500 tons placed and tested at 7 and 28 days to determine unconfined compressive strength.

During placement and compaction, Compaction Curves will be required for each material used in accordance with ASSHTO T 134. Field moisture-density test shall be taken of each lift of material at random locations at approximate intervals of 500 feet in each travel lane. At least 20 percent of the tests shall be taken within one (1) foot of manholes, valves and curbs.

The results of laboratory tests and field density tests shall be submitted to and reviewed by the Engineering Department. Provided all tests are acceptable, the cement treated aggregate base course materials, placement and compaction will be approved and the next paving course can be placed. Should testing indicate satisfactory work, necessary adjustments will be made to the pavement section to comply with original design strength requirements.

7. Plant Mix Hot Bituminous Pavement (HBP)

All asphalt, aggregate, fillers and additives shall be combined to form a mix design in accordance with CDOT Standard Specifications. The mix design must be submitted to and approved by the Engineering Department.

Materials shall be placed upon an approved subgrade base course or previous paving course in accordance with the CDOT Standard Specifications. Prime or tack coats shall be applied in accordance with CDOT Standard Specifications.

When more than one lift of pavement is required, where possible, the joints and seams between lifts shall be staggered so that joints are separated by at least two (2) feet in the horizontal direction.

The bituminous paving mix shall be compacted to at least 95 percent of the mix determined Marshall density or specified density from Hveem testing to achieve design strength.

During placement and compaction of plant mix bituminous pavement, observation and testing shall be on a full-time basis. For each 1000 tons of material placed or at least one for each day of production, a field sample shall be taken and subjected to Marshall or Hveem testing, extraction and gradation analysis. Testing intervals may be increased to approximately one-half (1/2) of the daily tonnage to be placed at the discretion of the Town Engineer.

Mix temperatures will be checked on each truck and where the temperature does not meet specifications the load shall not be placed.

During compaction the density of the pavement will be checked randomly at the rate of one test for each 500 lineal feet of travel for each lift.

Either during or after completion of the paving, the final pavement thickness shall be determined for the plant mix bituminous pavement using corings, rings or other acceptable methods. Thickness determinations shall be made at random locations at intervals of approximately 500 feet in each travel lane.

The results of field density and laboratory tests shall be submitted to and reviewed by the Engineering Department. Provided all tests are acceptable, the asphalt concrete materials, placement and compaction will be approved. Acceptable results shall be in compliance with tolerances for gradation and extraction found in CDOT Standard Specifications. Marshall stability tests results shall average 1,500 lbs. or more. Should testing indicate unsatisfactory work, removal and replacement or overlay work will be required.

Criteria used to determine satisfactory work shall be all for the following:

a. Ninety percent (90%) of core test must meet or exceed design HBP thickness:
b. Average of all core tests must meet or exceed design HBP thickness:
c. All core test thickness must exceed design HBP thickness minus 1/4".

If all these criteria are not met, additional core tests or approved non-destructive testing at the expense of the owner/developer may be required to further delineate the area(s) of unsatisfactory work which will require correction prior to acceptance.

8. <u>Portland Cement Concrete</u>

All aggregate, Portland cement, fly ash, water, admixtures, curing materials and reinforcing steel shall meet the requirements of CDOT Standard Specifications. All materials shall be combined in accordance with CDOT Standard Specifications into a mix design and submitted to, and approved by, the Engineering Department.

Materials shall be proportioned, handled, measured, batched, placed and cured in accordance with CDOT Standard Specifications.

During placement of Portland Cement concrete pavement, observation and

testing shall be on a full-time basis. For each day of production or every 400 cubic yards placed (or portion thereof), aggregate samples shall be obtained for gradation of both the coarse and fine aggregates.

Slump, air content, unit weight and mix temperature shall be tested every 100 cubic yards of pavement placed. The first three loads shall be tested for slump and air content. If any one test fails to meet requirements, slump and air content tests shall continue until three consecutive loads meet requirements. Thereafter, slump and air shall be tested at least every fifth load.

Six compressive strength cylinders shall be fabricated for each 100 cubic yards placed. Cylinders shall be tested as follows: 2 at 7 days, 2 at 28 days and 2 for backup, as required by the Engineering Department. Testing interval may be increased to approximately one-third (1/3) of the daily volume to be placed at the discretion of the Town Engineer.

Portland cement and fly ash will be accepted on the basis of current certificates of compliance and pre-testing by CDOT. Reinforcing steel, dowels and tie bars will be accepted by certificate of compliance and mill reports. Water, if not potable, shall be sampled and tested before use. Only CDOT approved brands of air entraining agents, chemical admixtures and curing materials may be used and must be documented.

Thickness of fresh concrete must be checked every 500 lineal feet in each traffic lane. Any noted deficiency areas shall be corrected at that time. Surface deficiency areas shall be corrected at that time. Surface smoothness shall be tested and corrected as necessary according to CDOT.

All test results shall be submitted and reviewed by the Engineering Department. Provided all tests are acceptable, the pavement will be accepted. Should testing indicate unsatisfactory work, removal and replacement or grinding will be required.

J. ACCEPTANCE OF WORK

After completion of all work and the submittal of as-built plans and materials testing reports, the Town will perform a punch-list inspection with the owner/developer's Contractor, indicating all items of work to be completed before acceptance of the project.

When all punch-list items of work are completed, the Town will issue a Letter of Probationary Acceptance, which will begin a one year warranty period. During the warranty period the owner/developer's contractor shall repair any defective work immediately upon notification, unless other arrangements are made with the Town

Engineer. All defective work must be repaired before a Letter of Final Acceptance is issued to the developer, at which time the Town will assume maintenance and repair responsibilities.

K. CHECKLISTS

The following checklists are provided to assist in developing plans and reports which meet the Town's requirements for the specific submittal. Use of the checklists by designers has proven beneficial in speeding the Town review time for plan and report submittals.

The checklists include:

1) Grading Plans
2) Soils and Pavement Design Reports
3) Street Construction Plans
4) Retaining Wall Design
5) Geologic and Mining Hazards Reports
6) Drainage Report
7) Water System Design
8) Sanitary System Design

DEVELOPMENT REVIEW CHECKLIST
GRADING PLANS

The Town of Hudson requires grading plans to detail overlot grading and document significant features such as retaining walls. Submittals also are necessary to ensure that on-site drainage is adequately handled and that the proposed development grading plans are compatible with adjacent property topography.

If the grading and drainage plans are being combined in one submittal, the plan sheet should indicate such. Also, the grading plan checklist should be used in conjunction with the drainage report checklist in preparation of the plans.

The following checklist has been developed to assist in preparation of grading plans. It includes items pertinent for the Town's review and reflects established professional engineering practice for preparation of grading plans. If you have any question regarding items on this list, please call the Development Review Section.

GENERAL NOTES

The general notes included with this checklist are to be used on grading plan submittals. This list of general notes is not intended to be all inclusive for every project; therefore, additions may be appropriate.

APPROVAL BLOCK

The approval block on the last page of this checklist must be on all grading plan sheets. It should be placed as close as possible to the title block in the lower right corner of the sheet.

		PRESENT	COMMENT
I.	PLAN SHEET FORMAT		
	A. Scale: 1" = 50' or larger	_____	_____
	B. North arrow		
	C. Title Block		
	D. Vicinity Map 1" = 500'		
	E. Contour Lines (2' maximum intervals)		
	F. 24" x 36" plan sheets		
	G. Original and Revision Dates		
	H. Dated, checked, sealed and signed by a PE		
	I. Legend		
	J. Street names, dimensions and grades		
	K Match lines and sheet numbers		
	L. Approval block		
	M. General notes		
		PRESENT	COMMENT

N. Bench mark description and elevation (must be U.S.G.S.)
O. Baseline or control line

II. PRESENT SITE CONDITIONS

A. Existing site topography extending a min. of 50 feet past property limits
B. Existing features
   1. Easements and rights-of-way
   2. All utilities
   3. Drainageways with 100-year flood-plain and floodway limits
   4. Irrigation ditches or laterals
   5. Buildings, fences, retaining walls, trees and other physical features

III. PROPOSED SITE CONDITIONS

A. Proposed contours with match to existing contours
B. Drainage flow arrows
C. Grade breaks and slopes 3:1 or greater indicated on plan
D. Cut and fill areas and quantities* shown
E. Proposed improvements
   1. Sidewalks, bikepaths and other public improvements
   2. Driveway grades and dimensions
   3. Storm drainage structures
   4. Fences, retaining walls and other physical site improvements (cross sections may be necessary to detail these features)
   5. Lowest finished floor elevations for all buildings
F. Erosion Protection

IV. STANDARD DETAILS	PRESENT	COMMENT
A. Town or CDOT standard details referenced where applicable		
B. Where Town or CDOT standards cannot be used, details in the plans		

*Quantities are not required unless separate overlot grading permit requested

GENERAL NOTES

1. Grading plan is for rough grading only. Changes may be necessary to bring plan into conformance with approved Final Drainage Plan and Site Plan.

2. Water truck, if called for by the Town inspector, will be provided to keep wind erosion in check.

3. Any settlement or soil accumulations beyond the property limits due to grading or erosion shall be repaired immediately by the contractor.

4. No grading shall take place in delineated Flood Hazard Areas until the Final Drainage Plan has been approved and all appropriate permits have been obtained.

5. Any construction debris or mud tracking in the public right-of-way resulting from this development shall be removed immediately by the contractor. The contractor shall immediately fix any excavations or excessive pavement failures caused by the development and shall properly barricade the site until construction is complete. Failure by the Contractor to correct any of the above within 48 hours of written notice by the Town shall cause the Town to issue a stop work order (red tag) and/or do the work and make a claim against the letter of credit for any cost incurred by the Town.

6. Areas being disturbed by the grading shall be reseeded with native vegetation or as approved on the development plan.

7. It shall be the responsibility of the developer during construction activities to resolve construction problems due to changed conditions or design errors encountered by the contractor during the progress of any portion of the proposed work. If, in the opinion of the Town's inspector, the modifications proposed by the developer to the approved plans involve significant changes to the character of the work or to future contiguous public or private improvements, the developer shall be responsible for submitting revised plans to the Town of Hudson for approval prior to any further construction related to that portion of the work. Any improvements constructed not in accordance with the approved plans, or the approved revised plans, shall be removed and the improvements shall be reconstructed according to the

approved plans.

8. The contractor shall be solely and completely responsible for conditions at and adjacent to the job site, including safety of all persons and property during performance of the work. This requirement shall apply continuously and not be limited to normal working hours.

   The duty of the Town to conduct construction review of the contractor's performance is not intended to include review of the adequacy of the contractor's safety measures in, on, or near the construction site.

9. Utilities contractor shall contact Blue Stakes for location of underground gas, electric, and telephone utilities at least 48 hours prior to commencement of construction (1-800-922-1987)

APPROVAL BLOCK

ENGINEERING REVIEW TOWN OF HUDSON	Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities and design safety.	
☐ No Exceptions Taken ☐ Make Corrections Noted ☐ Rejected-See Checklist	Town Engineer	Date

DEVELOPMENT REVIEW CHECKLIST
SOILS AND PAVEMENT DESIGN REPORT

The Town of Hudson requires pavement design reports for proposed streets and parking lots. The reports are to include the soils information necessary to substantiate the proposed pavement design.

The Colorado Department of Transportation methodology is accepted for both rigid and flexible street pavement designs. For parking lots, the Asphalt Institute or Portland Cement Association methodologies are also accepted in lieu of the Colorado Department of Transportation methodology. In no case shall flexible pavement sections be less than 6" HBP for full depth pavement or 3" HBP on 8" A.B.C. Rigid pavement sections shall not be less than 6" P.C.C.

The following checklist has been developed to assist in preparation of soils and pavement design reports. It includes items pertinent for the Town's review and reflects established professional engineering practice for pavement design. If you have any questions regarding items on this list, contact the Development Review Section.

APPROVAL BLOCK

The approval block shown on the last page of this checklist must be on the title page of the submittal.

I. REPORT FORMAT	PRESENT	COMMENT
A. Title page with project address and approval block		
B. 8½" x 11" report, bound or in a folder		
C. Dated, checked, signed and sealed by a Professional Engineer (both soils and pavement if done by different parties)		
D. Original and revision dates		

II. SOILS INFORMATION		
A. Boring locations on site plan		
B. Boring logs		
C. Gradation tests		
D. Atterberg limits		
E. Compaction tests		
F. Percent swell*		
G. Soils classification (AASHTO)		
H. Problem areas on the site		

III. DESIGN CRITERIA	PRESENT	COMMENT
A. Roadway classification		

B. Forecast traffic volumes
C. Construction traffic forecast
D. 18 KIP EDLA or DTN
E. Serviceability index
F. Regional factor

IV. PAVEMENT DESIGN
A. Weighted structural number
B. CBR Tests
C. Design CBR
D. R value
E. Subgrade properties
F. Town of Hudson pavement design nomographs
G. Base course
H. Pavement
I. Alternatives

V. CONSTRUCTION METHODS

A. Utility trench test
B. Subgrade test
C. Curb, gutter and sidewalk test
D. Base course test
E. Pavement test
F. Paving sequence
G. Construction traffic control plan

*Note: If percent swell exceeds 1.5%, the report shall include the proposed method(s) to deal with swelling soil characteristics.

APPROVAL BLOCK

ENGINEERING REVIEW TOWN OF HUDSON	Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities and design safety.
☐ No Exceptions Taken ☐ Make Corrections Noted ☐ Rejected-See Checklist	Town Engineer Date

DEVELOPMENT REVIEW CHECKLIST
STREET CONSTRUCTION PLANS

The Town of Hudson requires construction plan submittals on development projects when improvements are proposed within easements, public rights-of-way or on private streets. Plan submittals are required at two points in the development process. The first is at the preliminary (functional) design stage and the second is when plans are finalized.

The following checklist has been developed to assist in preparation of street construction plans. It includes items pertinent for the Town's review and reflects established professional engineering practice for preparation of construction plans. If you have any questions regarding items on this list, please call the Engineering Department.

PRELIMINARY CONSTRUCTION PLANS

The purpose of the preliminary construction plan submittal is to allow the engineering staff and applicant to discuss the functional or preliminary design at an early stage in development. This will allow for a constructive discussion of the design submittal prior to initiation of the details required with final construction plans. The preliminary submittal should address the horizontally controlled plan elements plus any topographic details involving grade changes of 3' or more that would require walls, slopes, utility relocations, etc. The preliminary submittal is also used for preparation of the subdivision improvement agreement (SIA) and therefore must contain an approximate list of quantities for improvements within Town right-of-way or easements. The items required on the preliminary plan submittal are indicated by an asterisk (*) on the following checklist.

FINAL CONSTRUCTION PLANS

The final construction plan submittal should be based on the approved preliminary plan. The submittal should be a complete and self-supporting plan set including all the details and documentation necessary for construction of the proposed improvements. Town of Hudson and CDOT standards which are being used on the project can be referenced rather than detailed if desired.

GENERAL NOTES

The general notes included with this checklist are to be used on construction plan submittals. This list of general notes is not intended to be all inclusive for every project; therefore, additions may be appropriate.

APPROVAL BLOCK

The approval block found on the last page of this checklist must be on all construction plan sheets. It should be placed as close as possible to the title block in the lower right corner of the sheet.

I. PLAN SHEET FORMAT	PRESENT	COMMENT

*A. Scale: 1" = 50' horizontal or larger;
1" = 5' vertical or larger
*B. North arrow
*C. Title block
*D. Vicinity map 1" = 500' or larger
*E. 24" x 36" plan sheets
*F. Original and revision dates
*G. Plans checked, sealed, signed and dated by a Professional Engineer
*H. Legend
*I. Street names and dimensions
*J. Match lines and sheet numbers
*K. Approval block
L. General notes

II. HORIZONTAL AND VERTICAL CONTROL

*A. Bench mark description and elevation (must be Town of Hudson, USGS or NGS datum)
*B. Section line or control line with ties to section corner
*C. Beginning station tied and referenced to section line or control line

III. PLAN REQUIREMENTS

*A. Existing improvements for the full width of the street up to 50' beyond the construction limits depicted by dashed lines; proposed construction depicted by solid lines
*B. Limits of construction noted
*C. Location of proposed and existing property lines, easements, Town right-of-way, etc.
*D. List of quantities (preliminary submittal only)
*E. Existing utilities, proposed utilities and utilities to be relocated (these may be on a separate plan sheet)
*F. Locations of fixed objects (trees, poles, fences, etc.)

	PRESENT	COMMENT
*G. Proposed street improvements (sidewalk,		

curb and gutter, asphalt patch-back, etc.)

*H. Existing and proposed drainage structures (inlets, manholes, channels, outlet structures, etc.)

I. Curve layout including radius, length of curve, P.I. deflection angle, degree of curvature, P.C., P.T., and offsets

*J. Proposed 1" = 50' striping and signing plan indicating lane width, etc.

*K. Proposed 1" = 20' traffic signal plan

IV. PROFILE/CROSS SECTION REQUIREMENTS

A. Three line profiles (centerline and flow-lines) or centerline profile and cross sections every 50' extending a minimum of 50' beyond the project limits

B. On widening/matching projects, 3 line profiles and cross sections every 25' extending a minimum of 50' beyond the project limits are required.

C. Vertical curve data including length of curve, P.V.C., P.V.T., P.V.I., beginning and end grades

D. Profiles for all curb returns

E. Existing profile elevations extended 100' beyond the end/beginning of the project

F. Cross sections extended 25' beyond property line

V. STANDARD DETAILS

A. Town or CDOT standard details referenced where applicable

B. Where Town or CDOT standards cannot be used, details on the plans

*Items required on preliminary street construction plans.

GENERAL NOTES

1. All work within the public right-of-way or easement shall conform to the Town of Hudson Engineering Regulations, Construction Specifications and Design Standards.

2. A Street Cut/Closure Permit for Work in Public Ways is required for all work in the public right-of-way, and any work performed within State right-of-way will also require a State construction permit.

3. It shall be the Contractor's responsibility to notify the Owner/Developer of any problem in conforming to the approved plans for any element of the proposed improvements prior to its construction.

4. It shall be the responsibility of the developer during construction activities to resolve construction problems due to changed conditions or design errors encountered by the contractor during the progress of any portion of the proposed work. If, in the opinion of the Town's inspector, the modifications proposed by the developer to the approved plans involve significant changes to the character of the work or to future contiguous public or private improvements, the developer shall be responsible for submitting revised plans to the Town of Hudson for approval prior to any further construction related to that portion of the work. Any improvements constructed not in accordance with the approved plans, or the approved revised plans, shall be removed and the improvements shall be reconstructed according to the approved plans.

5. Blue Stakes - Utilities Contractor shall contact Blue Stakes for location of underground gas, electric, and telephone utilities at least 48 hours prior to commencement of construction. Phone 1-800-922-1987.

6. All utility poles shall be relocated prior to placement of concrete. Public Service electric pole relocations are coordinated through the Town and require a minimum of 120 days written notice for relocation.

7. With notification of the respective owner, adjust rims of all cleanouts, manholes, valve covers and survey monuments to finish grade prior to final lift paving.

8. The Contractor shall provide all lights, signs, barricades, flagmen or other devices necessary to provide for public safety in accordance with the current Manual on Uniform Traffic Control Devices.

9. The Contractor shall provide ingress and egress to private property adjacent to the work throughout the period of construction and prior to beginning work shall obtain written agreement from the affected property owners impacted by this access.

10. Prior to final placement of surface pavement, all underground utility mains shall be installed and service connections stubbed out beyond curb line when allowed by the utility. Service from public utilities and from sanitary sewers shall be made available for each lot in such a manner that will not be necessary to disturb the street pavement, curb, gutter, and sidewalk when connections are made.

11. Mylar copy of "AS BUILT" plans shall be submitted to the Town of Hudson prior to final acceptance of work.

12. The contractor shall notify the Town inspector at least 24 hours prior to desired inspection.

13. No portion of the street may be final paved until all street lighting improvements designed to serve the street and/or development have been completed.

14. Survey Monuments must be set within 60 days of completion of project.

APPROVAL BLOCK

ENGINEERING REVIEW TOWN OF HUDSON	Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities and design safety.
☐ No Exceptions Taken ☐ Make Corrections Noted ☐ Rejected-See Checklist	_____ _____ Town Engineer Date

DEVELOPMENT REVIEW CHECKLIST
RETAINING WALL DESIGN

The Town of Hudson requires retaining wall submittals for proposed retaining walls which exceed 30" above the lowest finished grade and are on or near a property line, public right-of-way or public use area or impact the current grading or drainage characteristics on adjacent properties. This includes concrete, timber and rock walls.

The following checklist has been developed to assist in preparation of retaining wall submittals. It includes items pertinent for the Town's review and reflects established professional engineering practice for design of retaining walls. If you have any questions regarding items on this list, contact the Development Review Section.

CALCULATIONS

Engineering calculations must be submitted with the construction drawings covering items noted in the checklist. If any commonly accepted "standard" wall design such as one from CDOT Bridge Standards is used, a copy of the design and the reference or source for the design can be submitted in lieu of calculations.

GENERAL NOTES

The general notes included with this checklist are to be used on retaining wall plan submittals. This list of general notes is not intended to be all inclusive for every project; therefore, additions may be appropriate.

APPROVAL BLOCK

The approval block shown on the last page of this checklist must be on the title page of the submittal.

I. REPORT/PLAN FORMAT	PRESENT	COMMENT
A. Title page w/address and approval block		
B. 8½" x 11" Report and details on 24" x 36" plan sheet w/supporting calculations		
C. Dated, checked, signed and sealed by Professional Engineer		
D. Original and revision dates		
E. Site Plan with wall location (1" = 50' or larger)		

II. DESIGN DATA	PRESENT	COMMENT
A. Soils report and/or source of design data		

B. Weight/Density soil, concrete, rock, timber
C. Allowable bearing pressure
D. Equivalent fluid pressure
E. Construction material strengths
F. Coefficient of friction
G. Adjacent ground surface slopes
H. Surcharge loadings

III. SYSTEM STABILITY CHECK

A. Overturning factor of safety greater than 1.5
B. Sliding factor of safety greater than 1.5
C. Bearing pressure less than allowable soil bearing pressure
D. Footing base at or below 36" frost depth
E. Slope Stability

IV. PLAN REQUIREMENTS

A. Existing improvements depicted by dashed lines; proposed construction by solid lines
B. Limits of construction noted
C. Location of proposed and existing property lines, easements, etc.
D. Locations of fixed objects (trees, poles, fences, etc.)
E. Layout data
   1. Profiles
   2. Cross sections
   3. Elevations with benchmark
   4. Control line
   5. Horizontal layout
F. Wall Dimensions

V. WALL DETAILS

A. Concrete/Masonry
   1. Reinforcing steel
   2. Weep holes
   3. Control/expansion joints

	PRESENT	COMMENT
4. Type of concrete		
5. Facing		

B. Timber
   1. Lumber Treatment
   2. Dead men
   3. Drift pins
   4. Tie backs/Anchors
   5. Batter

C. Stacked Rock

   1. Base material
   2. Rock sizes/shapes
   3. Batter

VI. GRADING/DRAINAGE

A. Ground slope
B. Backfill material
C. Drainage system

GENERAL NOTES

1. A Building Permit is required for construction of retaining walls over 30" tall.

2. Blue Stakes - Utilities Contractor shall contact blue stakes for location of underground gas, electric and telephone utilities at least 48 hours prior to commencement of construction. Phone 1-800-922-1987

3. It shall be the responsibility of the developer during construction activities to resolve construction problems due to changed conditions or design errors encountered by the contractor during the progress of any portion of the proposed work. If, in the opinion of the Town's inspector, the modifications proposed by the developer to the approved plans involve significant changes to the character of the work or to future contiguous public or private improvements, the developer shall be responsible for submitting revised plans to the Town of Hudson for approval prior to any further construction related to that portion of the work. Any improvements constructed not in accordance with the approved plans, or the approved revised plans, shall be removed, and the improvements shall be reconstructed according to the approved plans.

4. Copies of "As Built" plans shall be submitted to the Town of Hudson prior to final acceptance of work.
5. The contractor shall notify the Town Engineer least 24 hours prior to desired inspection.

APPROVAL BLOCK

ENGINEERING REVIEW TOWN OF HUDSON	Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities and design safety.
☐ No Exceptions Taken ☐ Make Corrections Noted ☐ Rejected-See Checklist	_____ _____ Town Engineer Date

STANDARD FORM SF-1
DEVELOPMENT REVIEW CHECKLIST
DRAINAGE REPORT

PREPARED BY DATE

The drainage report for the development as noted below has been received and found to lack the information noted. This information must be submitted before the report will be accepted for review. Please provide the required information and return the checklist with your submittal.

DEVELOPMENT:
LOCATION:
DATE SUBMITTED: TYPE OF RPT: PHASE I , PHASE I , PHASE III
SUBMITTED BY: FIRM
CONTACT
PHONE
SUBMITTED DATE: (1) (2) (3) (4)
DATE APPROVED:

CHECKLIST

		PRESENT	COMMENT
I.	TYPED, BOUND REPORT		
II.	PROFESSIONAL ENGINEERS CERTIFICATE		
III.	GENERAL LOCATION AND DESCRIPTION		
	A. Location Map		
	B. Existing Site Drainage		
	C. Description of Existing Drainage		
IV.	DRAINAGE BASINS AND SUB-BASINS		
	A. Major Basin description		
	B. Sub-Basin Description		
V.	DESIGN CRITERIA		
	A. Development Master Plan Discussion		
	B. Hydrologic Criteria Discussion		
	C. Impact on Offsite Facilities		
	D. Impact on Master Plan		
VI.	DRAINAGE FACILITY DESIGN	PRESENT	COMMENT

A. Topographic Contours
B. ROW and Easements
C. Delineation of Basin and Sub-Basins
D. Existing Drainage Patterns and Facilities
E. Proposed Drainage Patterns and Facilities
F. Proposed Outfall Points
G. Routing of Offsite Drainage
H. Routing from Site to Major Drainageway

APPROVAL BLOCK

ENGINEERING REVIEW TOWN OF HUDSON	Review is for general compliance with Town of Hudson Engineering standards and requirements. The Town of Hudson is not responsible for the correctness of design, dimensions, details, quantities and design safety.
☐ No Exceptions Taken ☐ Make Corrections Noted ☐ Rejected-See Checklist	Town Engineer Date

DEVELOPMENT REVIEW CHECKLIST
WATER PLANS

The purpose of this approval procedure check list is to familiarize all interested parties in the procedures followed by the Town concerning Town water plan approvals.

PLAN CHECK - CHECK LIST

The following information shall be included, where applicable, on all plans submitted to the Town Engineer.

I. GENERAL UTILITY PLANS

A. Cover Sheet

The following must be included on the Cover Sheet:

1. Name of project
2. Vicinity and location maps
3. P.E. stamp and signature
4. Sheet index

B. Overall Utility (Water and/or Sewer)

1. Required notes (see attached sheets for examples of general notes, water main and sanitary sewer notes required by the Town)
2. All street names
3. North arrow and scale (1"=100')
4. Indicate individual sheet numbers for specific sections of lines to be shown on following sheets
5. Lot and block numbers and front lot dimensions
6. A list of quantities shown for water (or sanitary sewer)

C. Title Blocks

1. Title, date, sheet number
2. Designed by, drawn by, checked by

II. WATER PLANS

A. Overall Sheet

1. An overall sheet is all that is required, provided the streets have been paved at finished grade and the water main is 12" or less in diameter. If the streets have not been paved to finish grade, the water main shall be shown in profile along with the

existing ground and proposed finished grade. All water mains larger than 12" shall be profiled. All water mains of any size which are not under a designed street shall also be profiled on the construction plans.

2. Water lines to be generally located 10' north or east of street centerlines, with a minimum of 10' between water lines. The centerline of the water main shall be a minimum of 5' from lip of curb and gutter pan on the street side.

3. Show station and label all fittings with top of pipe elevations, pipe distances between all fittings, valves, plugs, and size of pipe.

4. All valves and fire hydrants should be located on property line extensions if possible.

5. Indicate location of water lines from street centerlines or property lines.

6. Minimum cover of pipe shall be noted on the plans.

7. Length of restrained pipe, when and where required, shall be noted.

8. Show linear feet of pipe of all fire hydrant laterals.

9. The overall water sheet (or cover sheet) shall contain the following statement and appropriate signature:

   "All fire hydrants shall be installed according to Town standards. The number and locations of the fire hydrants as shown on this water main installation are correct as specified by the appropriate fire department.

   (Signature of Fire Chief or Designated Representative)

   Signed

   Date

   Note: If water plans are to be submitted to the Water Department for approval, "Town" in the above statement shall be followed by "and Water Department."

B. <u>Detail Sheet</u>

1. Compliance with applicable local government specifications.

2. Detail sheets to show blowoff assemblies, meter pits, thrust blocks, bedding, fire hydrant assemblies, fire hydrant locations relative to property lines and walks, rodding details, etc.

3. Technical notes and installation instructions are also required.

C. All plans submitted for review and approval by the Water Department shall be prepared in accordance with the latest revision of the Engineering Standards and plan submittal procedure of the Water Department and the Town.

III. OVERALL MASTER PLAN

Overall master plan showing relative locations of multiple filings and proposed overall water layout, if available, should be included with the initial submittal. Distances are not necessary for small projects where only one submittal is anticipated.

IV. EASEMENTS AND RECORDED PLATS

All submittals must be accompanied by recorded plats and/or easements for locations of all lines.

V. CONSTRUCTION PROCEDURES

1. A pre-construction meeting shall be held with Town Engineer, Inspector, Design Engineer, Contractor and other inspecting agencies at least one (1) week prior to the start of construction.

2. Construction begins, inspected by Town and other inspecting agencies.

3. Upon completion of construction, compaction test results shall be received by the Town Engineer.

4. Reproducible full-size mylar as-builts, including plats showing addresses for each lot to be served, submitted to Town Engineer.

5. Water mains tested in accordance with Town specifications and results submitted to Town Engineer.

6. Clean-up work completed by Contractor and project reinspected for probationary or preliminary acceptance of construction.

7. Review and approval of as-builts by inspector and other approving agencies.

8. Completion of curb, gutter and pavement inspection.

9. Notice of probationary acceptance and starting date sent to Developer, Design Engineer and Contractor.

10. The project will be inspected for final acceptance approximately eleven (11) months

after probationary acceptance.

11. Upon completion of the inspection, any problems which need to be corrected will be itemized and sent to the Developer for correction prior to final acceptance.

12. A final inspection will be made if deemed necessary.

13. Final acceptance of project and acceptance forms signed, dated and distributed.

GENERAL WATER NOTES

1. Only the following fire hydrants and valve boxes listed below shall be accepted for construction.

   Fire Hydrants:

   A. Waterous Pacer Model WB-67 with bronze bushed shoe and bronze shaft coupling.

   Valve Boxes:

   A. Tyler screw - Type "C" cast iron valve box assembly series 6860 with No. 160 oval base.

   B. Clay and Bailey screw - type 6 inch cast iron valve box assembly No. P-108 with No. 160 large oval base.

2. The Contractor is responsible for:

   A. Notifying all customers possibly affected by outage of water during construction.

3. Prior to installation of water mains, road construction must have progressed to at least the "sub-grade" stage. Sub-grade is defined as an elevation of no more than seven inches below the finished street grade.

   All valve boxes and fire hydrants will be adjusted to the final finished grade by the Contractor.

4. Before any taps are made from mains, application for said taps must be received and approved by the Town.

TOWN ACCEPTANCE NOTE

1. Upon completion of water construction and testing, the Developer or Contractor shall contact the Town for a probationary acceptance inspection. A punch list will be provided the Developer and Contractor upon completion of the initial walk-thru and Probationary Acceptance will be issued following completion and acceptance of the work outlined in the punch list.

2. The Contractor will be held responsible for the proper functioning of the lines for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any malfunction during this period of guarantee shall be remedied by the Contractor to the satisfaction of the Town Engineer at no expense to the Town.

3. The date of final acceptance will be indicated in the conditions of the Probationary Acceptance Letter. The Developer shall be responsible for contacting the Town for a final inspection and final acceptance.

ACCEPTANCE PROCEDURES

1. Upon completion of paving Contractor and/or Developer notifies Town Engineer of requests for probationary acceptance inspection.

2. Contractor and/or Developer submits final stamped and bound compaction reports to Town Engineer.

3. Contractor and/or Developer submits As-Built drawings to Town Engineer for review. Town Engineer compares as-builts against his field data makes revisions if necessary, and returns as-builts to Contractor or Developer. Changes are made and the as-builts are returned to the Town and Town Engineer.
   Town Engineer - Bluelines
   Town - Mylars and two (2) sets Bluelines

4. Town Engineer conducts probationary acceptance inspection with Town personnel, Developer and/or Utility Contractor present. A punch-list will be complied by the Town Engineer of any deficient construction and transmitted to each party.

5. Developer and/or Contractor will make necessary modifications to the water and sanitary sewer systems and notify the Town Engineer to make a follow-up inspection.

6. Town Engineer will conduct a follow-up inspection with Town personnel, Developer and/or Contractor to confirm modifications have been completed.

7. Town Engineer writes letter of recommendation to Town Manager.

8. Town will confirm that all fees owed to the Town are current, as-builts are in their possession, and that they have received their copy of the compaction report.

9. Town will notify the Developer or Contractor in writing that the probationary acceptance period is in effect.

10. The Contractor or Developer is responsible for all repairs and maintenance of the water and/or sanitary sewer mains he has constructed for a period of 1 year from the effective date of probationary acceptance.

FINAL ACCEPTANCE PROCEDURES

1. After approximately 11 months have passed following the effective date of probationary acceptance, the Developer and/or Contractor shall contact the Town Engineer to schedule a final acceptance walk-through inspection.

2. Town Engineer conducts final acceptance inspection with Town Personnel, Developer, and/or Utility Contractor present. A punchlist of deficient items will be complied by the Town Engineer and transmitted to each party.

3. Developer and/or Contractor will make necessary modifications to the items contained in the punchlist and notify the Town Engineer to make a follow-up inspection.

4. Town Engineer conducts follow-up inspection with Town personnel, Developer and/or Contractor to confirm modifications have been completed.

5. Town Engineer writes letter of recommendation to Town Manager.

6. If all outstanding issues have been satisfied the Town will notify the Contractor and/or Developer in writing of the effective date of final acceptance.

7. The Town will then have the responsibility of ownership and maintenance of the water and/or sewer mains from the effective date of final acceptance forward.

GENERAL NOTES

1. All construction shall comply with Town, and Specifications. Copies of Town Specifications may be obtained from the office of the Town Engineer.

2. The Contractor shall contact all appropriate utility companies and the Town of prior to the beginning of any construction. Contractor shall be responsible for locating any existing utility (including depths) which may conflict with the proposed construction. All existing utilities shall be protected from damage by the Contractor. Damaged utilities shall be repaired by the Contractor at his own expense.

   All items shown on the plans as existing are shown in approximate locations only. The actual location may vary from the plans, especially in the case of underground utilities. Whenever Contractor discovers a discrepancy in locations, he shall contact the Engineer immediately.

3. The Town Engineer and other approving agencies are to be notified at least 48 hours prior to construction.

4. The Contractor shall obtain, at his own expense, all permits which are necessary to perform the proposed work.

5. All concrete shall be a minimum of Class A, 6 sack, Type II, 3000 pound compression strength.

6. The Design Engineer shall submit one (1) set of rolled "As-Built" blueline prints to the Town Engineer for approval prior to printing mylar sepias for the Town. After approval has been granted by the Town Engineer, full size mylar sepia prints shall be transmitted to the Town office and an additional set of rolled blueline prints shall be transmitted to the Town Engineer's office prior to probationary acceptance.

7. All backfill material shall be compacted to 95% standard proctor density. Compaction tests must be submitted to the Town Engineer prior to probationary acceptance.

8. Trenches shall be excavated and the pipe exposed for the inspection at any location of the project if so ordered by the inspector.

9. The Contractor will be held responsible for the proper functioning of the water lines for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any malfunction during this period of guarantee shall be remedied by the Contractor to the satisfaction of the Town Engineer at no expense to the Town.

10. Surface grades are to be within plus or minus one foot of finished grade and verification of

compaction results obtained prior to the installation of the water lines. Results must be submitted to the Town Engineer.

11. No work shall be backfilled until the construction has been inspected and approved for backfilling by the Town Engineer or representative of the Town Engineer.

WATER MAINS

1. All materials and workmanship shall be in conformance with the Town and Engineering Standards, Materials Specifications and Standard Drawings. All work shall be inspected and approved by personnel of the and the Town Engineer.

2. All water mains shall be . Provide 8 Mil. polyethylene wrapping per A.W.W.A. Standard C105 at storm and conduit crossings, and fire hydrants and valves. All fittings shall be made from gray-iron or ductile iron and furnished with mechanical joint ends. All fittings shall have a pressure rating of 250 PSI and shall be wrapped with an 8 Mil. minimum thickness polyethylene material per A.W.W.A. Standard C105. All ductile iron pipe to be polyethylene wrapped.

3. All bends to be rodded.

4. There shall be a minimum cover of 4.5 feet over all water mains.

5. Fire hydrants shall conform to Section of materials specifications. Fire hydrant assemblies shall include all pipe, fittings, valves, materials, and labor which are necessary to install the hydrant complete-in-place.

6. All bends, tees, fire hydrants, blow-offs and plugs at dead end mains shall be protected from thrust by using concrete thrust blocks per .

7. Chlorination and flushing: The lines shall be chlorinated in accordance with A.W.W.A. C-601., "Disinfecting Water Mains." The preferred method is to use sufficient chlorine tablets to produce a 50 mg to 1 solution. These tablets should be adhered to the top of the pipe section with permatex no. 1 (red). The chlorination of any finished pipeline shall be done prior to the hydrostatic testing. Sterilization and flushing of all mains shall be inspected and certified by the Health Department having jurisdiction. The certification shall state the location of the main, that the main has been inspected by a representative of the Health Department having jurisdiction, and was found to comply with the procedures set forth by that department.

8. Hydrostatic Testing: All pipe shall be field pressure tested to a minimum of 150 PSI. All testing shall be done in the presence of a Town Inspector. Allowable leakage for each section of pipe between line valves shall not exceed 1.47 GPH for 8" water line.

9. All valves are to be located at property line extensions except for tapping tees where an additional valve shall be placed on the tapping tee. Other valve locations may be required as shown on the plan.

10. When necessary to lower or raise water lines at storm drains and other utility crossings, a minimum clearance of 1.50 feet shall be maintained between outside of pipes.

11. The Contractor shall have in his possession at all times one (1) signed copy of the plans which have been approved by the Town and the .

12. The Contractor shall notify the Construction Division and the Town at least 48 hours prior to any construction.

13. All required permits shall be obtained by the Contractor from the and the Town of for work performed in the public right of way.

14. The Contractor shall notify the Public Utility Companies and determine the location of all existing underground utilities prior to proceeding with the excavation. All work performed in the area of the public utilities shall be performed according to the requirements of these agencies.

15. The applicant is:

16. Compaction of all trenches must be attained in accordance with the soils report and compaction test results submitted to the Town Engineer prior to probationary acceptance.

17. Fire Hydrants: Waterous pacer Model WB-67 with bronzed bushed shoe, bronze shaft coupling.

18. Valve Boxes: Tyler screw-type 6 inch cast iron valve box assembly series 6860 with No. 160 oval base. Clay and Bailey screw-type 6 inch cast iron valve box assembly No. P-108 with No. 106 large oval base.

19. All pipe lengths are approximate.

20. At least five (5) days prior to the start of construction, a pre-construction meeting will be held at the office of the Town Engineer and attended by the Contractor and representatives of other approving agencies. It will be the responsibility of the Contractor to contact the Town Engineer.

21. The Contractor is responsible for:

    A. Notifying all customers possibly affected by outage of water during construction.

22. Prior to installation of water mains, road construction must have progressed to at least the "sub-grade" stage. Sub-grade is defined as an elevation of no more than seven inches below the finished street grade.

    All valve boxes and fire hydrants will be adjusted to the final finished grade by the Contractor.

23. Before any taps are made from mains, application for said taps must be received and approved by the Town.

DEVELOPMENT REVIEW CHECKLIST
SANITARY SEWER PLANS

The purpose of this approval procedure check list is to familiarize all interested parties in the procedures followed by the Town concerning Town plan approvals.

PLAN CHECK - CHECK LIST

The following shall be included, where applicable, on all plans submitted to the Town Engineer.

1. GENERAL UTILITY PLANS

   A. Cover Sheet

      The following must be included on the Cover Sheet:

      1. Name of Project
      2. Vicinity and location Maps
      3. P.E. Stamp and Signature
      4. Sheet Index

   B. Overall Utility (Water and/or Sewer)

      1. Required Notes (See attached sheets for examples of General Notes, Water Main and Sanitary Sewer notes required by the District)
      2. All Street Names
      3. North Arrow and Scale (1"=100')
      4. Indicate individual sheet numbers for specific sections of lines to be shown on following sheets.
      5. Lot and block number and front lot dimensions.
      6. A list of quantities shown for both sewer and water.

   C. Title Blocks

      1. Title, Date, Sheet Number
      2. Designed by, Drawn by, Checked by.

II. SEWER PLANS

   A. Overall Sheet

      1. All MH numbers, distances and sizes of lines, directional flow arrows.

      2. Sewers are generally located 5' south or west of street centerlines. On curved

streets, manholes may be located on centerlines providing no portion of the sewer line crosses the street centerline. Design should attempt to minimize the number of manholes. The centerline of sanitary sewer shall be a minimum of 5' from the lip of curb and gutter pan on the street sides.

3. Extra notes, such as tie-ins to be exiting lines, and verification of existing inverts and compaction locations prior to start of new construction.

4. Manholes sequencing should be logical and non-confusing. All subdivision manhole numbers should begin with the abbreviation of the subdivision.

5. "As-builts" must have all wye locations, stationed from downstream manhole, and must indicate type of pipe used and materials use.

6. Sheet numbers relating to specific plan and profile sheets.

7. Sewer Hydraulic data including Q, V, D, D, S, N, and peak flow factor at the point, or points where proposed sewer is tied into existing sewer. This should be based on Manning's Formula for flow in open conduits and flow generation per applicable jurisdictional agency.

B. Plan and Profile Sheet

1. Where possible, plan should be located in line above profile.

2. Plan should indicate manhole numbers, distances between manholes, size of pipe, grade, flow directions, and interior angles of sewer lines at manholes.

3. Grade shall be calculated by dividing the difference between the outlet of the upstream manhole and the inlet of the downstream manhole (as shown) by the distance between centers of the two manholes.

4. Street names, lot and block numbers and North Arrows.

5. Match lines with sheet numbers on both plan and profile.

6. Distances from street centerline or property line of manholes that are located on curved streets. Centerline dimensions are preferred. All manholes are to be located by dimensions in two directions.

7. Plan scale: horizontal 1"=50'.

DISTRICT ACCEPTANCE NOTE

1. Upon completion of sanitary sewer and water construction and testing, the Developer or Contractor shall contact the Town for probationary acceptance inspection. A punchlist will be provided the Developer and Contractor upon completion of the initial walk-through and Probationary Acceptance will be issued following completion and acceptance of the work outlined in the punchlist.

2. The Contractor will be held responsible for the proper functioning of the lines for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any malfunction during this period of guarantee shall be remedied by the Contractor to the satisfaction of the Town Engineer at no expense to the District.

3. The date of final acceptance will be indicated in the conditions of the Probationary Acceptance Letter. The Developer shall be responsible for contacting the Town for final inspection and final acceptance.

PROBATIONARY ACCEPTANCE PROCEDURES

1. Upon completion of paving Contractor and/or Developer notifies Town Engineer of requests for probationary acceptance inspection.

2. Contractor and/or Developer submits final stamped and bound compaction reports to Town Engineer.

3. Contractor and/or Developer submits As-Built drawings to Town Engineer for review. Town Engineer compares as-builts against his field data makes revisions if necessary, and returns as-builts to Contractor or Developer. Changes are made and the as-builts are returned to the Town and Town Engineer.
   Town Engineer - Bluelines
   Town - Mylars and two (2) sets bluelines

4. Town Engineer conducts probationary acceptance inspection with Town personnel, Developer and/or Utility Contractor present. A punch-list will be complied by the Town Engineer of any deficient construction and transmitted to each party.

5. Developer and/or Contractor will make necessary modifications to the water and sanitary sewer systems and notify the Town Engineer to make a follow-up inspection.

6. Town Engineer will conduct a follow-up inspection with Town personnel, Developer and/or Contractor to confirm modifications have been completed.

7. Town Engineer writes letter of recommendation to Town Manager.

8. Town will confirm that all fees owed to the Town are current, as-builts are in their possession, and that they have received their copy of the compaction report.

9. Town will notify the Developer or Contractor in writing that the probationary acceptance period is in effect.

10. The Contractor or Developer is responsible for all repairs and maintenance of the water and/or sanitary sewer mains he has constructed for a period of 1 year from the effective date of probationary acceptance.

FINAL ACCEPTANCE PROCEDURES

1. After approximately 11 months have passed following the effective date of probationary acceptance, the Developer and/or Contractor shall contact the Town Engineer to schedule a final acceptance walk-through inspection.

2. Town Engineer conducts final acceptance inspection with Town Personnel, Developer, and/or Utility Contractor present. A punchlist of deficient items will be complied by the Town Engineer and transmitted to each party.

3. Developer and/or Contractor will make necessary modifications to the items contained in the punchlist and notify the Town Engineer to make a follow-up inspection.

4. Town Engineer conducts follow-up inspection with Town personnel, Developer and/or Contractor to confirm modifications have been completed.

5. Town Engineer writes letter of recommendation to Town Manager.

6. If all outstanding issues have been satisfied the Town will notify the Contractor and/or Developer in writing of the effective date of final acceptance.

7. The Town will then have the responsibility of ownership and maintenance of the water and/or sewer mains from the effective date of final acceptance forward.

GENERAL NOTES

1. All construction shall comply with Town of Hudson Specifications.

2. The Contractor shall contact all appropriate utility companies and the Town of Hudson prior to the beginning of any construction. Contractor shall be responsible for locating any existing utility (including depths) which may conflict with the proposed construction. All existing utilities shall be protected from damage by the Contractor. Damaged utilities shall be repaired by the Contractor at his own expense.

   All items shown on the plans as existing are shown in approximate locations only. The actual locations may vary from the plans, especially in the case of underground utilities. Whenever contractor discovers a discrepancy in locations, he shall contact the Engineer immediately.

3. The Town and other approving agencies are to be notified at least 48 hours prior to construction.

4. The Contractor shall obtain, at his expense, all permits which are necessary to perform the proposed work.

5. All concrete shall be a minimum of Class A, 6 sack, Type 11, 3000 pound compression strength.

6. The Design Engineer shall submit one (1) set of rolled "As-Built" blueline prints to the Town Engineer for approval prior to printing mylar sepias and elctroinc files for the Town. After approval has been granted by the Town Engineer, full size mylar sepia prints shall be transmitted to the Town of Hudson office and an additional set of rolled blueline prints shall be transmitted to the Town Engineer's office prior to probationary acceptance.

7. All backfill material shall be compacted to 95% standard proctor density. Compaction tests must be submitted to Engineer prior to probationary acceptance.

8. Trenches shall be excavated and the pipe exposed for the inspection at any location on the project if so ordered by the inspector.

9. The Contractor will be held responsible for the proper functioning of lines (water and sewer) for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any malfunction during this period of guarantee shall be remedied by the Contractor to the satisfaction of the Town Engineer at no expense to the District.

10. Surface grades are to be within plus or minus one foot of finished grade and verification of compaction results obtained prior to the installation of water and sewer lines. Results must be submitted to the Town Engineer.
11. No work shall be backfilled until the construction has been inspected and approved for

backfilling by the Town Engineer or representative of the Town Engineer.

SANITARY SEWER

1. All sanitary sewer construction shall conform with the Town of Hudson Specification.

2. All sewer mains shall be PVC, ASTM D-3034, SDR 35 or approved equal. All sewer main size is 8" in diameter unless otherwise noted.

3. Sewer lines shall be installed 5.0 feet south or west of street centerline, unless otherwise shown on plans. Sewer lines shall be 10.00 feet from water lines except when crossing each other. Sewer lines which cross less than 1.50 feet vertically from the water main shall be encased in concrete as per Town of Hudson Standard and Specifications. Use rubber gaskets for PVC encasement.

4. Sewer rim elevations shown are appropriate only and are not to be taken as final elevations. Ring and cover shall be set in centered concrete rings with Ram-neck for adjustment to match final pavement elevations.

5. The Contractor and survey crew shall verify elevations of existing sewer lines and manholes to be tied to prior to construction or staking of sanitary sewer.

6. Gravel and/or tile underdrains shall be installed in all sewer main trenches as shown on the sanitary sewer plan and profile sheets. Underdrains shall be PVC - ASTM 3034, SDR 35 installed without gaskets. The Town of Hudson is not responsible for maintenance of underdrains. Size of underdrain services shall be 3" inch.

7. Sewer service tees for each unit shall be staked by a survey crew and furnished and installed by the Contractor. The Contractor shall furnish to the Engineer "as constructed" location of tees. Sewer wyes shall be used rather than tees.

8. All manholes shall be 48-inches in diameter with 24-inch ring and cover, eccentric cone unless otherwise specified.

9. Pipe bedding shall be Class "B" and shall conform to ASTM C-33 or D-448 gradation No. 6 or No. 67.

10. At least five (5) days prior to the start of construction, a pre-construction meeting will be held at the office of the Town and attended by the Contractor and representatives of the other approving agencies. It will be the responsibility of the Contractor to contact the District Engineer to schedule this meeting.

11. All pipe lengths are approximate.

12. The Contractor shall have in his possession at all times one (1) signed copy of the plans which have been approved by the Town of Hudson and he Town Engineer.
13. All manholes shall have shaped inverts.

14. All sewer lines shall be tested in accordance with Town of Hudson Standards and Specifications prior to acceptance or any connection to an existing line.

15. Prior to start work where sewer main to be installed into existing Town sewer systems, the nearest manhole to the point of tie-in shall be plugged with a plumber's plug on the inlet side by the Contractor. The plug shall remain in place until final acceptance by the Town. Its purpose shall be to prevent any mud, water or other materials from entering the line during construction. The Contractor shall be responsible for pumping and cleaning these manholes and removing the plug and removing the plug when so instructed by the Town.

III. STORM DRAINAGE DESIGN AND TECHNICAL CRITERIA

A. CHAPTER 1 GENERAL PROVISIONS

1. Short Title

These regulations together with all future amendments shall be known as the "Town of Hudson Storm Drainage Design and Technical Criteria" (hereafter called CRITERIA) as referenced in the Town of Hudson Land Development Regulations (hereafter called REGULATIONS).

2. Jurisdiction

These CRITERIA shall apply to all land within the Town, including any public lands. These CRITERIA shall apply to all facilities constructed on the Town ROW, easements dedicated for public use, and to all privately owned and maintained drainage facilities, including but not limited to detention ponds, storm sewers, inlets, manholes, culverts, swales, and channels.

3. Purpose and Effect

Presented in these CRITERIA are the minimum design and technical criteria for the analysis and design of storm drainage facilities. All subdivisions, re-subdivisions, planned unit development, or any other proposed development or construction submitted for approval under the provisions of the REGULATIONS shall include adequate storm drainage system analysis and appropriate drainage system design. Such analysis and design shall meet or exceed the criteria set forth herein. Options to the provisions of these CRITERIA may be suggested by the applicant. The applicant shall have the burden of showing that the options are equal or better. The applicant is also referred to the Colorado Department of Highways' Standard Plans for additional design details not covered in these CRITERIA. Drainage facilities in place or under construction at the time of CRITERIA adoption shall be accepted without regard to the provisions of these CRITERIA.

4. Enactment Authority

The REGULATIONS have been adopted pursuant to the authority conferred within: Article 28 of Title 30 (Town Planning); Article 2 of Title 43 (State, County, and Town Highway Systems); Article 20 of Title 29 (Land Use Control and Conservation); and other applicable sections of Colorado Revised Statutes, as amended. As part of the authority provided by which the Town promulgates the REGULATIONS, these CRITERIA are adopted by the resolution.

5. Amendment and Revisions

These policies and criteria may be amended as new technology is developed and/or if experience gained in the use of these CRITERIA indicates a need for revision. Amendments and revisions will be made by resolution.

6. Enforcement Responsibility
It shall be the duty of the Town's Board of Trustees acting through the Director of Public Works to enforce the provisions of these CRITERIA.

7. Review and Approval
The Town will review all drainage submittals for general compliance with these CRITERIA. An approval by the Town does not relieve the owner, engineer, or designer from responsibility of ensuring that the calculations, plans, specifications, construction, and record drawings are in compliance with the CRITERIA.

8. Interpretation
In the interpretation and application of the provisions of the CRITERIA, the following shall govern.

8.1 In its interpretation and application, the provisions shall be regarded as the minimum requirements for the protection of the public health, safety, comfort, morals, convenience, prosperity, and welfare of the residents of the Town.

8.2 Whenever a provision of these CRITERIA and any other provisions of the REGULATIONS or any provision in any law, ordinance, resolution, rule, or regulation of any kind, contain any restriction covering any of the same subject matter, whichever restrictions are more restrictive or impose higher standards of requirement shall govern.

8.3 These CRITERIA shall not abrogate or annul any permits or approved drainage reports, construction plans, easements, or covenants issued before the effective date of these CRITERIA.

9. Relationship to Other Standards
If special districts impose a more stringent criteria, than presented herein, this difference is not considered a conflict. If the State or Federal Government imposes stricter criteria, standards, or requirements, these shall be incorporated into the Town's requirement after due process and public hearing(s) needed to modify Town's regulations and standards.

10. Abbreviations
As used in these CRITERIA, the following abbreviations shall apply:

CDOT Colorado Department of Transportation
CSP Corrugated Steel Pipe
CSPA Corrugated Steel Pipe Arch
CWCB Colorado Water Conservation Board

FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
HERCP	Horizontal Elliptical Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
SCS	Soil Conservation Service
SPP	Structural Plate Pipe
SPPA	Structural Plate Pipe Arch
UD&FCD	Urban Drainage and Flood Control District
USDCM	Urban Storm Drainage Criteria Manual (MANUAL)
USGS	United States Geological Survey

B. CHAPTER 2 DRAINAGE PLANNING SUBMITTAL REQUIREMENTS

1. Review process

Drainage reports and plans, construction drawings, specifications, and as-built information shall be submitted and approved as required by the REGULATIONS and Building Permit Procedure. All submitted reports shall be clearly and cleanly reproduced. Photostatic copies of charts, tables, nomographs, calculations, or any other referenced material shall be legible. Washed out, blurred, or unreadable portions of the report are unacceptable and could warrant re-submittal of the report. The submittal shall include a declaration of the type of report submitted (i.e., Phase-I, Phase-II, or Phase-III). Standard Form SF-1 (located at the back of these CRITERIA) will be used to determine the adequacy of the submittal. Incomplete or absent information may result in the report being rejected for review.

A pre-application consultation is suggested of all applicants for all processing steps of the subdivision REGULATIONS. The applicant shall consult with the Planning Director for general information regarding subdivision regulations, required procedures, possible drainage problems, and specific submittal requirements.

2. Phase I Drainage Report

A Phase I Drainage Report is required to be submitted as part of the zoning process if the property to be zoned is traversed by a major drainageway that is to be modified in any way. This report will review at a conceptual level the feasibility and design characteristics of the proposed development. The Phase I drainage report shall be in accordance with the following outline and contain the applicable information listed:

2.1. Phase I Report Contents

I. GENERAL LOCATION AND DESCRIPTION

A. Location
1. Town, County, State Highway and local streets within and adjacent to the site, or the area to be served by the drainage improvements
2. Township, range, section, 1/4 section
3. Major drainageways and facilities
4. Names of surrounding developments

B. Description of Property
1. Area in acres
2. Ground cover (type of ground cover and vegetation)
3. Major drainageways
4. Existing major irrigation facilities such as ditches and canals
5. Proposed land use

II. DRAINAGE BASINS AND SUB-BASINS

A. Major Basin Description
   1. Reference to major drainageway planning studies such as flood hazard delineation report, major drainageway planning reports, and flood insurance rate maps.
   2. Major basin drainage characteristics, existing and planned land uses within the basin, as defined by the Planning Department
   3. Identification of all nearby irrigation facilities within 100-feet of the property boundary, which will influence or be influenced by the local drainage

B. Sub-Basin Description
   1. Discussion of historic drainage patterns of the property in question
   2. Discussion of offsite drainage flow patterns and impact on development under existing and fully developed basin conditions as defined by the Planning Department

III. DRAINAGE FACILITY DESIGN

A. General Concept
   1. Discussion of concept and typical drainage patterns
   2. Discussion of compliance with offsite runoff considerations
   3. Discussion of anticipated and proposed drainage patterns
   4. Discussion of the content of tables, charts, figures, plates, or drawings presented in the report

B. Specific Details (Optional Information)
   1. Discussions of drainage problems encountered and solutions at specific design points
   2. Discussion of detention storage and outlet design
   3. Discussion of maintenance and access aspects of the design
   4. Discussion of impacts of concentrating the flow on the downstream properties

IV. REFERENCES
Reference all criteria, master plans, and technical information used in support of concepts.

2.2. <u>Phase I Drawing Concepts</u>

A. <u>General Location Map</u>: All drawings shall be 24" x 36" in size. A map shall be provided in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. The map should be at a scale of 1" = 1000' to 1" = 4000' and show a path of all drainage from the upper end of any offsite basins to the defined major drainageways. The map shall identify any major facilities from the

property (i.e., development, irrigation ditches, existing detention facilities, culverts, storm sewers) along the flow path to the nearest major drainageway.

Basins and divides are to be identified and topographic contours are to be included.

B. Floodplain Information
A copy of the location map showing the location of the subject property shall be included with the report as outlined in Section 2.1. All major drainageways (see Section 2.5) shall have the 100 year floodplain defined and shown on the report drawings.

C. Drainage Plan
Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on a 24" x 36" drawing shall be included. The plan shall show the following:

1. Existing topographic contours at 2-foot maximum intervals. In steep areas, the maximum interval is 5 feet. The contours shall extend a minimum of 100-feet beyond the property lines.

2. All existing drainage facilities.

3. Approximate flooding limits based on available information.

4. Conceptual major drainage facilities including detention basins, storm sewers, swales, riprap, and outlet structures in the detail consistent with the proposed development plan.

5. Major drainage boundaries and sub-boundaries.

6. Any offsite feature influencing development.

7. Proposed flow directions and, if available, proposed contours.

8. Legend to define map symbols.

9. Title block in lower right corner.

3. Phase II Drainage Report
The purpose of the Phase II Drainage Report is to identify and/or refine conceptual solutions to the problems which may occur onsite and offsite as a result of the development. The Phase II Drainage Report shall be submitted during the subdivision process with the application for Preliminary Plat. If the zoning and preliminary plat

applications are submitted concurrently, the submittal requirements of this section shall apply. In addition, those problems that exist on site prior to development must be addressed during the preliminary phase. All reports shall be typed on 8 1/2" by 11" paper and bound. The drawings, figures, plates, and tables shall be bound with the report or included in a pocket attached to the report. The report shall include a cover letter presenting the preliminary design for review and shall be prepared by or supervised by an engineer licensed in Colorado. The report shall contain a certification sheet as follows:

"This report (plan) for the Phase II drainage design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of the Town of Hudson Storm Drainage Design and Technical Criteria, and was designed to comply with the provisions thereof. I understand that the Town of Hudson does not and will not assume liability for drainage facilities designed by others."

Registered Professional Engineer State of
Colorado No. __
(Affix Seal)

3.1 Phase II Report Contents

The Report shall be in accordance with the following outline and contains the applicable information listed:

I. GENERAL LOCATION AND DESCRIPTION

A. Location
1. Township, range, section, 1/4 section
2. Local streets within and adjacent to the subdivision with ROW width shown
3. Major drainageways, facilities, and easements within and adjacent to the site
4. Names of surrounding developments

B. Description of Property
1. Area in acres
2. Ground cover (type of trees, shrubs, vegetation, general soil conditions, topography, and slope)
3. Major drainageways
4. General project description
5. Irrigation facilities
6. Proposed land use

II. DRAINAGE BASINS AND SUB-BASINS

A. Major Basin Description

1. Reference to major drainageway planning studies such as flood hazard delineation reports, major drainageway planning reports, and flood insurance rate maps.
2. Major basin drainage characteristics, existing and planned land uses
3. Identification of all irrigation drainage patterns of the property in question

B. Sub-Basin Description
1. Discussion of historic drainage patterns of the property in question
2. Discussion of offsite drainage flow patterns and impact on development under existing and fully developed basin conditions.

III. DRAINAGE DESIGN CRITERIA

A. Regulations: Discussion of the optional provisions selected or the deviation from the CRITERIA, if any, and its justification.

B. Development Criteria Reference and Constraints
1. Discussion of previous drainage studies (i.e., project master plans) for the site in question that influence or are influenced by the drainage design and how the plan will affect drainage design for the site
2. Discussion of the effects of adjacent drainage studies
3. Discussion of the drainage impact of site constraints such as streets, utilities, light rail rapid transit, existing structures, and development or site plan

C. Hydrological Criteria
1. Identify design rainfall
2. Identify runoff calculation method
3. Identify detention discharge and storage calculation method
4. Identify design storm recurrence intervals
5. Discussion and justification of the criteria or calculation methods used that are not presented in or referenced by the CRITERIA

D. Hydraulic Criteria
1. Identify various capacity references
2. Discussion of other drainage facility design criteria used that are not presented in the CRITERIA

E. Waivers from Criteria
1. Identify provisions by section number for which a waiver is requested
2. Provide jurisdiction for each waiver requested

IV. DRAINAGE FACILITY DESIGN

A. General Concept
1. Discussion of concept and typical drainage patterns

2. Discussion of compliance with offsite runoff considerations
3. Discussion of the content of tables, charts, figures, plates, or drawings presented in the report
4. Discussion of anticipated and proposed drainage patterns

B. Specific Details
1. Discussion of drainage problems encountered and solutions at specific design points
2. Discussion of detention storage and outlet design
3. Discussion of maintenance access and aspects of the design
4. Discussion of easements and tracts for drainage purposes, including the conditions and limitations for use

V. CONCLUSIONS

A. Compliance with Standards
1. "CRITERIA"
2. "Major Drainageway Planning Studies"
3. Urban Drainage and Flood Control District (MANUAL)

B. Drainage Concept
1. Effectiveness of drainage design to control damage from storm runoff
2. Influence of proposed development on the Major Drainageway Planning Studies recommendation(s)

VI. REFERENCES
Reference all criteria and technical information used

VII. APPENDICES

A. Hydrologic Computations
1. Land use assumptions regarding adjacent properties
2. Initial and major storm runoff at specific design points
3. Historic and fully developed runoff computations at specific design points
4. Hydrographs at critical design points
5. Time of concentration and runoff coefficients for each basin

B. Hydraulic Computations (Optional for Phase II)
1. Culvert capacities
2. Storm sewer capacity, including energy grade line (EGL) and hydraulic grade line (HGL) elevations
3. Gutter capacity as compared to allowable using Figures-1003 and -1004
4. Storm inlet capacity including inlet control rating at connection to storm sewer

5. Open channel design
6. Check and/or channel drop design
7. Detention area/volume capacity and outlet capacity
8. Downstream/outfall system capacity to the Major Drainageway System

3.2 Phase II Drawing Concepts

A. General Location Map

All drawings shall be 24" x 36" in size. A map shall be provided in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. The map should be at a scale of 1" = 1000' to 1" = 4000' and show the path of all drainage from the upper end of any offsite basins to the defined major drainageways. The map shall identify any major construction (i.e., development, irrigation ditches, existing detention facilities, culverts, storm sewers) along the entire path of drainage. Basins and divides are to be identified and topographic contours are to be included.

B. Floodplain Information

A copy of the location map showing the location of the subject property shall be included with the report. All major drainageways (see Section 3.2.5) shall have the floodplain defined and shown on the report drawings.

C. Drainage Plan

Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on a 24" x 36" drawing shall be included. The plan shall show the following:

1. Existing and (if available) proposed contours at 2-foot maximum intervals. In steep areas, the maximum interval is 5 feet. The contours shall extend a minimum of 100-feet beyond the property lines.
2. Property lines and easements with purposes notes.
3. Streets, indicating ROW width, flowline width, curb type, sidewalk, and approximate slopes.
4. Existing drainage facilities and structures, including irrigation ditches, roadside ditches, crosspans, drainageways, gutter flow directions, and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included.
5. Overall drainage area boundary and drainage sub-area boundaries.
6. Proposed type of street flow (i.e., vertical or combination curb and gutter), roadside ditch, gutter, slope and flow directions, and cross pans.
7. Proposed storm sewers and open drainageways, including inlets, manholes, culverts, FES, and other appurtenances, including riprap protection.
8. Proposed outfall point for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties.

9. Routing and accumulation of flows at various critical points for the minor storm runoff listed on the drawing using the format shown in Table-202.
10. Routing and accumulation of flows at various critical points for the major storm runoff listed on the drawing using the format shown in Table-202.
11. Volumes and release rates for the minor and major storm event for associated detention storage facilities and information on outlet works.
12. Location and elevations of all existing floodplains affecting the property.
13. Location and (if known) elevations of all existing and proposed utilities affected by or affecting the drainage design.
14. Routing of offsite drainage flow through the development.
15. Definition of flow path leaving the development through the downstream properties ending at a major drainageway.
16. Legend to define map symbols (see Table-202 for symbol criteria).

Insert Table 202 here

17. Title block in lower right hand corner.

4. Phase III Drainage Report

The purpose of the Phase III Drainage Report is to update the concepts, and to present the design details for the drainage facilities discussed in the Phase II Drainage Report. Also, any change to the Phase II concept must be presented.

The Phase III Drainage Report, which shall be submitted with the application for corrected plat, must address comments made during review of the Phase II Report. A Phase III Report which complies with the requirements of this Section 4 must be submitted by the developer or owner and reviewed and approved by the Public Works Department prior to scheduling the corrected plat for Board of Trustees hearing.

All reports shall be typed on a 8-1/2" x 11" paper and bound. The drawings, figures, charts, plates and/or tables shall be bound with the report or included in a folder/pocket attached at the back of the report.

The report shall include a cover letter presenting the final design for review and shall be prepared by or under the direction of an engineer licensed in Colorado, certified as shown above in Section 3 for the Phase-II report. The report shall also contain a developer certification sheet as follows:

"(Name of Developer) hereby certifies that the drainage facilities for (Name of Development) shall be constructed according to the design presented in this report. I understand that the Town of Hudson does not and will not assume liability for drainage facilities designed or reviewed by my engineer. I also understand that the Town of Hudson relied on the representations of others to establish that drainage facilities are designed and built in compliance with applicable guidelines, standards, or specifications. Review by the Town of Hudson can therefore in no way limit or diminish any liability which I or any other party may have with respect to the design or construction of such facilities."

(NAME OF DEVELOPER)

By:

The Phase III Drainage Report shall be prepared in accordance with the outline shown in Section 13.1. The report drawings shall follow the requirements presented in Section 13.3.2, above.
Three (3) copies of the approved Phase III Drainage Plan and Report shall be submitted to the Town for signature and retention in its files.

5. CONSTRUCTION PLANS

Where drainage improvements are to be constructed, the final construction plans (24" x 36") shall be submitted with the Phase III Drainage Report. Approval of the final construction plans by the Town Engineer is a condition of issuing the construction permits. Seven (7) copies of the approved plans will be submitted to the Town for file. The plans for the drainage improvements will include:

(1) Storm sewers, inlets, outlets and manholes with pertinent elevations, dimensions, type, and horizontal control indicated.

(2) Culverts, end sections, and inlet/outlet protection with dimensions, type, elevations, and horizontal control indicated.

(3) Channels, ditches, and swales (including side/rear yard swales) with lengths, widths, cross-sections, and erosion control (i.e. riprap, concrete, grout) indicated.

(4) Checks, channel drops, erosion control facilities.

(5) Detention pond grading, trickle channels, outlets, and landscaping.

(6) Other drainage related structures and facilities (including underdrains and sump pump lines).

(7) Maintenance access considerations.

(8) Overlot grading and erosion and sedimentation control plan (refer to Chapter 13).

The information required for the plans shall be in accordance with sound engineering principles, these CRITERIA and the Town requirements for sub-division designs. Construction documents shall include geometric, dimensional, structural, foundation, bedding, hydraulic, landscaping, and other details as needed to construct the storm drainage facility. The approved Phase III Drainage Plan shall be included as part of the construction documents for all facilities affected by the drainage plan. Construction plans shall be signed by a registered professional engineer as being in accordance with the Town approved drainage report/drawings.

6. As-built Drawings and Final Acceptance Certificate

As-built drawings for all improvements are to be submitted to the Town with the request for Probationary Acceptance. Certification of the record drawings is required as follows:

The Town of Hudson may require as-built drawings as a condition of acceptance. Certification of the record drawings requires the following:

A professional engineer registered in the State of Colorado shall undertake such investigation as may be necessary to determine or confirm the as-built detention pond volumes and surface areas at the design depths, outlet structure sizes and elevations, storm sewer sizes and invert elevations at inlets, manholes and discharge location, and representative open channel cross-sections, and dimensions of all the drainage structures. The Town Engineer will compare the as-built drawing information as verified by an engineer with the construction drawings. If the improvements for a project are constructed in phases, as-built drawings may be submitted at the completion of each phase.

Prior to the issuance of a Certificate of Acceptance, a professional engineer, registered in the State of Colorado, shall inspect the constructed facilities and submit to the Town in writing that he has been afforded adequate opportunity to review and evaluate the drainage facilities during the course of construction thereof, and on the basis of such review and evaluation, has determined to the best of his knowledge and belief that such facilities were constructed in accordance with the approved drainage report and construction drawings.

C. CHAPTER 3 DRAINAGE POLICY

1. Introduction

The provisions for adequate drainage in urban areas is necessary to preserve and promote the general health, welfare, and economic well being of the region. Drainage is a regional feature that affects all governmental jurisdictions and all parcels of property. This characteristic of drainage makes it necessary to formulate a program that balances both public and private involvement. Overall coordination and master planning must be provided by the governmental units most directly involved, but drainage must be integrated on a regional level.

When planning drainage facilities, certain underlying principles provide direction for the effort. These principles are made operational through this set of policy statements. The application of the policy is in turn facilitated by technical criteria and data. A brief discussion of the requirements or basis for a policy is presented followed by the actual policy statement, which is highlighted by capital letters and underlined.

2. Basic Principles

2.1 Urban Sub-System

Drainage is a sub-system of all urbanization. The planning of drainage facilities must be included in the urbanization process. The first step is to include drainage planning with all regional and local development master plans. The report shall address multiple purpose use of land for drainage and open space.

Storm water management facilities, such as channels and storm sewers, serve both a conveyance and storage function. When a channel is planned as a conveyance feature, it requires an outlet as well as downstream storage space. When the space requirements are considered, the provision for adequate drainage becomes a competing use for space along with other land uses. If adequate provision is not made in a land use plan for the drainage requirements, storm water runoff will conflict with other land uses and will result in water damages, and will impair or even disrupt the functioning of other urban systems.

The policy of the Town shall be to consider storm drainage a sub-system of the over-all urban system and to require storm drainage planning for all developments to include the allocation of space for drainage facilities.

2.2 Multi-Purpose Resource

Storm water runoff is an urban resource. Whereas the runoff can be a liability to urbanization, storm runoff has potential for beneficial use. This use, however, must be compatible with adjacent land uses and Colorado Water Law.

When storm water runoff is treated as a resource, quality aspects of the water become important. This in turn relates to issues such as street cleaning practices,

solid waste collection and removal services, and regulations on the development of raw land to control erosion and resulting silt loads. These practices influence succeeding water uses.

The storm water urban sub-system should be multi-purpose to satisfy the competing demands placed on water within the urban environment. Drainage facilities can fulfill other purposes aside from just drainage; and facilities not designed primarily for drainage frequently can be designed to provide drainage benefits.

The policy of the Town shall be to consider storm runoff as a multi-purpose resource with the potential for practical use and to encourage the multi-purpose use.

2.3 Water Rights

When the drainage sub-system interferes with existing water rights, the value and use of the water are affected. The existing drainageways and storage locations frequently interrelate with the water rights, which must be addressed when planning the facility to preserve their integrity.

Ditches which have direct flow rights from a stream are controlled by headgates. Drainage improvements, which alter the quantity (or quality) of the water available to the headgate, affect the ability to divert water. Other ditches obtain all or portions of the rights by intercepting the shallow groundwater (seepage right). If the water right has not been abandoned or transferred to another location, the drainage design (including the sub-surface system) must be planned and constructed to preserve the water right. Similar situations can also occur when planning drainage facilities near reservoirs.

The policy of the Town shall be to recognize the possible effects on the water rights and to include the interrelationship in the planning and design of the proposed drainage facility.

2.4 Jurisdictional Boundaries

Since drainage considerations and problems are regional in nature, and do not respect jurisdictional boundaries, a successful plan must emphasize regional cooperation in accomplishing the goals.

The policy of the Town shall be to pursue a jurisdictionally unified approach to drainage to assure an integrated plan.

2.5 Major Drainageway

The definition of a major drainageway is necessary for the clarification and administration of these CRITERIA. For the purpose of these CRITERIA, a Major Drainageway shall be defined as any drainage flowpath with a tributary area of

130 acres or more.

3. REGIONAL AND LOCAL PLANNING

3.1 Basin Transfer

Colorado drainage law recognizes the inequitability of transferring the burden on managing storm drainage from one location or property to another. Liability questions also arise when the historic drainage continuum is altered. The diversion of storm runoff from one basin to another should be avoided unless specific and prudent reasons justify and dictate such a transfer. Prior to selecting a solution, alternatives should be reviewed. Planning and design of storm water drainage systems should not be based on the premise that problems can be transferred from one location to another.

The subdivision process can significantly alter the historic or natural drainage paths. When these alterations allow water to drain into the subdivision in its natural quantity and manner, and discharges water back into the natural drainageway in the historic quantity and manner, the alterations are generally acceptable. When, however, the improvements or alterations impede the natural drainage flow into the subdivision, it violates the rule of Colorado law that a property within a natural drainageway is subject to the historic drainage from upper lands. In addition, if the subdivision outfall system does not return the drainage to the natural drainageway, then the rule that drainage water cannot be sent down to do more harm than formerly to lower lands is violated. Development which alters drainage patterns in violation of either of these principles will not be approved.

The policy of the Town shall be to avoid inter-basin transfer of storm drainage runoff and to maintain the historic drainage path within the basin. However, the transfer of drainage from basin to basin is a viable alternative in certain instances and will be reviewed on a case-by-case basis.

3.2 Master Planning

As set forth in the policy statement C.2.1, drainage planning is required for all new development plans. In recognition that drainage boundaries are non-jurisdictional, the Town has participated in regional basin wide master plans to define the Major Drainageway Facilities. The Town will also encourage and participate in future master plans.

The policy of the Town shall be to encourage the development of detailed regional drainage master plans which will set forth site requirements for new development and identify the required public improvements. Master plans will be approved and adopted.

3.3 Special Planning Areas

Presently, there are areas in the Town where significant drainage problems currently exist. Any new development or redevelopment in these areas may compound the existing drainage problems.

The policy of the Town is to require additional analysis and/or definition of additional facilities required for development and redevelopment in current drainage problem areas as defined by the Town.

3.4 Public Improvements

When the drainage master plans identify that public improvements are justified, mechanisms for funding the improvements are required. The funding should equitably distribute the initial costs and maintenance cost in proportion to the benefits received.

Include with the public improvements defined by drainage master plans is the Local Drainage System and the major Drainage System. The Local Drainage System consists of curb and gutter, inlets and storm sewers, culverts, bridges, swales, ditches, channels, detention areas, and other drainage facilities within the development required to convey the minor and major storm runoff to the Major Drainageways. The Major Drainageway System consists of channels, storm sewers, bridges, detention areas, and other facilities serving more than the subdivision or property in question.

The policy of the Town requires that all new development and redevelopment shall participate in the required drainage improvements as set forth below:

(1) Design and construct the local drainage system as defined by the Phase-III Drainage Report and Plan (Sections B.4 and B.5 of these CRITERIA).

(2) Design and construct connection of the local drainage system to the major drainageway system.

(3) Equitable participation in the design and construction of the major drainageway system within the development as defined by adopted Master Drainage Plans (Section C.2 of the CRITERIA) or as required by the Town and designated in the Phase-III Drainage Report.

3.5 Storm Runoff Detention and Water Quality Enhancement

The value of the storm runoff detention as part of the urban system has been explored by many individuals, agencies, and professional societies. Detention is considered a viable method to reduce urban drainage costs. Temporarily detaining a few acre-feet of runoff can significantly reduce downstream flow hazards as well as pipe and channel requirements in urban areas. Storage also provides for sediment and debris collection which helps to keep streams and rivers cleaner. Thus, public health benefits may accrue from storage of storm runoff. However,

all benefits can only be obtained through consistent administration of the detention policy. This policy may be adjusted by adopted master plans.

The policy of the Town requires onsite detention for all new development, expansion, and redevelopment. The required minimum detention volume and maximum release rates at these volumes for the 10-year and 100-year recurrence interval storm shall be determined in accordance with the procedure and data set forth in this CRITERIA.

Exemptions from the detention requirement may be granted for in-fill areas and for additions to existing buildings and paved areas, provided the total impervious area of the in-fill or the total of all expansions cover less than 10,000 square feet of impervious paved and roof surface. Onsite detention requirements will be waived where regional detention facilities have been constructed with the capacity to accommodate flows from a fully developed basin and are publicly owned and maintained.

3.6 Operations and Maintenance

An important part of all storm drainage facilities is the continued maintenance of the facilities to ensure they will function as designed. Maintenance of detention facilities involves removal of debris and sediment. Such tasks are necessary to preclude the facility from becoming unhealthy and to retain the effectiveness of the detention basin. Sediment and debris must also be periodically removed from channels and storm sewers. Trashracks and street inlets must be regularly cleared of debris to maintain system capacity. Channel bank erosion, damage to drop structures, crushing or pipe inlets and outlets, and deterioration to the facilities must be repaired to avoid reduced conveyance capability, unsightliness, and ultimate failure.

Maintenance responsibility lies with the owner of the land, except as modified by specific agreement. Maintenance responsibility shall be delineated on corrected Plats and Final Development Plans. Maintenance access for detention ponds need not be specified but must be adequate for maintenance and be shown on the corrected Plats and Final Development Plans.

The policy of the Town requires that maintenance access be provided to all storm drainage facilities to assure continuous operational capability of the system. The property owner shall be responsible for the maintenance of all drainage facilities including inlets, pipes, culverts, channels, ditches, hydraulic structures, and detention basins located on their land unless modified by the subdivision improvements agreement. Should the owner fail to adequately maintain said facilities, the city shall have the right to enter said land for the purposes of operations and maintenance. All such maintenance costs will be assessed to the property owner.

The easements required to provide adequate maintenance access are as follows:

REQUIRED OPERATIONS & MAINTENANCE EASEMENT

DRAINAGE FACILITY	NON-EXCLUSIVE EASEMENT WIDTH
(1) Storm Sewer	
(a) less than 36" dia.	20'
(b) equal to or greater than 36" dia.	Twice the pipe invert depth with sewer placed within the middle third of the easement (minimum width = 20')
(2) Open Channel/Swales	
(a) Q_{100} less than 20 cfs	15'
(b) Q_{100} less than 100 cfs	25'
(c) Q_{100} greater than 100 cfs	see Figures 703, 704, and 705 (Includes Freeboard and Maintenance Access Roadway)
(3) Detention Pond	As required to contain storage and associated facilities plus adequate maintenance access around perimeter.

Drainage easements shall be shown on the Corrected Plats and state that the Town has the right of access on the easements which shall be kept clear of obstructions to the flow and/or obstructions to maintenance access.

4. Technology Planning and Design

4.1 Drainage Criteria

The design criteria presented herein represents the state-of-the-art for stormwater management. The CRITERIA are intended to establish guidelines, standards, and methods for effective planning and design. The CRITERIA should be revised and updated as necessary to reflect advances in the field of urban drainage engineering and urban water resources management.

The policy of the Town requires that all storm drainage facilities shall be planned and designed in accordance with the CRITERIA set forth in this document. The CRITERIA will be revised or amended as new technology is developed and/or experience gained in the use of this document.

4.2 Minor and Major Drainage System

Every urban area has two separate and distinct drainage systems, whether or not they are actually planned or designed. One is the Minor Drainage System and the other is

the Major Drainage System, which are combined to form the Total Drainage System.

The Minor Drainage System is designed to transport the runoff from five year frequency events with a minimum disruption to the urban environment. Minor storm drainage can be conveyed in the curb and gutter area of the street or roadside ditch (subject to street classification and capacity, as defined herein), by storm sewer, channel, or other conveyance facility.

The policy of the Town requires that all minor drainage systems be sized without accounting for peak flow reductions from onsite detention, unless otherwise approved by the Town Engineer.

The Major Drainage System is designed to convey runoff from the 100-year recurrence interval flood to minimize health and life hazards, damage to structures, and interruption to traffic and services. Major storm flows can be carried in the urban street system (within acceptable depth criteria), channels, storm sewers, and other facilities.

The policy of the Town requires that all subdivisions include the planning, designing and implementation for both the minor and major drainage systems in accordance with the following recurrence intervals:

LAND USE	RECURRENCE INTERVAL (YRS) MINOR DRAINAGE SYSTEM	RECURRENCE INTERVAL (YRS) MAJOR DRAINAGE SYSTEM
Residential - Urban	5	100
Residential - Rural	5	100
Commercial - Business	5	100
Industrial	5	100
Open Space	5	100
School	5	100

4.3 Storm Runoff

Storm runoff shall be determined by the Rational Method for basins less than 160 acres. The CUHP Method may be used for basins greater than 90 acres (or as noted in Section F.5 of these CRITERIA) and Applicable Soil Conservation Services (SCS) methods as defined in "Peak Flows in Colorado" may be used with approval of the Director of Public Works.

The policy of the Town allows storm runoff to be determined by either the rational

method or the Colorado Urban Hydrograph Procedure (CUHP), within the limitations as set forth in this CRITERIA. For basins larger than 160 acres, the peak flows and volumes shall be determined by the Colorado Urban Hydrograph Procedure.

4.4 Streets

Streets are an integral part of the urban drainage system and may be used for transporting storm runoff up to design limits. The engineer designer should recognize that the primary purpose of streets is for traffic, and therefore the use of streets for storm runoff must be restricted.

The policy of the Town allows the use of streets for drainage within the following limitations:

4.4.1 Allowable Use of Streets for Minor Storm Runoff

DRAINAGE CLASSIFICATION	MAXIMUM THEORETICAL STREET ENCROACHMENT
Type A (Local)	No curb overtopping. Flow may spread to Crown of street. (Flow may spread to back of the sidewalk for a 4-inch combination curb and sidewalk).
Type B (Collector)	No curb overtopping. Flow spread must (collector) leave at least one 10-foot lane free of water, 5-feet either side of the street crown.
Type C (Arterial)	No curb overtopping. Flow spread must leave at least two 10-foot lanes free of water, 10-feet each side of the street crown or median.

The maximum allowable street flow for minor storm runoff shall be the product of the flow calculated at the "Maximum Theoretical Street Encroachment" and the required reduction factor as provided in Chapter 10 of these CRITERIA.

4.4.2 Allowable Use of Streets for Major Storm Runoff

DRAINAGE CLASSIFICATION	MAXIMUM THEORETICAL STREET ENCROACHMENT
Types A and B (Local, Collector)	Residential dwellings, public, commercial, and (Local, Collector) industrial buildings shall not be inundated at the ground line. The depth of water at the gutter flowline shall not exceed 12-inches.
Type C (Arterial)	Residential dwellings, public, commercial, and (Arterial) industrial building shall not be inundated at the ground line. To allow for emergency vehicles, the depth of

water shall not exceed 6-inches at the street crown and 12-inches at the gutter flowline, whichever is more restrictive.

The maximum allowable street flow for major storm runoff shall be the product of the flow calculated at the "Maximum Theoretical Depth" and the required reduction factor as provided in these CRITERIA.

4.4.3 Allowable Cross Street Flow

DRAINAGE SYSTEM CLASSIFICATION	MINOR DRAINAGE SYSTEM MAXIMUM DEPTH	MAJOR DRAINAGE SYSTEM MAXIMUM DEPTH
Type A (Local)	6-inches of depth in cross pan or gutter flowline	12-inches of depth at gutter flowline
Type B (Collector)	None	12-inches of depth at gutter flowline
Type C (Arterial)	None	None

Cross street flow can occur in an urban drainage system under three conditions. One condition occurs when the runoff in a gutter spreads across the street crown to the opposite gutter. The second is when cross pans are used. The third condition occurs when the flow in a drainageway exceeds capacity of a road culvert and subsequently overtops the crown of the street.

4.4.4 Allowable Culvert Overtopping

DRAINAGE SYSTEM CLASSIFICATION	MINOR DRAINAGE SYSTEM MAXIMUM DEPTH	MAJOR DRAINAGE SYSTEM MAXIMUM DEPTH
Types A and B (Local, collector)	None	12-inches of depth at gutter flowline
Type C (Arterial)	None	None, minimum clearance between the low chord or culvert crown and the energy grade line shall be 6-inches for basins less than 2 square miles,

1-foot for basins up to 10 square miles, and 2-feet for basins greater than 10 square miles.

The maximum headwater for the 100-year design flows shall be 1.5 times the culvert diameter or 1.5 times the rise dimension for pipe shapes other than round (Type A and Type B streets only).

4.5 Floodproofing

Floodproofing can be defined as those measures which reduce the potential for flood damages to existing properties within a floodplain. The floodproofing measures can range from elevating structures to intentional flooding of non-critical building spaces to minimize structural damages. Floodproofing measures are only a small part of good floodplain management which encourage wise flood-plain development to minimize the adverse effects of floods.

The policy for existing structures is as follows:

The policy of the Town shall be to encourage the floodproofing of existing structures not in conformance with the adopted floodplain regulations by utilizing the CRITERIA presented in the "Colorado Floodproofing Manual" prepared by the Department of Natural Resources, Colorado Water Conservation Board, dated September 1983.

D. CHAPTER 4 FLOODPLAIN REGULATIONS

1. Introduction

The regulation of floodplains is necessary to preserve and promote the general health, welfare, and economic well being of the region. The general purposes of floodplain regulations are summarized as follows:

(1) To reduce the hazard of floods to life and property;

(2) To protect and preserve hydraulic characteristics of water courses used for conveyance of flood waters; and

(3) To protect the public from the extraordinary financial expenditures for flood control and relief.

It is the designer's responsibility to utilize the most current adopted floodplain regulations.

E. CHAPTER 5 RAINFALL

1. Introduction

Presented in this section are the design rainfall data to be used with the Colorado Urban Hydrograph Procedure (CUHP) and the Rational Method. All hydrological analysis within the jurisdiction of the CRITERIA shall utilize the rainfall data presented herein for calculating storm runoff.

2. Hudson Rainfall Zones

2.1 Description of the Rainfall Zone

A review of the isopluvial maps presented in the NOAA Atlas for Colorado shows that Hudson is located within rainfall zone IIA:

3. Colorado Urban Hydrograph Procedure Design Storms

For drainage basins less than five square miles, a two-hour storm distribution without area adjustment of the point rainfall values shall be used for the Colorado Urban Hydrograph Procedure (CUHP). For drainage basins between five and ten square miles, a two-hour storm distribution is used but the incremental rainfall values are adjusted for the large basin area in accordance with suggested procedures in the NOAA Atlas for Colorado. The adjustment is an attempt to relate the average of all point values for a given duration and frequency within a basin to the average depth over the basin for the same duration and frequency. For drainage basins between ten and twenty square miles, a three-hour storm duration with adjustment for area shall be used. The distribution for the last hour was obtained by uniformly distributing the difference between the two- and three-hour point rainfall values. The adjustment for area was obtained from the NOAA Atlas for Colorado. The incremental rainfall distributions for all basin areas up to 20 square miles are presented in Table 502.

4. TIME-INTENSITY-FREQUENCY CURVES

The Time-Intensity-Frequency curves for each zone were developed by distributing the one-hour point rainfall values (Table 501) using the factors obtained from the NOAA Atlas presented below:

FACTORS FOR DURATIONS OF LESS THAN ONE HOUR

Duration (minutes)	5	10	15	30	
Ratio to 1-hour depth		0.29	0.45	0.57	0.79

Source: NOAA Atlas 2, Volume III, Colorado 1973

The point values were then converted to intensities and plotted on Figure-502. The data are also presented in Table 503.

TABLE 501

Design Point Rainfall Values
Zone IIA

One Hour Point Rainfall (IN.)

2 - Year	0.97
5 - Year	1.38
10 - Year	1.65
50 - Year	2.32
100 - Year	2.67

Insert Table 502 here

Insert Figure 501 here

F. CHAPTER 6 RUNOFF

1. Introduction

This chapter presents the CRITERIA and methodology for determining the storm runoff design peaks and volumes to be used in the Town in the preparation of storm drainage studies, plans, and facility design. The details of the rainfall/runoff models are presented in the Urban Storm Drainage Criteria Manual (Manual). The specific input data requirements and modifications to the procedures are presented in this chapter.

2. Rational Method

The Rational Method, in widespread use in the Denver Region, will continue to be utilized for the sizing of storm sewers and for determining runoff magnitude from unsewered areas. The limit of application of the Rational Method is approximately 160 acres. It has been concluded that, for tributary basins in excess of 160 acres, the cost of the drainage works justifies significantly more study, thought, and judgement on the part of the engineer than is permitted by the Rational Method. When the urban drainage basin exceeds 160 acres, the CUHP method represents better practice and shall be used.

The procedures for the Rational method, as explained in the MANUAL, Volume-1 "Runoff" (Revised May 1, 1984), shall be followed in the preparation of drainage reports and storm drainage facility designs in the Town.

Standard forms for the calculation of Time of Concentration and Storm Drainage System Design have been provided at the end of these CRITERIA.

3. Colorado Urban Hydrograph Procedure

The CUHP is required for watershed areas larger than 160 acres. The procedures for the CUHP, as explained in the MANUAL, Volume-1 "Runoff," shall be followed in the preparation of drainage reports and storm drainage facility designs in the Town. The design storms to be used with the CUHP method are presented in Table-502.

4. Storm Flow Analysis

When determining the design storm flows, the engineer shall follow particular CRITERIA and guidelines to assure that minimum design standards and uniformity of drainage solutions are maintained throughout the Town. The information presented herein shall be used by the design engineer in the development of design storm runoff.

4.1 Onsite Flow Analysis

When analyzing the flood peaks and volumes, the design engineer shall use the proposed fully developed land use plan to determine runoff coefficients. In addition, the engineer shall take into consideration the changes in flow patterns (from the undeveloped site conditions) caused by the proposed street alignments. When evaluating surface flow times, the proposed lot grading shall be used to

calculate the time of concentration or the CUHP parameters.

4.2 Offsite Flow Analysis

The analysis of offsite runoff is dependent on the development status and whether the tributary offsite area lies within a major drainageway basin as defined in Section 3.2.5. In all cases, the minor system is designed for the fully developed major storm runoff (Section 3.4.2) without the benefits of onsite detention. In some cases credit is given for detention for the design of the major system.

4.2.1 Tributary Area Within a Major Drainageway Basin

(a) Where the offsite area is undeveloped, the runoff shall be calculated assuming the basin is fully developed as defined by the Planning Department. If this information is not available, then the runoff shall be calculated using the coefficients defined in Table 3-1 of Section 3.6, "Runoff", Volume I of the MANUAL, "Undeveloped Areas - Offsite Flow Analysis." No credit will be given for onsite detention in the offsite area for any design frequency.

(b) Where the offsite area is fully or partially developed, the storm runoff shall be based upon the existing platted land uses and topographic features. No credit will be given for onsite detention in the offsite area for any design frequency.

4.2.2 Tributary Area Not Within a Major Drainageway Basin

(a) Where the offsite area is undeveloped, the minor system runoff shall be calculated assuming the basin is fully developed as defined by the Planning Department. If this information is not available, then the runoff will be calculated using the coefficients defined in Table 3-1 of Section 3.6, "Runoff", Volume I of the MANUAL. The major system runoff (i.e., 10-year and 100-year) may be calculated assuming the historic runoff rates computed in accordance with procedures described in Chapter 14 of these CRITERIA.

(b) Where the offsite area is fully or partially developed, the storm runoff shall be based on the existing platted land uses and topographic features, unless onsite detention in the offsite area has been constructed and accepted by the Town. However, no credit will be given for onsite detention in the offsite area for the minor system design, unless otherwise approved by the Town Engineer.

5. Cuhp Computer Program

A computer program has been developed to calculate hydrographs using the CUHP method. This program is available for use on both large mainframe computers and on

the smaller IBM-PC XT or IBM-PC AT personal computers. In addition, the personal computer version has an added capability of using CUHP to compute runoff hydrographs for basins of 10-acres or larger in size. Only with the personal computer version will 10- to 90-acre CUHP basins be allowed. Specific details of the required input for this version are available in the CUHPE/PC Version Users Manual. Both the CUHPD (large mainframe) and CUHPE/PC (personal computer) computer programs can be obtained by contacting the UD&FCD at 2480 West 26th Avenue, Suite 156-B, Denver, Colorado 80211 or by calling (303) 455-6277.

G. CHAPTER 7 OPEN CHANNELS

1. Introduction

This chapter addresses the technical criteria for the hydraulic evaluation and hydraulic design of open channels in the Town. The information presented herein is considered to be a minimum standard. In many instances, special design or evaluation techniques will be required. Except as modified herein, all open channel criteria shall be in accordance with the Urban Storm Drainage Criteria Manual (MANUAL).

2. Channel Types

The channels in the Town area are defined as natural or artificial. Natural channels include all water courses that have occurred naturally by the erosion process such as Cherry Creek, South Platte River, Plum Creek, Happy Canyon Creek, Big Dry Creek, Dad Clark Gulch, and Marcy Gulch. Artificial channels are those constructed or developed by human effort such as Denver Highline Canal, large designated floodways, irrigation canals and flumes, roadside ditches, and grassed channels.

2.1 Natural Channels

The hydraulic properties of natural channels vary along the channel reach and can be either controlled to the extent desired or altered to meet given requirements. The initial decision to be made regarding natural channels is whether or not the channel is to be protected from erosion due to high velocity flows, or protected from excessive silt deposition due to low velocities.

Many natural channels in urbanized and to-be-urbanized areas have mild slopes, are reasonably stable, and are not in a state of serious degradation or aggradation. However, if a natural channel is to be used for carrying storm runoff from an urbanized area, the altered nature of the runoff peaks and volumes from urban development will cause erosion. Detailed hydraulic analysis will be required for natural channels in order to identify the erosion tendencies. Some onsite modifications of the natural channel may be required to assure a stabilized condition.

The investigations necessary to assure that the natural channels will be adequate are different for every waterway. The engineer designer must prepare cross sections of the channel, define the water surface profile for the minor and major design flood, investigate the bed and bank material to determine erosion tendencies, and study the bank slope stability of the channel under future conditions of flow. Supercritical flow does not normally occur in natural channels, but calculations must be made to assure that the results do not reflect supercritical flow.

2.2 Grass Lined Channels

Grass lined channels are the most desirable of the artificial channels. The grass will stabilize the body of the channel, consolidate the soil mass of the bed, check

the erosion on the channel surface, and control the movement of soil particles along the channel bottom. The channel storage, the lower velocities, and the greenbelt multiple-use benefits obtained create significant advantages over other artificial channels.

The presence of grass in channels creates turbulence which results in loss of energy and increased flow retardance. Therefore, the designer must give full consideration to sediment deposition and to scour, as well as hydraulics. Unless existing development within the Town restricts the availability of right-of-way (ROW), only channels lined with grass will be considered acceptable for major drainageways.

For the purposes of these CRITERIA, sandy soils are defined as non-cohesive sands classified as SW, SP, or SM in accordance with the Unified Soil Classification System.

2.3 Concrete Lined Channels

Concrete lined channels for major drainageways will be permitted only where ROW restrictions within existing development prohibit grass lined channels. The lining must be designed to withstand the various forces and actions which tend to overtop the bank, deteriorate the lining, erode the soil beneath the lining, and erode unlined areas, especially for the supercritical flow conditions.

If the project constraints suggest the use of a concrete channel for a major drainageway, such use shall be allowed only upon approval by the Town Engineer. The applicant shall present the concept with justification to the Town Engineer for consideration of a waiver from these CRITERIA. The design of concrete lined channels shall be in accordance with Section G.4.3. Such use shall be allowed only upon approval by Town Board of Trustees.

2.4 Rock Lined Channels

Riprap lined channels shall be permitted only in areas of existing development where right-of-way for major drainageways is limited and such limitation prohibits the use of grass lined channels.

If the project constraints dictates the use of riprap lining for a major drainageway, then the engineer must present the concept, with justification, to the Town Engineer for consideration of a waiver from these CRITERIA.

2.5 Other Lining Types

The use of synthetic fabrics in construction and geotechnical engineering has increased tremendously in the last decade or more. The use of fabrics for drainage construction (i.e., erosion control liners) has actually taken place over the past several years. The placement of a slope revetment mat is a method of erosion control and the subject of discussion in this section.

The mattresses generally consist of double layers of woven fabric forms placed on the slope to be protected, and filled with concrete or grout. This type of forming system is a simple, fast, and economical technique for the placement of concrete for slope protection both above and below the water without the need for dewatering. The performance characteristics and cost advantages make the process adaptable for stabilizing and protecting shorelines, levees, dikes, canals, holding basins, and similar erosion control projects.

The systems make use of the pressure injection of fluid fine-aggregate concrete into flexible fabric forms. Controlled bleeding of mixing water through the porous fabric produces all the desirable features of low water/cement ratio mortar--rapid stiffening, high strength, and exceptional durability.

For normal installations, the fabric forms, prefabricated to job specifications and dimensions, are simply spread over the terrain, which has received minimal grading. The fabric form is then pumped full of mortar. This same concept can be used where slide problems are caused by eroding of the toe of the slopes, and where access is difficult for placement of riprap. See Figure-701 for typical sections of mattresses.

There are several manufacturers of synthetic fabrics for erosion protection. Included in this category of channel lining are the products which consist of discrete blocks on a continuous fabric backing.

The use of synthetic fabrics for lining of channels for major drainageways within the Town is restricted to areas of existing development where the ROW constraints prohibit the use of a grass lined section. Such use shall be allowed only upon written approval for a waiver from the Town Engineer. The linings shall be restricted to channels with a Froude number of 0.8 or less.

3. Flow Computation

Uniform flow and critical flow computations shall be in accordance with the MANUAL, Sections B.2.3 and B.2.4, "Major Drainage."

4. Design Standards for Major Drainageways

These standards cover the design of major drainageways as defined by the policy of Section C.2.5. The design standards for open channels cannot be presented in a step-by-step fashion because of the wide range of design options available to the design engineer. Certain planning and conceptual design criteria are particularly useful in the preliminary design of a channel. These CRITERIA, which have the greatest effect on the performance and cost of the channel, are discussed below.

4.1 Natural Channels

The design criteria and evaluation techniques for natural channels are:

(1) The channel and overbank areas shall have adequate capacity for the 100-year storm runoff.

(2) Natural channel segments which have a calculated Froude number greater than 0.95 for the 100-year flood peak shall be protected from erosion.

(3) The water surface profiles shall be defined so that the floodplain can be zoned and protected.

(4) Filling of the Floodplain Overlay District reduces valuable channel storage capacity and tends to increase downstream runoff peaks. Filling of the flood fringe is a non-conforming use of the floodplain and shall require a Floodplain Development Permit in accordance with Chapter 4 of the CRITERIA.

(5) Roughness factors (n), which are representative of unmaintained channel conditions, shall be used for the analysis of water surface profiles.

(6) Roughness factors (n), which are representative of maintained channel conditions, shall be used to determine velocity limitations.

(7) Erosion control structures, such as check drops or check dams, may be required to control flow velocities, including the minor storm runoff.

(8) Plan and profile drawings of the floodplain shall be prepared. Appropriate allowances for known future bridges or culverts, which can raise the water surface profile and cause the floodplain to be extended, shall be included in the analysis. The applicant shall contact the Town Engineer for information on future bridges and culverts.

With most natural waterways, erosion control structures should be constructed at regular intervals to decrease the thalweg slope and to control erosion. However, these channels should be left in as near a natural condition as possible. For that reason, extensive modifications should not be undertaken unless they are found to be necessary to avoid excessive erosion with subsequent deposition downstream.

The usual rules of freeboard depth, curvature, and other rules which are applicable to artificial channels, do not apply for natural channels. All structures constructed along the channel shall be elevated a minimum of one foot above the 100-year water surface.

If a natural channel is to be utilized as a major drainageway for a development, then the applicant shall meet with the Design and Review Engineer to discuss the concept and to obtain the requirements for planning and design documentation.

Approval of the concept and design will be made in accordance with the requirements of Chapter 2 of these CRITERIA.

4.2 Grass Lined Channels (Major Drainageways)

Key parameters in grass lined channel design include velocity, slopes, roughness coefficients, depth, freeboard, curvature, cross section shape, and lining materials. Other factors such as water surface profile computation, erosion control, drop structures, and transitions also play an important role. A discussion of these parameters is presented below.

(1) Flow Velocity (Major Drainageways)

The maximum normal depth velocity for the 100-year flood peak shall not exceed 7.0 feet per second for grass lined channels, except in sandy soil where the maximum velocity shall not exceed 5.0 feet per second. The Froude number (turbulence factor) shall be less than 0.8 for grass lined channels. Grass lined channels having a Froude number greater than 0.8 shall not be permitted. The minimum velocity, wherever possible, shall be greater than 2.0 feet per second for the minor storm runoff.

(2) Longitudinal Channel Slopes (Major Drainageways)

Grass lined channel slopes are dictated by velocity and Froude number requirements. Where the natural topography is steeper than desirable, drop structures shall be utilized to maintain design velocities and Froude numbers.

(3) Freeboard (Major Drainageways)

Except where localized overflow in certain areas is desirable for additional ponding benefits or other reasons, the freeboard for the 100-year flow shall be as follows:

$$H_{FB} = 0.5 + \frac{V^2}{2g} \qquad \text{(Equation 701)}$$

where H_{FB} = freeboard height (feet)

V = average channel velocity (fps)

g = acceleration of gravity = 32.2 ft/sec^2

The minimum freeboard shall be 1.0 foot.

(4) Curvature (Horizontal, Major Drainageways)

The center line curvature shall have a radius twice the top width of the design flow but not less than 100 feet.

(5) Roughness Coefficient (Major Drainageways)
The variation of Manning's "n" with the retardance and the product of mean velocity and hydraulic radius, as presented in Figure-702, shall be used in the capacity computation.

Retardance curve C shall be used to determine the channel capacity, since a mature channel (i.e., substantial vegetation with minimal pervious maintenance) will have a higher Manning's "n" value. However, a recently constructed channel will have minimal vegetation and the retardance will be less than the mature channel. Therefore, retardance curve D shall be used to determine the limiting velocity in a channel.

For the purpose of floodplain definition, only the higher Manning's "n" values need to be considered in the hydraulic analysis.

(6) Cross Sections (Major Drainageways)
The channel shape may be almost any type suitable to the location and to the environmental conditions. Often the shape can be chosen to suit open space and recreational needs. Figure 703 and 704 present two cross sections for use with non-sandy soils. Figure 705 is the required cross section for sandy soils. The limitations within which the design must fall for the major storm design flow include:

(a) Trickle Channel
The base flow shall be carried in a trickle channel except for sandy soils. The minimum capacity shall be 1.0 percent to 3.0 percent of the 100-year flow but not less than 1 cfs. Trickle channels shall be constructed of concrete or other approved materials to minimize erosion, to facilitate maintenance (with considerations for the method of trickle channel cleaning, i.e. maintenance equipment size), and to aesthetically blend with the adjacent vegetation and soils.

(b) Main Channel
A main channel is required for sandy soils as shown in Figure-705. Riprap side slopes can be from 2:1 to 3:1. The depth of the main channel is not included in the normal depth limitation. A main channel can also be used for non-sandy soils, subject to the conditions shown in Figure-704.

(c) Bottom Width
The minimum bottom width shall be consistent with the maximum depth and velocity criteria. The minimum bottom width shall be four feet or the trickle channel width when trickle channel is required.

(d) Right-of-Way Width
The minimum ROW width shall include freeboard and a 12-foot wide

maintenance access road.

(e) Flow Depth
The maximum design depth of flow (outside the trickle channel area and main channel area for sandy soils) for the 100-year flood peak shall be limited to 5.0 feet in grass lined channels.

(f) Maintenance Access Road
Continuous maintenance access shall be provided for all major drainageways with a minimum width of 12 feet. The Town may require six inches of Class 2 road base or concrete slab. (Refer to Section C.3.7 of these CRITERIA.)

(g) Side Slopes
Side slopes shall be 4 (horizontal) to 1 (vertical) or flatter. Slopes as steep as 3:1 may be used in existing developed areas where ROW availability is restricted, provided prior written approval is obtained from the Town Engineer.

(7) Grass Lining (Major Drainageways)
The grass lining for channels shall be in accordance with the MANUAL, Section B.3.2, "Major Drainage - Grass Lined Channels," and "Grass".

(8) Erosion Control (Major Drainageways)
The requirements for erosion control for grass lined channels shall be as defined in the MANUAL, Section B.3.6, "Major Drainage Erosion Control." The design of riprap and erosion control devices shall be in accordance with Sections L.1 and L.2 of these CRITERIA.

(9) Water Surface Profiles (Major Drainageways)
Computation of the water surface profile shall be presented for all open channels utilizing standard backwater methods, taking into consideration losses due to changes in velocity of channel cross section, drops, waterway openings, or obstructions. The energy gradient shall be shown on all drawings.

4.3 <u>Concrete Lined Channels (Major Drainageways)</u>
The criteria for the design and construction of concrete lined channels is presented below:

(1) Hydraulics (Major Drainageways)

(a) Freeboard
Adequate channel freeboard above the designed water surface shall be provided and shall not be less than that determined by the following:

$$H_{FB} = 2.0 + 0.025\ V\ (d)^{1/3} \qquad \text{(Equation 702)}$$

where H_{FB}=freeboard height (feet)

V = velocity (fps)

d = depth of flow (feet)

Freeboard shall be in addition to superelevation, standing waves, and/or other water surface disturbances. These special situations are to be addressed in a Design Report to be submitted with the construction drawings and specifications (Section B.5).

Concrete side slopes shall be extended to provide freeboard.

(b) Superelevation
Superelevation of the water surface shall be determined at all horizontal curves, and design of the channel section adjusted accordingly.

(c) Velocities
Flow velocities shall not exceed 18 fps during the 100-year flood.

(2) Concrete Materials (Major Drainageways)

(a) Cement type: sulphate resistant and air entrained

(b) Minimum cement content: 550 lbs/C.Y.

(c) Maximum water-cement ratio: 0.50 (six gals. per sack).

(d) Maximum aggregate size: 1½ inches.

(e) Air entrainment content: 4 to 7 percent.

(f) Slump: 2 to 4 inches.

(g) Minimum compressive strength (f'_c): 3250 psi at 28 days.

(h) Admixtures: All proposed admixtures shall be discussed in the Design Report.

(3) Concrete Lining Section (Major Drainageways)

(a) All concrete lining shall have a minimum thickness of 7 inches.

(b) The side slopes shall be a maximum of 2 (vertical) to 1 (horizontal), or a structurally reinforced retaining wall if steeper.

(4) Concrete Joints (Major Drainageways)

(a) Channels shall be continuously reinforced without transverse joints. Expansion joints shall be installed where new concrete lining is connected to a rigid structure or to existing concrete lining which is not continuously reinforced.

(b) Longitudinal joints, where required, shall be constructed on the side walls at least one foot vertically above channel invert.

(c) All joints shall be designed to prevent differential movement.

(d) Construction joints are required for all cold joints and where the lining thickness changes. Reinforcement shall be continuous through the joint.

(5) Concrete Finish (Major Drainageways)

The surface of the concrete lining shall be provided with a wood float finish. Excessive working or wetting of the finish shall be avoided.

(6) Concrete Curing (Major Drianageways)

All concrete shall be cured by the application of a liquid membrane-forming curing compound (white pigmented) upon completion of the concrete finish.

(7) Reinforcement Steel

(a) Steel reinforcement shall be minimum grade-40 deformed bars. Wire mesh shall not be used.

(b) Ratio of longitudinal steel area to concrete cross sectional area shall be greater than 0.005.

(c) Ratio of transverse steel area to concrete cross sectional area shall be greater than 0.0025.

(d) Reinforcing steel shall be placed at the center of the section with a minimum clear cover of three inches adjacent to the earth.

(e) Additional steel as needed if a retaining wall structure is used.

(8) Earthwork (Major Drainageways)

The following areas shall be compacted to at least 95 percent of maximum density as determined by ASTM D698 (Standard Proctor):

(a) The 12 inches of subgrade immediately beneath concrete lining (both channel bottom and side slopes).

(b) Top 12 inches of maintenance road.

(c) Top 12 inches of earth surface within 10 feet of concrete channel lip.

(d) All fill material.

(9) Bedding (Major Drainageways)

Provide six inches of granular bedding equivalent in gradation to 3/4" concrete aggregate (Standard Specifications for Road & Bridge Construction), CDOH, Current Printing, Section 703.02, No. 67) under channel bottom and side slopes.

(10) Underdrain (Major Drainageways)

Longitudinal underdrains shall be provided on 10-foot centers and shall daylight at the check drops. A check valve or flap gate shall be provided at the outlet to prevent backflow into the drain. Weep holes shall be provided in vertical wall sections of the channel.

(11) Safety Requirements

(a) A six-foot high vinyl coated chain link or comparable fence shall be installed to prevent access wherever the 100-year channel flow depths exceed three feet. Gates, with top latch, shall be placed at 250' intervals and staggered where fence is required on both sides of the channel.

(b) Ladder-type steps shall be installed not more than 400 feet apart on alternating sides of the channel. Bottom rung shall be placed approximately 12 inches vertically above channel invert.

4.4 Riprap Lined Channels (Major Drainageways)
The CRITERIA for the design and construction of riprap lined channels shall be in accordance with the MANUAL, Volume 2, "Major Drainage - Riprap." Riprap lined channels shall be designed with a turbulence factor (Froude number) less than 0.8 for the 100-year flood peaks. The riprap shall be designed and

constructed in accordance with Section L.2 "Hydraulic Structures - Riprap" of these CRITERIA. Freeboard and maintenance access road requirements shall be in accordance with the standards for grass lined channels defined in Section G.4.2.3 of these CRITERIA.

4.5 Other Lining Types

The CRITERIA for the design of major drainageway channels with linings other than grass, rock, or concrete will be dependent on the manufacturer's recommendations for the specific product. The applicant will be required to submit the technical data in support of the proposed material. Additional information or calculations may be requested by the Town Engineer to verify assumptions or design criteria. The following minimum criteria will also apply:

(1) Flow Velocity (Major Drainageways)
The maximum normal depth velocity will be dependent on the construction material utilized; however, the Froude number shall be less than 0.8.

(2) Freeboard (Major Drainageways)
Defined by Equation 701. (One foot freeboard minimum)

(3) Curvature
The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 100 feet.

(4) Roughness Coefficient (Major Drainageways)
A Manning's "n" value range shall be established by the manufacturer's data, with the high value used to determine depth/capacity requirements and the low value used to determine Froude number and velocity restrictions.

(5) Cross Sections (Major Drainageways)
Same as for grass lined channels, Section 7.4.2.6. (Item 6).

5. Design Standards for Small Drainageways

These standards cover the design of channels that are not classified as a major drainageway in accordance with the policy of Section C.2.5. Additional flexibility and less stringent standards are allowed for small drainageways.

5.1 Natural Channels (Small Drainageways)

The design criteria and evaluation techniques for natural channels are:

(1) The channel and overbank areas shall have adequate capacity for the 100-year storm runoff.

(2) Natural channel segments which have a calculated Froude number greater than 0.95 for the 100-year flood peak shall be protected from erosion.

(3) Roughness factors (n), which are representative of unmaintained channel conditions, shall be used for the analysis of water surface profiles.

(4) Roughness factors (n), which are representative of maintained channel conditions, shall be used to determine velocity limitations.

(5) Erosion control structures, such as check drops or check dams, may be required to control flow velocities, including the minor storm runoff.

(6) Plan and profile drawings shall be prepared showing the 100-year water surface profile, floodplain, and details of erosion protection, if required.

5.2 Grass Lined Channels (Small Drainageways)

Key parameters in grass lined channel design include velocity, slopes, roughness coefficients, depth, freeboard, curvature, cross section shape, and lining materials. Other factors such as water surface profile computation, erosion control, drop structures, and transitions also play an important role. A discussion of these parameters is presented below.

(1) Flow Velocity (Small Drainageways)

The maximum normal depth velocity for the 100-year flood peak shall not exceed 7.0 feet per second for grass lined channels, except in sandy soil where the maximum velocity shall not exceed 5.0 feet per second (see Section G.2.2). The Froude number (turbulence factor) shall be less than 0.8 for grass lined channels. Grass lined channels having a Froude number greater than 0.8 shall not be permitted. The minimum velocity, wherever possible, shall be greater than 2.0 feet per second for the minor storm runoff.

(2) Longitudinal Channel Slopes (Small Drainageways)

Grass lined channel slopes are dictated by velocity and Froude number requirements. Where the natural topography is steeper than desirable, drop structures shall be utilized to maintain design velocities and Froude numbers.

(3) Freeboard (Small Drainageways)

A minimum freeboard of 1 foot shall be included in the design for the 100-year flow. For swales (i.e., small drainageways with a 100-year flow less than 20 cfs), the minimum freeboard requirements are 6 inches.

(4) Curvature (Horizontal, Small Drainageways)

The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 50 feet. The minimum radius for channels with a 100 year runoff of 20 cfs or less shall be 25 feet.

(5) Roughness Coefficient (Small Drainageways)

The variation of Manning's "n" with the retardance (curve "C") and the

product of mean velocity and hydraulic radius, as presented in Figure-702, shall be used in the computation of capacity and velocity.

(6) Cross Sections (Small Drainageways)
The channel shape may be almost any type suitable to the location and to the environmental conditions. Some suggested cross sections are shown on Figures 703, 704, and 705. The section may also be simple V-Section for swales (i.e., Q_{100} less than 20 cfs). The limitations on the cross section are as follows:

(a) Trickle Channel
The base flow (except for swales) shall be carried in a trickle channel for non-sandy soils. The minimum capacity shall be from 1.0 percent to 3.0 percent of the 100-year flow but not less than 1 cfs. The trickle channel can be constructed of concrete, rock, cobbles, or other suitable materials. For sandy soils, a main channel is required in accordance with Section G.4.2.6(b). For 100 year runoff peaks of 20 cfs or less, trickle channel requirements will be evaluated for each case. Trickle channels help preserve swales crossing residential property.

(b) Right-of-Way Width
The minimum ROW width shall include freeboard and should include a 12-foot wide maintenance access.

(c) Flow Depth
The maximum design depth of flow (outside the trickle channel area and main channel area for sandy soils) for the 100-year flood peak shall be limited to 5.0 feet in grass lined channels.

(d) Side Slopes
Side slopes shall be 4 (horizontal) to 1 (vertical) or flatter. Side slopes for channels with 100-year runoff peaks of 20 cfs or less shall be 3 (horizontal) to 1 (vertical) or flatter.

(7) Grass Lining
The grass lining for channels shall be in accordance with the MANUAL, Section B.3.2, "Major Drainage - Grass Lined Channels - Grass,"

(8) Erosion Control
The requirements for erosion control for grass lined channels shall be as defined in the MANUAL, Section B.3.6, "Major Drainage Erosion Control." The design of riprap and erosion control devices shall be in accordance with Sections L.1 and L.2 of these CRITERIA.

(9) Hydraulic Information

Calculations of the capacity, velocity, and Froude numbers shall be submitted with the construction drawings.

5.3 Concrete Lined Channels (Small Drainageways)
The CRITERIA for the design and construction of concrete lined channels is presented below:

(1) Hydraulics (Small Drainageways)

a. Freeboard
Adequate channel freeboard above the designed water surface shall be provided and shall not be less than that determined by the following:

$$H_{FB} = 2.0 + 0.025\ V\ (d)^{1/3} \qquad \text{(Equation 702)}$$

where H_{FB}= freeboard height (feet)

V = velocity (fps)

d = depth of flow (feet)

Freeboard shall be in addition to superelevation, standing waves, and/or other water surface disturbances. These special situations should be addressed in a Design Report to be submitted with the construction drawings and specifications (Section B.5).

Concrete side slopes shall be extended to provide freeboard.

b. Superelevation
Superelevation of the water surface shall be determined at all horizontal curves, and design of the channel section adjusted accordingly.

c. Velocities
Flow velocities shall not exceed 18 fps during the 100-year flood.

(2) Concrete Materials (Small Drainageways)

(a) Cement type: sulphate resistant and air entrained.

(b) Minimum cement content: 550 lbs/C.Y.

(c) Maximum water-cement ratio: 0.50 (six gals. per sack).

(d) Maximum aggregate size: 1½ inches.

(e) Air entrainment content: 4 to 7 percent.

(f) Slump: 2 to 4 inches.

(g) Minimum compressive strength (f'_c): 3250 psi at 28 days.

(h) Admixtures: All proposed admixtures shall be discussed in the Design Report.

(3) Concrete Lining Section (Small Drainageways)

(a) All concrete lining shall have a sufficient thickness to withstand the structural and hydraulic loads.

(b) The side slopes shall be a maximum of 2 (vertical) to 1 (horizontal), or a structurally reinforced wall if steeper.

(4) Concrete Joints (Small Drainageways)

(a) Expansion/contraction joints shall be installed where new concrete lining is connected to a rigid structure or to existing concrete lining which is not continuously reinforced.

(b) Longitudinal joints, where required, shall be constructed on the side walls at least one foot vertically above channel invert.

(c) All joints shall be designed to prevent differential movement.

(d) Construction joints are required for all cold joints and where the lining thickness changes.

(5) Concrete Finish (Small Drainageways)

The surface of the concrete lining shall be provided with a wood float finish. Excessive working or wetting of the finish shall be avoided.

(6) Concrete Curing (Small Drainageways)

All concrete shall be cured by the application of a liquid membrane-forming curing compound (white pigmented) upon completion of the concrete finish.

(7) Reinforcement Steel (Small Drainageways, Where used)

(a) Steel reinforcement shall be minimum-grade-40 deformed bars. Wire mesh shall not be used.

(b) Ratio of longitudinal steel area to concrete cross sectional area shall be greater than .005.

(c) Ratio of transverse steel area to concrete cross sectional area shall be greater than .0025.

(d) Additional steel as needed if a retaining wall structure is used.

(8) Earthwork (Small Drainageways)

The following areas shall be compacted to at least 95 percent of maximum density as determined by ASTM D-698 (Standard Proctor):

(a) The 12 inches of subgrade immediately beneath concrete lining (both channel bottom and side slopes).

(b) Top 12 inches of maintenance road.

(c) Top 12 inches of earth surface within 10 feet of concrete channel lip.

(d) All fill material.

(9) Bedding (Small Drainageways)

Provide six inches of granular bedding equivalent in gradation to 3/4" concrete aggregate (Standard Specifications for Road & Bridge Construction, CDOH, 1981, Section 703.02, No. 67) under channel bottom and side slopes.

(10) Underdrain (Small Drainageways)

Longitudinal underdrains shall be provided and shall daylight at the check drops Weep holes shall be provided in vertical wall sections of the channel.

(11) Safety Requirements (Small Drainageways)

(a) A six-foot high vinyl coated chain link or comparable fence shall be installed to prevent access wherever the 100-year channel flow depths exceed three feet. Gates, with top latch, shall be placed at 250' intervals and staggered where fence is required on both sides of the channel.

(b) Ladder-type steps shall be installed not more than 400 feet apart on alternating sides of the channel. Bottom rung shall be placed approximately 12 inches vertically above channel invert.

5.4 Riprap Lined Channels (Small Drainageways)
The CRITERIA for the design and construction of riprap channel linings shall be in accordance with the MANUAL, Volume 2, "Major Drainage - Riprap."

Riprap lined channels shall be designed for a turbulence factor (Froude number) less than 0.8 for the 100-year flood peaks. The riprap shall be designed and constructed in accordance with Section L.2 "Hydraulic Structures - Riprap" of these CRITERIA. Freeboard requirements shall be in accordance with the standards for grass lined channels defined in Section G.4.2.3 of these CRITERIA.

5.5 Other Lining Types (Small Drainageways)
The CRITERIA for the design of channels with linings other than grass, rock, or concrete will be dependent on the manufacturer's recommendations for the specific product. The applicant will be required to submit the technical data in support of the proposed material. Additional information or calculations may be requested by the Town Engineer to verify assumptions or design criteria. The following minimum criteria will also apply.

(1) Flow Velocity (Small Drainageways)
The maximum normal depth velocity will be dependent on the construction material utilized; however, the Froude number shall be less than 0.8.

(2) Freeboard (Small Drainageways)
Refer to Section G.5.2.3.

(3) Curvature
The center line curvature shall have a minimum radius twice the top width of the design flow but not less than 50 feet. The minimum radius of curvature for channels with a 100 year runoff of 20 cfs or less shall be 25 feet.

(4) Roughness Coefficient (Small Drainageways)
A Manning's "n" value range shall be established by the manufacturer's data, with the high value used to determine depth/capacity requirements and the low value used to determine Froude number and velocity restrictions.

(5) Cross Sections
Same as for grass lined channels, Section G.5.2.6.

6. Roadside Ditches
The CRITERIA for the design of roadside ditches is similar to the CRITERIA for grass lined channels with modifications for the special purpose of minor storm drainage. The CRITERIA is as follows (refer to Figure-706):

(1) Capacity

Roadside ditches shall have adequate capacity for the minor storm runoff peaks. Capacity shall be as defined in Table 701. Where the storm runoff exceeds the capacity of the ditch, a storm sewer system shall be required.

(2) Flow Velocity
The maximum velocity for the five-year flood peak shall not exceed 5.0 feet per second.

(3) Longitudinal Slope
The slope shall be limited by the average velocity of the five-year flood peaks. Check drops may be required where street slopes are in excess of 2.0%.

(4) Freeboard
Freeboard shall be equal to the velocity head, or a minimum of six inches.

(5) Curvature
The minimum radius of curvature shall be 25 feet.

(6) Roughness Coefficient
Manning's "n" values presented in Figure 702 shall be used in the capacity computation for roadside ditches.

(7) Grass Lining
The grass lining shall be in accordance with the MANUAL, Section B.3.2, "Major Drainage - Grass Lined Channels - Grass."

(8) Driveway Culverts
Driveway culverts shall be sized to pass the five-year ditch flow capacity without overtopping the driveway. The minimum size culvert shall be a 22" x 13" CMPA (18" equivalent round pipe) with flared end sections. More than one culvert may be required.

(9) Major Drainage Capacity
The capacity of roadside ditches for major drainage flow is restricted by the maximum flow depth allowed at the street crown (Policy Section-C.4.4). However, the flow spread should not exceed outside the street ROW.

7. Checklist
To aid the designer and reviewer, the following checklist has been prepared.

(1) Check flow velocity with low retardance factor and capacity with high retardance factor.

(2) Check Froude number and critical flow conditions.

(3) Grass channel side slopes must be 4:1 or flatter except for roadside ditches which shall be 3:1 or flatter unless approved by the Town.

(4) Show energy grade line and water surface profile on design drawings.

(5) Consider all backwater conditions (i.e., at culverts) when determining channel capacity.

(6) Check flow velocity for flood conditions without backwater effects.

(7) Provide adequate freeboard.

(8) Provide adequate ROW for the channel and continuous maintenance access.

Insert Table 701 here

Insert Figure 701 here

Insert Figure 702 here

Insert Figure 703 here

Insert Figure 704 here

Insert Figure 705 here

Insert Figure 706 here

Insert Figure 707a here

Insert Figure 707B here

H. CHAPTER 8 STORM SEWERS

1. Introduction

Storm sewers are a part of the Minor Drainage System, and are required when the other parts of the minor system, primarily curb, gutter, and roadside ditches no longer have capacity for additional runoff.

Except as modified herein, the design of storm sewers shall be in accordance with the MANUAL Section on "Storm Sewers." Reference is made to follow specific sections in the MANUAL for clarity. The user is referred to the MANUAL and other references cited for additional discussion and basic design concepts.

A computer program for the design of a storm sewer system will be permitted provided the model is calibrated to three or more design points using the procedures presented in these CRITERIA. Contact the Town Engineer for specific information required.

2. Construction Materials

Reinforced Concrete Pipe (RCP) in accordance with ASTM C-76, C-506, or C-507 is the only material acceptable for use in storm sewer construction within Town right-of-way. The minimum class of pipe shall be Class-II; however, the actual depth of cover, live load, and field conditions may require structurally stronger pipe.

3. Hydraulic Design

Storm sewers shall be designed to convey the minor storm flood peaks without surcharging the sewer. To ensure that this objective is achieved, the hydraulic and energy grade line shall be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses will include friction, expansion, contraction, bend, and junction losses. The methods for estimating these losses are presented in the following sections. The final energy grade line shall be at or below the proposed ground surface.

3.1 Pipe Friction Losses

The Manning's "n" values to be used in the calculation of storm sewer capacity and velocity are presented in Table 801.

3.2 Pipe Form Losses

Generally, between the inlet and outlet the flow encounters a variety of configurations in the flow passageway such as changes in pipe size, branches, bends, junctions, expansions, and contractions. These shape variations impose losses in addition to those resulting from pipe friction. Form losses are the result of fully developed turbulence and can be expressed as follows:

$$H_L = K \frac{V^2}{2g} \qquad \text{(Equation 801)}$$

where H_L = head loss (feet)

K = loss coefficient

$V^2/2g$ = velocity head (feet)

g = gravitational acceleration (32.2 ft/sec^2)

The following is a discussion of a few of the common types of form losses encountered in sewer system design. The reader is referred to References 1 and 6 for additional discussion.

(1) Expansion Losses
Expansion in a storm sewer conduit will result in a shearing action between the incoming high velocity jet and the surrounding sewer boundary. As a result, much of the kinetic energy is dissipated by eddy currents and turbulence. The loss of head can be expressed as:

$$H_L = K_e \frac{V_1^2}{2g}\left[1 - Asub\frac{1}{A_2}\right]^2 \qquad \text{(Equation 802)}$$

in which A is the cross section, V is the average flow velocity, and K_e is the loss coefficient. Subscripts 1 and 2 denote the upstream and downstream sections, respectively. The value of K_e is about 1.0 for a sudden expansion, and about 0.2 for a well designed expansion transition. Table-802 presents the expansion loss coefficients for various flow conditions.

(2) Contraction Losses
The form loss due to contraction is:

$$H_L = K_c \frac{V_2^2}{2g}\left[1 - \left(\frac{A_2}{A_1}\right)^2\right]^2 \qquad \text{(Equation 803)}$$

where K_c is the contraction coefficient. K_c is equal to 0.5 for a sudden contraction and about 0.1 for a well designed transition. Subscripts 1 and 2 denote the upstream and downstream sections, respectively. Table 802 presents the contraction loss coefficient for various flow conditions.

(3) Bend Losses
The head losses for bends, in excess of that caused by an equivalent length

of straight pipe, may be expressed by the relation

$$H_L = K_b \frac{V^2}{2g} \qquad \text{(Equation 804)}$$

in which K_b is the bend coefficient. The bend coefficient has been found to be a function of, (a) the ratio of the radius of curvature of the bend to the width of the conduit, (b) deflection angle of the conduit, (c) geometry of the cross section of flow, and (d) the Reynolds number and relative roughness. A table showing the recommended bend loss coefficients is presented in Table 802.

(4) Junction and Manhole Losses
A junction occurs where one of more branch sewers enter a main sewer, usually at manholes. The hydraulic design of a junction is in effect the design of two or more transition, on for each flow path. Allowances should be made for head loss due to the impact at junctions. The head loss for a straight through manhole or at an inlet entering the sewer is calculated from Equation 801. The head loss at a junction can be calculated from:

$$H_L = \frac{V_2^2}{2g} - K_j \frac{V_1^2}{2g} \qquad \text{(Equation 805)}$$

where V_2 is the outfall flow velocity and V_1 is the inlet velocity. The loss coefficient, K_j, for various junctions is presented in Table 803.

3.3 Storm Sewer Outlets
When the storm sewer system discharges into the Major Drainageway System (usually an open channel), additional losses occur at the outlet in the form of expansion losses (refer to Section H.3.2). For a headwall and no wingwalls, the loss coefficient $K_e = 1.0$ [refer to Table 802], and for a flared-end section the loss coefficient is approximately 0.5 or less.

3.4 Partially Full Pipe Flow
When a storm sewer is not flowing full, the sewer acts like an open channel, and the hydraulic properties can be calculated using open channel techniques (refer to Chapter 7). For convenience, charts for various pipe shapes have been developed for calculating the hydraulic properties (Figures 801, 802, 803). The data presented assumes that the friction coefficient, Manning's "n" value, does not vary through the depth.

4. Vertical Alignment

The sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 (or as designated by the Town) loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall be not less than 1-foot at any point along the pipe.

The minimum clearance between storm sewer and water main, either above or below, shall be 12-inches. Concrete encasement of the water line will be required for clearances of 12-inches or less.

The minimum clearance between storm sewer and sanitary sewer, either above or below, shall also be 12-inches. In addition, when a sanitary sewer main lies above a storm sewer, or within 18-inches below, the sanitary sewer shall have an impervious encasement or be constructed of structural sewer pipe for a minimum of 10-feet on each side of where the storm sewer crosses.

5. Horizontal Alignment
Storm sewer alignment may be curvilinear for pipe with diameters of 48-inches or greater but only when approved in writing by the Design and Review Engineer. The applicant must demonstrate the need for a curvilinear alignment. The limitations on the radius for pulled-joint pipe is dependent on the pipe length and diameter, and amount of opening permitted in the joint. The maximum allowable joint pull shall be 3/4-inches. The minimum parameters for radius type pipe are shown in Table-801. The radius requirements for pipe bends are dependent upon the manufacturer's specifications.

6. Pipe Size
The minimum allowable pipe size for storm sewers except for detention outlets is dependent upon a practical diameter from the maintenance standpoint. The length of the sewer also affects the maintenance and, therefore, the minimum diameter. Table 801 presents the minimum pipe size for storm sewers.

7. Manholes
Manholes or maintenance access ports will be required whenever there is a change in size, direction, elevation, grade, or where there is a junction of two or more sewers. A manhole may be required at the beginning and/or at the end of the curved section of storm sewer. The maximum spacing between manholes for various pipe sizes shall be in accordance with Table 801. The required manhole size shall be as follows:

MANHOLE SIZE

SEWER DIAMETER	MANHOLE DIAMETER

15" to 18"	4'
21" to 42"	5'
48" to 54"	6'
60" and larger	Std. Detail SD-6

Larger manhole diameters or a junction structure may be required when sewer alignments are not straight through or more than one sewer line goes through the manhole.

8. Design Example

The following calculation example, including the calculation Table 804, and Figures 804A and 804B, were obtained form Modern Sewer Design, AISI, Washington, D.C., 1980 (Ref. 26) and edited for the calculation of manhole and junction losses in accordance with this Section.

EXAMPLE 1: HYDRAULIC DESIGN OF STORM SEWERS

Given: (a) Plan and Profile of storm sewer (Figures 804A and 804B)

(b) Station 0+00 (outfall) data as follows:

Design discharge	Q=145 cfs	[9]	
Invert of pipe	=94.50'[2]		
Diameter		D=66" RCP	[3]
Starting water surface	W.S.=100'	[4]	
Area of pipe	A=23.76 sq. ft.		[6]
Velocity = Q/A	V=6.1 f/s	[8]	

Note: (1) Number in brackets refers to the columns on Table 804.

(2) Sizes of the storm sewer were determined during the preliminary design phases.

FIND: Hydraulic Grade Line and Energy Grade Line for storm sewer.

DISCUSSION: The following procedure is based on full-flow pipe conditions. If the pipe is flowing substantially full (i.e., greater than 80 percent), the following procedures can be used with minimal loss of accuracy. However, the designer is responsible for checking the assumptions (i.e., check for full flow) to assure that the calculations are correct.

STEP 1: The normal depth is greater than critical depth, $d_n > d_c$; therefore, calculations to begin at outfall, working upstream. Compute the following

parameters:

¢ value [7]: ¢ =

$$\frac{2\,gn^2}{2.21} = \frac{(2)(32.2)(0.013\ )^2}{2.21}$$

This equation is derived form the Manning's equation by solving for velocity and converting to velocity head.

¢ = 0.00492

This value remains constant for this design since the n-value does not change.

STEP 2: Velocity head [10]: $H_V = V^2/2g = (6.1)^2/(2)(32.2)$

H_V = 0.58

STEP 3: Energy Grade Point, E.G. [11]:

E.G.= W.S. + H_V = 100 + 0.58

E.G.= 100.58

For the initial calculation, the Energy Grade Line is computed as described above. For subsequent calculations, the equation is reversed, and the water surface is calculated as follows (see Step 12):

W.S. = E.G. - H_V

This equation is used since the losses computed in Step 8 are energy losses which are added to the downstream energy grade elevation as the new starting point from which the velocity head is subtracted as shown above.

STEP 4: S_f value [12]: S_f= ¢ $H_V/R^{4/3}$ = $(0.00492)(0.58)(1.375)^{4/3}$

NOTE: R = the hydraulic radius of the pipe.

S_f = 0.0019

STEP 5: Avg. S_f [13]: Average skin fraction: This is the average value between S_f of the station being calculated and the previous station. For the first station, Avg. S_f = S_f.

STEP 6: Enter sewer length, L, in column 14.

STEP 7: Friction loss H_f [15]: $H_f = (\text{Avg. } S_f)(L)$

$H_f = (0.0019)(110)$

$H_f = 0.21$

STEP 8: Calculate the form losses for bends, junctions, manholes, and transition losses (expansion or contraction) using equations 801, 802, 803, 804, and 805. The calculation of these losses is presented below for the various sewer segments, since all the losses do not occur for one sewer segment.

(a) station 1 + 10 to 1 + 52.4 (bend)

$H_b = K_b H_V$, where the degree of bend is 60°

$K_b = 0.20$ (Table 802)

$H_b = (0.20)(0.58) = 0.12$, enter in column 16

(b) station 2 + 48 to 2 + 55.5 (transition: expansion)

$H_L = K_e H_{v-1} [1-A_1/A_2]^2$

$K_e = 1.06$ (Table 802) for $D_2/D_1 = 1.5$, and $\theta = 45°$

$H_L = (1.06)1.29 [1 - (15.9/23.76)]^2 = 0.15$, enter in column 19

(c) station 3 + 55.5 (manhole, straight through)

$H_m = K_m H_v$

$K_m = 0.05$ (Table 803, Case I)

H_m = (0.05)(1.29) = 0.06, enter in column 18

(d) station 4 + 55.5 to 4 + 65.5 (junction)

H_j = H_{v-2} - K_j H_{v-1}

K_j = 0.62 (Table 803, Case III), θ = 30°

H_j = 1.29 - (.62)(0.99) = 0.68, enter in column 17

(e) station 5 + 65.5 to 5 + 75.5 (junction) - since there are two laterals, the loss is estimated as twice the loss for one lateral

K_j = 0.33 (Table 804, Case III) = 70°

H_j = 0.99 - (0.33)(0.64) = 0.78 for one lateral

STEP 9: Sum all the form losses from columns 15 through 19 and enter in column 20. For the reach between Station 00+0 to 1+10, the total loss is 0.21.

STEP 10: Add the total loss in column 20 to the energy grade at the downstream end (Sta. 0+00) to compute the energy grade at the upstream end (Sta. 1+10) for this example.

E.G. (U/S)= E.G. (D/S) + TOTAL LOSS= 100.58 + 0.21

= 100.79 (Column 11)

STEP 11: Enter the new invert [2], pipe diameter D[3], pipe shape [5], pipe area A, [6], the computed constant ¢ from Step 1 in column [7], the computed velocity V in column [8], the new Q [9], and the computed velocity head H_V [10].

STEP 12: Compute the new hydraulic grade line, H.G., for the upstream station (1+10 for this example).

H.G. = E.G. - H_V

= 100.79 - 0.58

= 100.21 (column 4)

STEP 13: Repeat Steps 1 through 12 until the design is complete. The hydraulic grade line and the energy grade line are plotted on the profile (Fig. 804B).

DISCUSSION OF RESULTS:

The HGL is at the crown of the pipe from Station 0+00 to 2+48. Upstream of the transition (Station 2+55.5) the 54" RCP has a greater capacity (approximately 175 cfs) at the slope than the design flow (145 cfs). The pipe is therefore not flowing full but is substantially full (i.e., 145/175 = 0.84 greater than 0.80). The computed HGL is below the crown of the pipe. However, at the outlet, the actual HGL is higher, since the outlet of the 54" RCP is submerged by the headwater for the 66" RCP. To compute the actual profile, a backwater calculation would be required; however, this accuracy is not necessary for storm sewer design in most cases.

At the junction (Station 4+55.5), the HGL is above the top of the pipe due to the losses in the junction. In this case, however, the full flow capacity (100 cfs) is the same as the design capacity, and the HGL remains above and parallel to the top of the pipe. A similar situation occurs at the junction at Station 5+65.5.

If the pipe entering a manhole or junction is at an elevation significantly above the manhole invert, a discontinuity in the EGL may occur. If the EGL of the incoming pipe for the design flow condition is higher than the EGL in the manhole, then a discontinuity exists, and the higher EGL is used for the incoming pipe.

9. Checklist

To aid the designer and reviewer, the following checklist has been prepared:

(1) Calculate energy grade line (EGL) and hydraulic grade line (HGL) for all sewers and show on the construction drawings or on a separate copy of the plans submitted with the construction drawings.

(2) Account for all losses in the EGL calculation including outlet, form, bend, manhole, and junction losses.

(3) Provide adequate erosion protection at the outlet of all sewers into open channels.

(4) Check for minimum pipe cover and clearance with utilities.

Insert Table 801 here

Insert Table 802A here

Insert Table 802B

Insert Table 803

Insert Table 804 here

Insert Figure 801 here

Insert Figure 802 here

Insert Figure 803 here

Insert Figure 804A here

Insert Figure 804B here

I. CHAPTER 9 STORM SEWER INLETS

1. Introduction

There are three types of inlets: curb opening, grated, and combination inlets. Inlets are further classified as being on a "continuous grade" or in a sump. The term "continuous grade" refers to an inlet so located that the grade of the street has a continuous slope past the inlet and, therefore, ponding does not occur at the inlet. The sump condition exists whenever water is restricted or ponds because the inlet is located at a low point. A sump condition can occur at a change in grade of the street from positive to negative, or at an intersection due to the crown slope of a cross street.

Presented in this chapter is the criteria and methodology for design and evaluation of storm sewer inlets in the Town. Except as modified herein, all storm sewer inlet criteria shall be in accordance with the MANUAL.

2. Standard Inlets

The standard inlets permitted for use in the Town are:

INLET TYPE	STANDARD DETAIL	PERMITTED USE
Curb Opening Inlet Type R	SD-1	All street types
Grated Inlet Type C	SD-2	All streets with a roadside or median ditch
Grated Inlet Type 13	SD-3	Alleys or private drives with a valley gutter [Private areas only]
Combination Inlet Type 13	SD-4	Private areas only vertical curb

3. Inlet Hydraulics

The procedures and basic data used to define the capacities of the standard inlets under various flow conditions were obtained from the MANUAL, Volume I, Section on "Storm Inlets," and from Reference-11 for curb opening inlets. The procedure consists of defining the amount and depth of flow in the gutter and determining the theoretical flow interception by the inlet. To account for effects which decrease the capacity of the various types of inlets, such as debris plugging, pavement overlaying, and variations in design assumptions, the theoretical capacity calculated for the inlets is reduced to the allowed capacity by the factors presented below for the standard inlets.

ALLOWABLE INLET CAPACITY

CONDITION	INLET TYPE	PERCENTAGE OF THEORETICAL CAPACITY ALLOWED
Sump or Continuous Grade	CDOH Type R (SD-1)	
	5' length	88
	10' length	92
	15' length	95
Sump or Continuous Grade	Grated Type 13 (SD-3)	50
Continuous Grade	Combination Type 13 (SD-4)	66
Sump	Grated Type C (SD-2)	50
Sump	Combination Type 13 (SD-4)	

Allowable inlet capacities for the standard inlets have been developed and are presented in Figures 901, and 902, for "continuous grade" and Figure 903 for sump conditions. These figures include the reduction factors in the above table. The allowable inlet capacity is compatible with the allowable street capacity (refer to Chapter 10). The values shown were calculated on the basis of the maximum flow allowed in the street gutter (or roadside ditch for Type C). For the gutter flow amounts less than the maximum, the allowable inlet capacity must be proportionately reduced.

3.1 Continuous Grade Condition

For the "continuous grade" condition, the capacity of the inlet is dependent upon many factors including gutter slope, depth of flow in the gutter, height and length of curb opening, street cross slope, and the amount of depression at the inlet. In addition, all of the gutter flow will not be intercepted and some flow will continue past the inlet area ("inlet carryover"). The amount of carryover must be included in the drainage facility evaluation as well as in the design of the inlet.

The use of Figures 902 and 903 is illustrated by the following examples:

EXAMPLE 2: Design of Type R Curb Opening Inlets

GIVEN:
Street Type = Arterial (64' Flowline to Flowline) - Type C, S = 1.0 percent
Maximum flow depth = 0.47 feet (refer to Chapter 10)

Maximum allowable gutter capacity = 11.0 cfs (refer to Chapter 10)
Starting gutter flow (Q_L) = 8.0 cfs

FIND:
Interception and carryover amounts for the inlets and flow conditions illustrated on Figure-904.

SOLUTION:
From Figure-905, we can see that inlets 1 and 2 are in a continuous grade condition and inlet 3 is in a sump condition. The first step is to calculate the interception ratio R, for the continuous grade inlets. This ratio is then applied to the actual gutter flow (local runoff plus carryover flow) to determine amount intercepted by the inlet and the carryover flow. The final step is to calculate the size of the inlet required for the sump condition, which is discussed in Example #3 in the following section.

STEP 1: From Figure 902 for an allowable depth of 0.50 feet and a 15-foot inlet, read the value 8.6 cfs. Note that even though the gutter flow is less than maximum allowable, the maximum depth is used for Figure 902. The effect of the lower depth on the inlet capacity will be accounted for in the following steps.

STEP 2: Compute the interception ratio R

$$R = \frac{\text{Allowable Inlet Capacity}}{\text{Allowable Street Capacity}} = \frac{8.6}{11.0}$$

$$R = 0.78$$

STEP 3: Compute the interception amount Q_I

$$Q_I = R \times Q \text{ street}$$

$$= 0.78 \times 8.0$$

Q_I = 6.2 cfs amount intercepted by inlet

STEP 4: Compute the carryover amount Q_{co}

$$Q_{co} = Q \text{ street} - Q_I$$
$$= 8.0 - 6.2$$

$$Q_{co} = 1.8 \text{ cfs}$$

STEP 5: Compute the total flow at the next inlet, which is the sum of the carryover (Q_{co}) from inlet #1 plus the local runoff to inlet #2

Q_T (inlet #2) = Q_{co} (inlet #1) + Q_L (inlet #2)

= 1.8 cfs + 4 cfs

Q_T (inlet #2) = 5.8 cfs

STEP 6: Compute the interception ratio, intercepted amount, and carryover flow for inlet #2 using the procedure described in steps 1 through 4

Allowable inlet capacity = 7.2 cfs (Fig. 902)

R = (7.2 cfs)/(11.0 cfs) = 0.65

Q_I (inlet #2) = (0.65)(5.8 cfs) = 3.8 cfs

Q_{co} (inlet #2) = 5.8 cfs - 3.8 cfs = 2.0 cfs

STEP 7: Compute the flow for inlet #3 using the procedure described in step 5

Q_T (inlet #3) = 8 cfs + 2.0 cfs = 10.0 cfs

STEP 8: Size the inlet in the sump condition using the procedures described in Example #3, Section I.3.2, and Fig. 904. For this example, with an allowable maximum depth of flow of 0.5 cfs, a 10-foot type R inlet will intercept more than the total gutter flow and is therefore acceptable.

3.2 Sump Condition

The capacity of the inlet in a sump condition is dependent on the depth of ponding above the inlet. Typically the problem consists of estimating the number of inlets or depth of flow required to intercept a given flow amount. The use of Figure 904 is illustrated by the following example:

EXAMPLE 3: Allowable Capacity for Combination Type 13 Inlet in a Sump

GIVEN:
Flow in gutter = 8.0 cfs
Maximum allowable street depth = 0.50 feet

Combination Type 13 double inlet

FIND:
Depth of ponding

SOLUTION:

Step 1: From Figure 904, read the "Depth of Ponding" for a double Combination Type 13 inlet as D = 0.28' at the gutter flow of 8.0 cfs (inlet capacity)

Step 2: Compare computed to allowable depth. Since the computed depth is less than the allowable depth, the inlet is acceptable, otherwise the amount of inlets or the type of inlet would be changed and the procedure repeated.

4. Inlet Spacing

The optimum spacing of storm inlets is dependent upon several factors including traffic requirements, contributing land use, street slope, and distance to the nearest outfall system. The suggested sizing and spacing of the inlets is based upon the interception rate of 70% to 80%. This spacing has been found to be more efficient than a spacing using 100% interception rate. Using the suggested spacing only, the most downstream inlet in a development would be designed to intercept 100% of the flow. Also, considerable improvements in over-all inlet system efficiency can be achieved if the inlets are located in the sumps created by street intersections. The following example illustrates how inlet sizing and interception capacity may be analyzed.

EXAMPLE 4: Inlet Spacing

GIVEN:
Maximum allowable street flow depth = 0.50 ft.
Street slope = 1.0 percent
Maximum allowable gutter flow = 11.0 cfs
Gutter flow = 11.0 cfs

FIND: Size and type of inlet for 75 percent interception

SOLUTION:

Step 1: Compute desired capacity

Q = (0.75) (11.0 cfs) = 8.3 cfs

Step 2: Read the allowable inlet capacities from Figures 901 and 902 for various inlets. The following values were obtained:

INLET TYPE	CAPACITY	% INTERCEPTION
Triple Combination Type 13	4.7 cfs	43
Double Type R	6.5 cfs	59
Triple Type R	7.7 cfs	70

Therefore, a curb opening inlet Type R, L = 15 feet is required and will intercept 7.7 cfs. The remaining 3.3 cfs will continue downstream and contribute to the next inlet. Spacing between such inlets will depend on the local runoff, and the amount of flow bypassed at the upstream inlet.

A comparison of the inlet capacity with the allowable street capacity (refer to Chapter 10) will show that the percent of street flow interception by the inlets varies from less than 50 percent to as much as 95 percent of the allowable street capacity. Therefore, the optimum inlet spacing cannot be achieved in all instances, and the spacing requirements should be analyzed by the design engineer.

5. Checklist

To aid the designer and reviewer, the following checklist has been prepared:

(1) Check the inlet capacity to determine the carryover flow, and account for this flow plus the local runoff in the sizing of the next downstream inlet.

(2) Place inlets at optimum grade or in sump conditions where possible to increase capacity.

(3) Space inlets based upon the interception rate of 70 to 80% of the gutter flow to optimize inlet capacity.

Insert Figure 901 here

Insert Figure 902 here

Insert Figure 903 here

Insert Figure 904 here

J. CHAPTER 10 STREETS

1. Introduction

The criteria presented in this section shall be used in the evaluation of the allowable drainage encroachment within public streets. The review of all planning submittals (refer to Chapter 2) will be based on the criteria herein.

2. Function of Streets in the Drainage System

Urban and rural streets, specifically the curb and gutter or the roadside ditches, are part of the Minor Drainage System. When the drainage in the street exceeds allowable limits (refer to Section C.4.4), a storm sewer system (Chapter 9) or an open channel (Chapter 7) is required to convey the excess flows. The streets are also part of the Major Drainage System when they carry floods in excess of the minor storm (refer to Section C.4.2), also subject to certain limitations (refer to Section C.4.4). However, the primary function of urban streets is for traffic movement and, therefore, the drainage function is subservient and must not interfere with the traffic function of the street.

Design criteria for the collection and moving of runoff water on public streets is based on a reasonable frequency and magnitude of traffic interference. That is, depending on the character of the street, certain traffic lanes can be fully inundated once during the minor design storm return period. However, during lesser intense storms, runoff will also inundate traffic lanes but to a lesser degree. The primary function of the streets for the Minor Drainage System is therefore to convey the nuisance flows quickly and efficiently to the storm sewer or open channel drainage without interference with traffic movement. For the Major Drainage System, the function of the streets is to provide an emergency passageway for the flood flows with minimal damage to urban environment.

3. Street Classification

The streets in the Town are classified for drainage use as Type A, B, or C according to the average daily traffic (ADT) for which the street is designed. The larger the ADT, the more restrictive the allowable drainage encroachment into the driving lanes. The limits of storm runoff encroachment for each Drainage Classification and storm condition is set forth under the Policy Section of this manual (refer to Section C.4.4).

Presented below is the Traffic Classification (i.e., Arterial, Collector, etc.), the corresponding Drainage Classification (i.e., Type A, B, or C), and the allowable theoretical flow depth before the reduction factor is applied for the minor storm. The limitations on the depth are based on the policy for encroachment (refer to Section C.4.4).

Traffic Classification	Drainage Classification	Allowable Theoretical Minor Storm Flow Depth

Arterial (84' Flowline to Flowline with raised median)	Type C	0.50'
Arterial (84' Flowline to Flowline without raised median)	Type C	0.50'
Arterial (68' Flowline to Flowline with raised median)	Type C	0.39'
Arterial (68' Flowline to Flowline without raised median)	Type C	0.50'
Arterial (64' Flowline to Flowline)	Type C	0.47'
Collector (44' Flowline to Flowline)	Type B	0.47'
Collector (36' Flowline to Flowline)	Type B	0.39'
Local (34' Flowline to Flowline, 6" V.C.)	Type A	0.47'
Local (34' Flowline to Flowline, Hollywood Curb)	Type A	0.42'
Local (28' Flowline to Flowline, 6" V.C.)	Type A	0.41'
Local (28' Flowline to Flowline, 4" pan)	Type A	0.41'

4. Hydraulic Evaluation

4.1 Allowable Capacity - Minor Storm

Eased upon the policy of Section C.4.4 and the Drainage Classification of each street in Section J.3, the allowable minor storm capacity of each street section is calculated using the modified Manning's formula.

$$Q = (0.56)(Z/n)S_{1/2}\, d_{8/3} \qquad \text{(Equation 1001)}$$

Where Q = discharge in cfs

$Z = 1/S_x$, where S_x is the cross slope of the pavement (ft/ft)

d = depth of water at face of curb (feet)

S = longitudinal grade of street (ft/ft)

n = Manning's roughness coefficient

The solution to the above equation can also be obtained through the use of the nomograph of Figure 1001 which is included for information only.

The allowable gutter capacity for each street cross section has been calculated and is presented in Figure 1003. The calculations are on file with the Town and have been published in a Technical Memorandum. The calculations were performed for various allowable theoretic flow depths and street slopes. A Manning's n-value of 0.016 was used for the calculations at all street slopes. The allowable gutter capacity was computed by multiplying the theoretical street capacity by the appropriate reduction factor shown on Figure 1002. The purpose of the reduction factor is to account for various street conditions which decrease the street capacity. These conditions include street overlays, parked vehicles, debris and hail accumulation, and deteriorated pavement. The reduction factor also is used to minimize damaging gutter flow velocities.

The allowable gutter capacity was computed using a symmetrical street section. Therefore, the allowable gutter capacity will need to be reduced for non-symmetrical street sections. Street capacity calculations shall be submitted to the Town at critical locations of the non-symmetrical streets. This computed street capacity must never exceed the allowable street capacity presented in these CRITERIA. The use of Figure 1003 is illustrated by an example in Section J.5.

4.2 Allowable Capacity - Major Storm

The allowable street capacity for the major storm is calculated using the Manning's formula by first dividing the street cross section into the pavement area and sidewalk/grass area and then computing the individual flow contributions. The capacity is subject to the limitations set forth in the Policy Section C.4.4 and the drainage classification of Section J.3. The capacity calculations were performed for each street cross section and published in a Technical Memorandum on file with the Town. The calculations were performed for various street slopes and plotted in Figure 1004. A Manning's n-value of 0.016 for the pavement area and 0.025 for the sidewalk/grass area was used to determine the capacity. The backslope from the curb was assumed to be 2 percent. The maximum allowable depth at the gutter is 12 inches (Section C.4.4). For non-symmetrical streets (see Figure 1005), street capacity calculations shall be submitted to the Town at critical locations. This computed street capacity must never exceed the allowable street capacity presented in these CRITERIA. The use of Figure 1004 is illustrated by an example in Section J.5.

4.3 Rural Streets

Rural streets are characterized by roadside ditches rather than curb and gutters for urban streets. The capacity is limited by the depth in the ditch and the maximum flow velocity. Refer to Section G.4.5 for the design and capacity of roadside ditches.

5. Design Example

Example 5: Determination of Street Capacity

GIVEN:
Street with a traffic classification of Minor Arterial and a slope of 1.0 percent.

FIND:
Maximum allowable capacity for minor and major storm.

SOLUTION:

STEP 1: Determine maximum allowable depth:
From Section J.3 for a "Arterial (64' Flowline to Flowline)," read the drainage classification as a Type C street. The maximum allowable theoretical depth for the initial storm is 0.47 feet.

STEP 2: Determine the allowable minor storm gutter capacity:
From Figure 1003, for a "Arterial (64' Flowline to Flowline)" with an allowable theoretical depth of 0.47 feet and a slope of 1.0 percent, read the allowable gutter capacity of 11.0 cfs. The flow velocity can also be obtained from Figure 1003 by interpolating between the velocity lines (V = 3.0 fps).

STEP 3: Determine the allowable major storm gutter capacity:
From Figure 1004 for a "Arterial (64' Flowline to Flowline)" with a slope of 1.0 percent, read the allowable capacity of 125 cfs per gutter assuming the street is symmetrical. If the street cross-section is not symmetrical (i.e., one gutter flowline higher than the other), the capacity of the upper gutter would have to be reduced so that the lower gutter capacity is not exceeded by street cross flow from the upper gutter (see Fig. 1005).

6. Checklist

To aid the designer and reviewer, the following checklist has been prepared:

(1) Use the flattest street slope to calculate the allowable gutter capacity.

(2) Determine street classification first, then allowable depth and gutter capacity.

(3) Non-symmetrical street evaluation.

(4) Storm sewer required for gutter capacity exceedance.

Insert Figure 1001 here

Insert Figure 1002 here

Insert Figure 1003 here

Insert Figure 1004 here

Insert Figure 1005 here

K. CHAPTER 11 CULVERTS

1. Introduction

A culvert is defined as a conduit for the passage of surface drainage water under a highway, railroad, canal, or other embankment (except detention outlets). Culverts may be constructed with many shapes and materials. Reinforced concrete pipe (RCP) is available in round, elliptical, or arch cross sections, in sizes ranging from 12 inches to 108 inches in diameter (Reference 9). The pipe may also be cast-in-place, although this construction method is generally only used for storm sewers.

Corrugated Steel Pipe (CSP) and Aluminum Pipe culverts are available in round or arch cross sections (Reference-10). Sections of corrugated metal can also be bolted together to form several other cross sectional shapes, such as elliptical and pear shapes, forming structural plate pipe (SPP). Corrugations also come in various dimensions, which affect the hydraulics of the pipe flow.

Reinforced Concrete Box Culverts (RCBC) can be constructed with generally any rectangular cross section, the only limitations being the physical site constraints and the structural requirements. Precast box culverts are also available in several standard dimensions.

2. Culvert Hydraulics

The procedures and basic data to be used for the hydraulic evaluation of culverts in the Town shall be in accordance with the MANUAL Volume-2, "Inlets and Culverts," Section-2, "Hydraulics," except as modified herein. The reader is also referred to the many texts covering the subject for additional information.

3. Culvert Design Standards

3.1 Construction Material and Pipe Size

Within the Town, culverts shall be constructed from corrugated steel or concrete. Other materials for construction shall be subject to written approval by the Design and Review Engineer.

The minimum pipe size for culverts within a public ROW shall be 18 inches diameter round culvert, or shall have a minimum cross sectional area of 1.6 ft^2 for arch shapes. Roadside ditch culverts for driveways shall be 15-inches diameter round culvert or shall have a minimum cross sectional area of 1.1 ft^2.

3.2 Inlet and Outlet Configuration

Within the Town, all culverts are to be designed with headwalls and wingwalls, or with flared-end sections at the inlet and outlet. Flared-end sections are only allowed on pipes with diameters of 42-inches (or equivalent) or less. No multiple

barrel installations will be allowed.

Headwalls, wingwalls, and flared-end sections should be designed and constructed to use the existing land forms of the site and blend with the natural landscape. Naturally occurring stone or river rock used as a cover material is preferred.

Additional protection in the form of riprap will also be required at the inlet and outlet due to the potential scouring velocities. Refer to Section L.2 and L.3.

3.3 Hydraulic Data

When evaluating the capacity of a culvert, the following data shall be used:

(a) Roughness Coefficient Table 1101.

(b) Entrance Loss Coefficients Table 1101.

(c) Capacity Curves - There are many charts, tables, and curves in the literature for the computation of culvert hydraulic capaTown. To assist in the review of the culvert design computations and to obtain uniformity of analysis, the following data shall be used:

All Culverts: Urban Storm Drainage Criteria Manual, DRCOG, Denver, Colorado 1969 (Reference-1) - Vol. 2, "Inlets and Culverts" section

Concrete Pipe: Concrete Pipe Design Manual, ACPA, Arlington, Virginia February, 1970 (Reference-9)

Corrugated Metal Pipe: "Handbook of Steel Drainage and Highway Construction Products," AISI, Washington D.C. (Reference 10)

Copies of the product manuals may be obtained through the local pipe suppliers.

(d) Design Forms - Standard Form SF-4 is to be used for determining culvert capacities. A sample computation is discussed in Section K.4 and shown on Table 1102.

3.4 Velocity Considerations

In design of culverts, both the minimum and maximum velocities must be considered. A minimum velocity of flow is required to assure a self-cleaning condition of the culvert. A minimum velocity in the culvert of 3-fps at the outlet is recommended.

The maximum velocity is dictated by the channel conditions at the outlet. If the outlet velocities are less than 5-fps to 7-fps for grassed channels (dependent upon soil type), then the minimum amount of protection is required due to the eddy currents generated by the flow transition. Higher outlet velocities will require substantially more protection. If the culvert outlet velocity is greater than 12-fps, an energy dissipator will be required. Refer to Sections L.2 and L.3 for protection requirements at culvert outlet.

3.5 Headwater Considerations

The maximum allowed headwater for the 100-year design flows shall be 1.5 times the culvert diameter, or 1.5 times the culvert rise dimension for shapes other than round. Also, the headwater depth may be limited by the street overtopping policy in Section C.4.4.

3.6 Structural Design

As a minimum, all culverts shall be designed to withstand an HS-20 loading (unless designated differently by the Town) in accordance with the design procedures of AASHTO, "Standard Specifications for Highway Bridges," and with the pipe manufacturer's recommendation.

3.7 Trashracks

Trashracks may be required at the entrance of culverts for some installations are designated by the Town. Installation of trashracks prevents debris from entering culverts. The culverts are protected from blockage since the debris accumulates at the trashracks. This centralized collection point allows routine cleaning of trashracks and hauling away of debris, which further protects culverts from blockage during flood events. In the event that someone is trapped in a channel during flood flows, a trashrack will enable the individual to climb to safety and not be swept into the culvert.

The following criteria shall be used for design of trashracks for storm drainage applications:

(1) Materials

All trashracks shall be constructed with smooth steel pipe with a minimum 1.25 inches outside diameter. The trashrack ends and bracing should be constructed with steel angle sections. All trashrack components shall have corrosion protective finish.

(2) Trashrack Design

The trashracks shall be constructed without cross-braces (if possible) in order to minimize debris clogging. The trashrack shall be designed to withstand the full hydraulic load of a completely plugged trashrack based on

the highest anticipated depth of ponding at the trashrack. The trashrack shall also be hinged and removed for maintenance purposes.

(3) Bar Spacing
The steel pipe bars shall be spaced with a maximum clear opening of six inches. In addition, the entire rack shall have a minimum clear opening area (normal to the rack) at the design flow depth of four times the culvert opening area.

(4) Trashrack Slope
The trashrack shall have a longitudinal slope of no steeper than 2.5 horizontal to 1 vertical for maintenance purposes.

(5) Hydraulics
Hydraulic losses through trashracks shall be computed using the following equation:

$$H_T = 0.11\,(TV/D)^2(\text{Sin } A) \qquad \text{(Equation 1101)}$$

where H_T = Head Loss through Trashrack (feet)

T = Thickness of Trashrack Bar (inches)
V = Velocity Normal to Trashrack (fps)
D = Center-to-Center Spacing of Bars (inches)
A = Angle of Inclination of Rack with Horizontal

This equation shall apply to all racks constructed normal to the approach flow direction. The velocity normal to the trashrack shall be computed considering the rack to be 50 percent plugged.

Equation 1101 is a modification of the equation presented in Reference 38. The modification consists of changing the computing head loss from inches to feet and eliminating the factor which accounts for approach flow directions other than normal to the trashrack.

4. Design Example
The procedure recommended to evaluate existing and proposed culverts is based on the procedures presented in HEC-5 Reference-12. The methodology consists of evaluating the culvert headwater requirements, assuming both inlet control and outlet control. The rating which results in the larger headwater requirements is the governing flow condition.

EXAMPLE 6: Culvert Rating

A sample calculation for rating an existing culvert is presented in Table 1102. The required data are as follows:

Culvert size, length, and type (48" CMP, L = 150', n = .024).
Inlet, outlet elevation, and slope (5540.0, 5535.5, s_o = 0.030).
Inlet treatment (flared end-section).
Low point elevation of embankment (EL = 5551.9).
Tailwater rating curve (see Table 1102, Column 5).

From the above data, the entrance loss coefficient, K_2, and the n-value are determined. The full flow Q and the velocity are calculated for comparison. The rating then proceeds in the following sequence:

STEP 1: Headwater values are selected and entered in column 3. The headwater to pipe diameter ratio (H_w/D) is calculated and entered in column 2. If the culvert is other than circular, the height of the culvert is used.

STEP 2: For the H_w/D ratios, the culvert capacity is read from the rating curves (Section K.3.3) and entered into column 1. This completes the inlet condition rating.

STEP 3: For outlet condition, the Q values in column 1 are used to determine the head values (H) in column 4 from the appropriate outlet rating curves (Section-11.3.3).

STEP 4: The tailwater depths (T_w) are entered into column 5 for the corresponding Q values in column 1 according to the tailwater rating curve (i.e., downstream channel rating computations). If the tailwater depth (T_w) is <u>less than</u> the diameter of the culvert (D), columns 6 and 7 are to be calculated (go to Step 5). If T_w is <u>more than</u> D, the tailwater values in column 5 are entered into <u>column 8</u> for the h_o values, and proceed to Step 6.

STEP 5: The critical depth (d_c) for the corresponding Q values in column 1 are entered into column 6. The average of the critical depth and the culvert diameter is calculated and entered into column 7 as the h_o values.

STEP 6: The headwater values (H_w) are calculated according to the equation:

$$H_w = H + h_o - LS_o$$

where H is from column 4, and h_o is from column 8 (for T_w>D) or the larger value between column 5 and column 7 (for T_w<D). The values are entered into column 9.

STEP 7: The final step is to compare the headwater requirements (columns 9 and 3) are to record the higher of the two values in column 10. The type of control is recorded in column 11, depending upon which case gives the higher headwater requirements. The headwater elevation is calculated by adding the controlling H_w (column 10) to the upstream invert elevation. A culvert rating curve can then be plotted from the values in columns 12 and 1.

To size a culvert crossing, the same form can be used with some variations in the basic procedures. First, a design capacity is selected and the maximum allowable headwater is determined. An inlet type (i.e., headwall) is selected, and the invert elevations and culvert slope are estimated based upon site constraints. A culvert type is then selected and first rated for inlet control and then for outlet control. If the controlling headwater exceeds the maximum allowable headwater, a different culvert configuration is selected and the procedure repeated until the desired results are achieved.

5. Culvert Sizing Criteria

The sizing of a culvert is dependent upon two factors, the drainage classification (i.e., Type-A, Type-B, or Type-C) and the allowable street overtopping. The allowable street overtopping for the various street classifications is set forth in Section C.4.4. In addition to this policy, a criteria requiring that no street overtopping occur for a 10-year frequency storm has been established. Therefore, as a minimum design standard for street crossings, the following procedure shall be used:

(1) Using the future developed conditions 100-year runoff, the allowable street overtopping shall be determined from overflow rating curves developed from the street profile crossing the waterway.

(2) The culvert is then sized for the difference between the 100-year runoff and the allowable overtopping.

(3) If the resulting culvert is smaller than the required to pass the 10-year flood peak without overtopping, the culvert shall be increased in size to pass the 10-year flow.

The criteria is considered a minimum design standard and must be modified where other factors are considered more important. For instance, if the procedure still results in certain structures remaining in the 100-year floodplain, the design frequency may be increased to lower the floodplain elevation. Also, if only a small increase in culvert size is required to prevent overtopping, then the larger culvert is recommended.

6. Checklist

To aid the designer and reviewer, the following checklist has been prepared:

(1) Minimum culvert size within the public ROW is 18 inch diameter round or equivalent for other shapes.

(2) Minimum culvert size for roadside ditches at driveways is 15-inch diameter round or equivalent for other shapes.

(3) Headwalls, wingwalls, or flared end sections required for all culverts.

(4) Check outlet velocity and provide adequate protection.

(5) Check maximum headwater for design condition.

(6) Check structural requirements.

Insert Table 1101 here

Insert 2nd half of Table 1101 here

Insert Table 1102 here

L. CHAPTER 12 HYDRAULIC STRUCTURES

1. Erosion Control

Hydraulic structures are used in storm drainage work to control the flow of the runoff. The energy associated with flowing water has the potential to create damage to the drainage works, especially in the form of erosion. Hydraulic structures, which include riprap, energy dissipators, check structures, brides, and irrigation ditch crossings, all control the energy and minimize the damage potential of storm runoff. All hydraulic structures should be designed and constructed to appear as natural land forms with natural colors.

The criteria to be used in the design of hydraulic structures shall be in accordance with the MANUAL Volume 2 in the "Major Drainage" and "Structures" sections. The specific criteria to be used with the modifications for the Town are presented herein.

2. Riprap

The design of the riprap protection for culverts, channel bottom and banks, check drops, bridges, gabions or other areas subject to erosion, shall be in accordance with the MANUAL Volume 2, "Major Drainage Section 5 - Riprap," as revised.

3. Energy Dissipators

Where riprap structures are insufficient or uneconomical to control the storm runoff, concrete energy dissipator structures (stilling basins) shall be provided in accordance with the MANUAL Volume 2, "Structures, Section B.2 - Energy Dissipators."

For culverts or storm sewers where the Froude number at the outlet is in excess of 2.5, the USBR Type VI impact stilling basin shall be used. An example USBR Type VI basin is shown on Figure 1201.

4. Check Structures

As discussed in chapter, "Open Channels," there is a maximum permissible velocity for major design storm runoff in grass lined channels. One of the more common methods of controlling the flow velocity is to reduce the channel invert slope, which requires a check drop to make up for the elevation difference occurring when the channel slope is reduced.

The design criteria for the check drops shall be in accordance with the MANUAL Volume 2, "Structures, Section 3 - Channel Drops." This section is being redrafted by the Urban Drainage and Flood Control District. Draft copies of the preliminary work may be obtained from the Urban Drainage and Flood Control District.

5. Bridges

The design of bridges within the Town shall be in accordance with the MANUAL Volume 2, "Structures, Section 4 - Bridges." The design capacity of the bridge shall be determined by the method presented in Section K.5 of these CRITERIA.

6. Irrigation Ditch Crossings

Any proposed development in the vicinity of the ditches or canals that crosses or utilizes the canal for surface drainage or proposes to make any modifications to the existing topography which alters and/or affects water quality and drainage patterns to the ditch shall have the plans approved by the ditch company prior to approval by the Town.

Insert Figure 1201 here

M. CHAPTER 13 EROSION AND SEDIMENTATION CONTROL FROM CONSTRUCTION ACTIVITIES AND WATER QUALITY

1. Introduction

All new development shall have prepared and implemented an erosion and sedimentation plan. The plan shall be prepared and will be reviewed in accordance with the criteria presented in the REGULATIONS.

The clearing and stripping of land for development can cause high localized erosion rates with subsequent deposition and damage to offsite properties. Whereas erosion and sedimentation is a natural process, the intensity is increased by development which can destroy the aesthetic and practical values of other properties, streams, and lakes. The purpose of implementing an erosion and sedimentation control plan is to reduce the process to an acceptable level without placing undue burdens on the homeowner, builder, or community.

Subsequent to the passage of the Federal Water Pollution Control Act Amendments (PL-92-500), the Denver Regional Council of Governments (DRCOG) initiated a federally funded area-wide water quality management study. The result of the study ("Clean Water Plan") identified the control of pollutants which originate from non-point or diffuse sources as an important consideration requiring preventative measures for developing areas.

2. Erosion and Sedimentation Control

Prior to construction, an erosion and sedimentation control plan must be approved by the Town Engineer.

3. Water Quality

Runoff from all areas of one quarter acre or more where automobiles, trucks, buses, and other gasoline or diesel powered vehicles or equipment are parked shall be collected and routed through a sand oil separator, prior to discharge from the site.

The sand oil separator shall be designed to accomodate flows equal to the ten percent (10%) of the 5-year peak flow. Flows in excess of the design flow may be routed directly to the storm drainage system, per the CRITERIA.

N. CHAPTER 14 DETENTION

1. Introduction

The criteria presented in this section shall be used in the design and evaluation of all detention facilities. The review of all planning submittals (refer to Chapter 2) will be based on the criteria presented in this section.

The main purpose of a detention facility is to store the excess storm runoff associated with an increased basin imperviousness and discharge this excess at a regulated release rate. The value of such detention facilities is discussed in Section C.3.6. Any special design conditions which cannot be defined by these CRITERIA shall be reviewed by the Town Engineer before proceeding with design.

Dams and water diversion/detention areas should be designed and constructed to appear as natural features, creating site amenities. Techniques to achieve this include creation of topographic changes that mimic natural conditions (including a variety of slope changes), using natural materials such as stone, blending with the textures and patterns of the surrounding landscape, and using materials that match the local environment. When possible, preserve existing drainage patterns.

2. Detention Methods

The various detention methods are defined on the basis of where the facility is constructed, such as open space detention, parking lot, underground or roof-top.

3. Design Criteria

3.1 Volume and Release Rates

The minimum required volume shall be determined using the CUHP method or the following equations. These empirical equations were developed as part of the UD&FCD hydrology research program. The equations are based on a computer modeling study and represent average conditions. One of the most difficult aspects of storm drainage is obtaining consistent results between various methods for estimating detention requirements. These equations will provide consistent and more effective approaches to the sizing of onsite detention ponds. For larger water sheds where the Colorado Urban Hydrograph Procedure can be used (i.e., 90+ acres), hydrograph routing procedures will be permitted in the design of these ponds, provided the historic imperviousness of two percent or less is used. Underlying assumption for 1404, 1405, and 1406 is historic imperviousness of 2 percent. Any additional imperviousness due to development should be added to the 2 percent.

Minimum Detention Volume:

$$V = KA \quad \text{(Equation 1404)}$$

For the 100-year,

$$K_{100} = (1.78I - 0.002[I]^2 - 3.56)/1000 \quad \text{(Equation 1405)}$$

For the 10-year,

$$K_{10} = (0.95I - 1.90)/1000 \quad \text{(Equation 1406)}$$

Where V = required volume for the 100- or 10-year storm (acre-feet)

I = Developed basin imperviousness (%)

A = Tributary area (Acres)

The maximum release rates at the ponding depths corresponding to the 10- and 100-year volumes are as follows:

ALLOWABLE RELEASE RATES
FOR DETENTION PONDS - CFS/ACRE

	SOIL GROUP		
CONTROL FREQUENCY	A	B	C & D
10-year	0.13	0.23	0.30
100-year	0.50	0.85	1.00

The predominate soil group for the total basin area tributary to the detention pond shall be used for determining the allowable release rate. Information on the soils in the Town can be found in Reference 25.

3.2 Design Frequency
All detention facilities are to be designed for two storm frequencies: the 10-year and the 100-year recurrence interval floods.

3.3 Hydraulic Design
Hydraulic design data for sizing of detention facilities outlet works is as follows:

(1) Weir flow
The general form of the equation for horizontal crested weirs is:

$Q = CLH^{3/2}$ (Equation 1401)

Where Q = discharge (cfs)

C = weir coefficient (Table 1401)

L = horizontal length (feet)

H = total energy head (feet)

Another common weir is the v-notch, whose equation is as follows:

$Q = 2.5 \tan(\theta/2)H^{5/2}$ (Equation 1402)

Where θ = angle of the notch at the apex (degrees)

When designing or evaluating weir flow, the effects of submergence must be considered. A single check on submergence can be made by comparing the tailwater to the headwater depth. The example calculation for a weir design of Figure 1403 illustrates the submergence check.

(2) Orifice Flow
The equation governing the orifice opening and plate is the orifice flow equation:

$Q = C_d A (2gh)^{1/2}$ (Equation 1403)

Where Q = Flow (cfs)

C_d = Orifice coefficient

A = Area (ft^2)

g = Gravitational constant = 32.2 ft/sec^2

h = Head on orifice measured from centerline of the orifice (ft)

An orifice coefficient (C_d) value of 0.65 shall be used for sizing of square edged orifice openings and plates.

4. <u>Design Standards for Open Space Detention</u>

4.1 <u>State Engineer's Office</u>

Any dam constructed for the purpose of storing water, with a surface area, volume, or dam height as specified in Colorado Revised Statutes 37-87-105 as amended, shall require the approval of the plans by the State Engineer's Office. All detention storage areas shall be designed and constructed in accordance with these CRITERIA. Those facilities subject to state statutes shall be designed and constructed in accordance with the criteria of the state.

4.2 Grading Requirements

Slopes on earthen embankments 5 feet in height or less shall not be steeper than 4 (horizontal) to 1 (vertical). For embankment heights between 5' and 10', the slopes shall not be steeper than 3 (horizontal) and 1 (vertical), but horizontal slope distance shall not be less than 20'. For embankments greater than 10 feet in height, the slopes shall be such to maintain slope stability, but horizontal slope distance shall not be less than 30 feet. Contact the Town Engineer for additional requirements. All earthern slopes shall be covered with topsoil and revegetated with grass. Slopes on riprapped earthern embankments shall not be steeper than 3 (horizontal) to 1 (vertical). For grassed detention facilities, the minimum bottom slope shall be 2.0 percent measured perpendicular to the trickle channel.

4.3 Freeboard Requirements

The minimum required freeboard for open space detention facilities is 1.0 feet above the computed 100-year water surface elevation.

4.4 Trickle Flow Control

All grassed bottom detention ponds shall include a concrete trickle channel or equivalent performing materials and design. Trickle flow criteria is presented in Section G.4.2.6(a).

4.5 Outlet Configuration

Presented on Figure-1401 are two examples for detention pond outlet configuration. A Type I outlet consists of a grated drop inlet, outlet pipe, and an overflow weir in the pond embankment. The control for the 10-year discharge shall be at the throat of the outlet pipe under the head of water as defined on Figure 1401. The grate must be designed to pass the 10-year flow with a minimum of 50 percent blockage (i.e., twice the 10-year flow). Since the minimum size of the outlet pipe is 18-inches, then a control orifice plate at the entrance of the pipe may be required to control the discharge of the design flow (see Section N.3.3). An example orifice plate is shown on Figure 1402. Other outlet configurations will be allowed provided they meet the requirements of the permitted release rates at the required volume and include proper provisions for maintenance and reliability.

The outlet shall be designed to minimize unauthorized modifications which effect proper function. A sign with a minimum area of 0.75 square feet shall be

attached to the outlet or posted nearby with the following message:

WARNING
Unauthorized modification of
this outlet is a code violation.

The difference between the 100-year discharge and the surcharged discharge on the 10-year outlet is released by the overflow weir or spillway. If sufficient pond depth is available, the drop inlet and the grate can be replaced by a depressed inlet with a headwall and trashrack. Depression of the inlet is required to reduce nuisance backup of flow into the pond during trickle flows. The maximum trashrack opening dimension shall be equal to the minimum opening in the orifice plate.

A Type 2 outlet consists of a drop inlet with an orifice controlled inlet for the 10-year discharge and a crest overflow and pipe inlet control for the 100-year discharge. The control for the 10-year discharge occurs at the orifice opening for the head as shown on the figure. The control for the 100-year discharge occurs at the throat of the outlet pipe as shown on the figure. However, the difference between the 100-year and 10-year discharge must pass over the weir and therefore the weir must be of adequate length. The effective weir length (L) occurs for three sides of the box. To ensure the 100-year control occurs at the throat of the outlet pipe, a 50 percent increase in the required weir length is required. In addition , the outlet pipe must have an adequate slope to ensure throat control in the pipe.

4.6 Embankment Protection

Whenever a detention pond uses an embankment to contain water, the embankment shall be protected from catastrophic failure due to overtopping. Overtopping can occur when the pond outlets become obstructed or when a larger than 100-year storm occurs. Failure protection for the embankment may be provided in the form of a buried heavy riprap layer on the entire downstream face of the embankment or a separate emergency spillway having a minimum capacity of twice the maximum release rate for the 100-year storm. Structures shall not be located in the path of the emergency spillway or overflow. The invert of the emergency spillway should be set equal to or above the 100-year water surface elevation.

4.7 Vegetation Requirements

All open space detention ponds shall be revegetated by either irrigated sod or natural dry-land grasses in accordance with the manual "Guidelines for Development and Maintenance of Natural Vegetation" by Donald H. Godi & Associates, Inc., July 23, 1984, available through the UD&FCD.

5. Design Standards for Parking Lot Detention
The requirements for parking lot detention are as follows:

5.1 Depth Limitation
The maximum allowable design depth of the ponding for the 100-year flood is 18 inches.

5.2 Outlet Configuration
The minimum pipe size for the outlet is 18" diameter where a drop inlet is used to discharge to a storm sewer or drainageway. Where a weir and a small diameter outlet through a curb are used, the size and shape are dependent on the discharge/storage requirements. A minimum pipe size of 3" diameter is recommended.

5.3 Performance
To assure that the detention facility performs as designed, maintenance access shall be provided in accordance with Section C.3.7. The outlet shall be designed to minimize unauthorized modifications which effect function. Any repaving of the parking lot shall be evaluated for impact on volume and release rates and are subject to approval by the Department of Highways and Transportation. A sign shall be attached or posted in accordance with Section N.4.5.

5.4 Flood Hazard Warning
All parking lot detention areas shall have a minimum of two signs posted identifying the detention pond area. The signs shall have a minimum area of 1.5 square feet and contain the following message:

WARNING
This area is a detention pond and is subject to periodic flooding to a depth of (provide design depth).

Any suitable materials and geometry of the sign are permissible, subject to approval by the Department of Highways and Transportation.

6. Design Standards for Underground Detention
The requirements for underground detention are as follows:

6.1 Materials
Underground detention shall be constructed using corrugated aluminum pipe (CAP) or reinforced concrete pipe (RCP). The pipe thickness cover, bedding, and backfill shall be designed to withstand HS-20 loading or as required by the Town.

6.2 Configuration

Pipe segments shall be sufficient in number, diameter, and length to provide the required minimum storage volume for the 100-year design. As an option, the 10-year design can be stored in the pipe segments and the difference for the 100-year stored above the pipe in an open space detention (Section N.4) or in a parking lot detention (Section N.5). The minimum diameter of the pipe segments shall be 36 inches.

The pipe segments shall be placed side by side and connected at both ends by elbow tee fittings and across the fitting at the outlet (see Figure 1405). The pipe segments shall be continuously sloped at a minimum of 0.25% to the outlet. Manholes for maintenance access (see Section N.6.4) shall be placed in the tee fittings and in the straight segments of the pipe, when required.

Permanent buildings or structures shall not be placed directly above the underground detention.

6.3 Inlet and Outlet Design

The outlet from the detention shall consist of a short (maximum 25 ft.) length(s) of CAP or RCP with a 18" minimum diameter. A two-pipe outlet may be required to control both design frequencies. The invert of the lowest outlet pipe shall be set at the lowest point in the detention pipes. The outlet pipe(s) shall discharge into a standard manhole (see Standard Detail SD-6) or into a drainageway with erosion protection provided per Sections K.3.2, L.2, and L.3. If an orifice plate is required to control the release rates, the plate(s) shall be hinged to open into the detention pipes to facilitate back flushing of the outlet pipe(s).

Inlet to the detention pipes can be by way of surface inlets and/or by a local private storm sewer system.

6.4 Maintenance Access

Access easements to the detention site shall be provided in accordance with Section C.3.7. To facilitate cleaning of the pipe segments, 3-foot diameter maintenance access ports shall be placed according to the following schedule:

MAINTENANCE ACCESS REQUIREMENTS

Detention Pipe Size	Maximum Spacing	Minimum Frequency

36" to 54"	150'	Every pipe segment
60" to 66"	200'	Every other pipe segment
>66"	200'	One at each end of the batter of pipes

The manholes shall be constructed in accordance with the detail on Figure-1405.

7. Design Standards for Rooftop Detention

Rooftop detention is generally discouraged and will only be allowed when all other options have been proven to be insufficient. Under no circumstances will the Town accept rooftop detention as a publicly owned facility. Only the area of the roof will be allowed in the computation of the drainage basin tributary to the rooftop pond. In addition, the roof pitch or slope must be included in the computation of the volume. However, if a developer must use this technique and agrees to maintain it, it will be allowed if designed according to the following additional criteria.

7.1 Depth Limitation

The maximum allowable design depth of ponding at the outlet for the 100-year flood is two inches. The current local building code may limit this depth to less than two inches. The stricter of these criteria shall apply.

7.2 Outlet Configuration

Rooftop detention outlets shall be designed to meet the volume and release rates specified in Section N.3.1.

7.3 Overflow Provisions

Overflow drains or scuppers shall be installed for all rooftop detention facilities. These overflow drains shall be designed in accordance with the uniform building code and shall have a minimum design capacity of the peak 100-year runoff considering the detention outlet to be plugged. These drains or scuppers shall have a minimum freeboard of one inch.

7.4 Structural Loading

Roofs to be used for detention shall be structurally designed to account for all loads including detention at the maximum possible depth in accordance with the applicable local building code.

7.5 Maintenance Easement

A maintenance easement and right of access to the Town are required for the entire roof area to allow for inspection and cleaning of the roof drains and overflows. This easement shall be provided in accordance with Section-3.3.7.

7.6 Approval
Construction, maintenance, and emergency access plans shall be included with the corrected plat submittal. Approval by the Building Department is required.

8. Design Examples

EXAMPLE 7: DETENTION DESIGN

GIVEN: A basin that has the following characteristics:

Basin Area (A) = 23 acres

Basin Imperviousness (I) = 55%

Predominate Soil Group = D

REQUIRED: 100-year and 10-year storage volumes and release rates.

SOLUTION:

STEP 1: Determine K_{100} using Equation 1405

$K_{100} = (1.78I - 0.0021I^2 - 3.56)/1000$

$= (1.78(55) - 0.002(55)^2 - 3.56)/1000$

$= 0.0883$

STEP 2: Determine K_{10} using Equation 1406

$K_{10} = (0.95I - 1.90)/1000$

$= 0.0504$

STEP 3: Determine minimum required 100-year storage volume using Equation 1404

$V = KA$
$= 0.0833 \times 23$

$= 2.03$ acre-feet (88,500 ft^3)

STEP 4: Repeat Step 3 for 10-year storage

$V = KA$

$= 0.0504 \times 23$

$= 1.16$ acre-feet (50,500 ft^3)

STEP 5: Determine maximum allowed 100-year release rate

$Q_{100} = 1.00\ A$

$= 1.00 \times 23$

$= 23.0$ cfs

STEP 6: Repeat Step 5 for 10-year release rate

$Q_{10} = 0.30\ A$

$= 0.30 \times 23$

$= 6.9$ cfs

<u>EXAMPLE 8</u>: <u>Detention Outlet Structure Design</u>

<u>GIVEN</u>: Detention pond with the following characteristics (see Example 7)

Maximum 100-yr release rate = 23.0 cfs

Maximum 10-year release rate = 6.9 cfs

Type 2 outlet (refer to Figure-1401)

100-year water surface elevation = 105.0

10-year water surface elevation = 103.0

100-year outlet pipe invert elevation = 100.0
10-year outlet orifice invert elevation = 100.0

18-inch diameter outlet pipe

<u>REQUIRED</u>: 10-year and 100-year outlet sizing

<u>SOLUTION</u>: (see Figure 1404)

STEP 1: Determine 10-year orifice opening size, depth to centerline or orifice = 2.5 feet

$A = Q/(C_d\,(2gh)^{1/2})$ (Rearranged Equation 1403)

$= 6.9/0.65\,(2(32.2)(2.5))^{1/2})$

$= 0.84\ ft^2$

STEP 2: Determine 10-year orifice diameter

$\text{Diameter} = (4A/\pi)^{1/2}$

$= (4(0.84)/\pi)^{1/2}$

= 1.0 feet (12-inches)

Therefore, an orifice opening with a 12-inch diameter hole is required at the entrance to the outlet box.

STEP 3: Determine discharge through 10-year outlet for 100-year headwater (h - 4.5 feet)

$Q = C_dA\,(2gh)^{1/2}$ (Equation 1403)

$= 0.65(.84)\,(2(32.2)(4.5))^{1/2}$

= 9.3 cfs

STEP 4: Determine discharge for sizing of 100-year weir

$Q_{weir} = Q_{100}$ - Q(from Step 3)

= 23.0 - 9.3

= 13.7 cfs (for sizing weir only)

STEP 5: Size orifice area for 100-year outlet (18" RCP, h = 4.25 feet)

$A = A/C_d(2gh)^{1/2})$ (Equation 1403)

$= 23.0/(0.65)(2(32.2)(4.25))^{1/2}$

$A = 2.14\ ft^2$

STEP 6: Determine 100-year orifice diameter

Diameter= $(4A/\pi)^{1/2}$

$= ((4)(2.14)/\pi)^{1/2}$

= 1.65 feet = 20 inches

Since orifice diameter is approximately equal to the pipe diameter (±15%), then no orifice plate is required.

STEP 7: Determine minimum box dimensions (i.e., weir length) to assure control of the pipe inlet.

$L = Q_{weir}/(CH^{3/2})$ (Equation 1401)

C = 3.4 from Table 1401

$L = 13.7/(3.4(2.0)^{3/2})$

L = 1.4 feet - Required Length = 1.4(1.5) 1 = 2.1'

Since required weir length is only 2.1 feet, select box dimensions to suit construction and maintenance access. A minimum size of 3' x 3' is recommended.

STEP 8: Check minimum size for 10-year trashrack total open area

Min. area = 9 x 10-year orifice area (from Figure 1402)

= 9 x 0.84

Min. area = $7.56\ ft^2$

9. <u>Checklist</u>
To aid the designer and reviewer, the following checklist has been prepared:

(1) Earth slopes are to be 4:1 or flatter.

(2) Minimum freeboard of 1 foot for the 100-year detention is required.

(3) Open space detention areas to include trickle channels.

(4) Protect embankment for overtopping condition by adding riprap.

(5) Provide trashracks at all outlet structures.

(6) Provide signs as required.

(7) Provide maintenance access.

Insert Table 1401 here

Insert Figure 140 here

Insert Figure 1402 here

Insert Figure 1403 here

Insert Figure 1404 here

Insert Figure 1405

Insert figure 1406 here

Insert Figure 1407 here

STANDARD FORM SF-1
DEVELOPMENT REVIEW CHECKLIST
DRAINAGE REPORT

See Drainage Report Checklist, Section II
Standard Design forms to follow in this section.

Insert Standard Form SF-2 (Time of Concentration)

Insert Standard Form SF-3 - Storm Drainage System Design (Rational Method Procedure)

Insert Standard Form SF-4
Culvert Location

Insert Standard Form SF-5
Sequential Detention Calculation

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IV. RIGHT-OF-WAY/STREET IMPROVEMENTS

A. PAVEMENT STRUCTURAL DESIGN

The pavement sections proposed for streets and parking lots in new developments are to be documented in a "Soils and Pavement Design Report" prepared by a Registered Professional Engineer. A checklist noting the items necessary in that report is included in Section II of this document.

Street Classifications

STREET CLASS	AVERAGE DAILY VOLUMES	ADJACENT LAND USES
Arterial or Major	12,000 plus	High Density Multi-Family Residential Regional Commercial/Office
Major Collectors	7,000 plus	Low Density Local Commercial High Density Multi-Family Residential
Minor Collectors	Less than 7,000	Low Density Neighborhood Commercial Low Density Multi-Family Single Family Residential
Local	Less than 2,500	Residential or Predominately Residential with Local Commercial Uses at Select Intersections

EDLA Values

The following tables may be used to calculate the 18 KIP Equivalent Daily Loaded Axle (EDLA) values for pavement design. They are based on collected traffic data and the Colorado Department of Transportation design methodology.

If traffic counts to forecast design year volume are not already available, the Town of Hudson Engineering Department should be contacted for forecast traffic volumes on a particular street. The "Design Year" shall be 20 years from the proposed development date for both streets and parking lot designs.

EDLA VALUES FOR PROPOSED MAJOR/ARTERIAL STREETS

DESIGN YEAR	TOTAL NUMBER OF THROUGH LANES	
VOLUME	4 LANE	6 LANE
12,000	58	39
15,000	88	58
20,000	117	78
25,000	146	97
30,000	176	117
35,000	205	137
40,000	235	156
45,000	264	176
50,000	293	195

EDLA VALUES FOR PROPOSED MAJOR COLLECTOR STREETS

DESIGN YEAR	TOTAL NUMBER OF THROUGH LANES	
VOLUME	4 LANE	6 LANE
7,000	44	33
8,000	51	38
9,000	57	43
10,000	64	48
11,000	70	52
12,000	76	57

EDLA VALUES FOR PROPOSED MINOR COLLECTOR STREETS

DESIGN YEAR	TOTAL NUMBER OF THROUGH LANES
VOLUME	4 LANE
3,000	16
4,000	22
5,000	28
6,000	33
7,000	39

EDLA VALUES FOR PROPOSED LOCAL STREETS

DESIGN YEAR VOLUME	2 THROUGH LANES
less than 1,000	5
2,000	8
2,500	10

The minimum EDLA for local streets and parking lots shall be 5.0.

Soil Conditions

A soils and pavement design report is required for all proposed street and parking lot pavements. Should the soils report indicate varying soil conditions with the potential presence of excessive swelling (greater than 2.0%) or other potentially troublesome characteristics, alternative designs will need to be presented for the potential "hot spots" on the project.

Also, should the field inspection upon completion of the overlot grading indicate areas apparently differing from the report conditions or presenting potential problems, an amended pavement design report will be required.

Design Criteria

Following are the design criteria for the respective pavement types which are to be used for developing an appropriate pavement design. An allowance must be made for construction truck traffic based on forecast volumes and loadings. Thicker pavement sections may be required based on these forecasts.

Flexible Pavements

The design shall be based on Colorado Department of Transportation's methodology, with soils classified in accordance with the AASHTO soil classifications. A sieve analysis and an Atterberg limit is required every tenth of a mile or on every street if street lengths are less than one-tenth mile. In parking lots, they are required in each representative use area. An R-valve test will be required for every representative soil type.

If the plastic index from the soil analysis exceeds 30 and the liquid limit exceeds 45, a swell consolidation test and additional R-valve tests may be required by the Town Engineer in order to properly design the pavement structural section.

The minimum regional factor shall be 1.25 (1.50 if curb and gutter is not used). The serviceability index shall be a minimum of 2.0 after twenty (20) years for streets with an ADT less than 750. Streets with an ADT greater than 750 shall be 2.5 after twenty years. The acceptable design nomographs for pavement design are shown in Design Aids Nos. 1, 2 and 5 located in the Appendix.

The minimum Weighted Structural Number shall be 2.04 with the minimum cross section allowed on any street being three inches (3") of Hot Bituminous Pavement and six inches (6") of Aggregate Base Course (Class 6) on compacted subgrade. An equivalent full depth asphalt section may also be used over compacted subgrade.

Lifts on asphalt pavement shall not be less than one and one-half inches (1½") or more than three inches (3") in depth. Final lifts shall not be placed between October 1 and April 1 without Town approval.

The minimum cross section for parking lots shall be two and one-half inches (2½") of Hot Bituminous Pavement and four inches (4") of aggregate base course (Class 6) on 6" compacted subgrade. An equivalent full depth asphalt section may also be used over compacted subgrade. Pavement thickness above the minimum must be used in areas such as trash truck service areas. The pavement design for parking lots may be based on the Asphalt Institute methodology in lieu of CDOT if desired.

The allowable strength coefficients for pavement design are:

Component	Coefficient
Road Mix Bituminous Pavement	0.20
Existing Bituminous Pavement	0.20
Plant Mix Bituminous Base	0.34
Hot Bituminous Pavement	0.44
Aggregate Base Course (CL 6) (R-valve>84)	0.14*
Aggregate Base Course (CL 6) (R-valve<84)	0.12
Aggregate Base Course (CL 1)	0.10
Emulsified Asphalt Treated A.B.C.	0.20
Cement Treated A.B.C.	0.23
Hydrated Lime Treated A.B.C.	0.14
Select Borrow	0.10

*Source and strength tests must be approved by Town prior to use

Rigid Pavements

The design of rigid pavements shall be based on the Colorado Department of Transportation's design procedure, with soils classified in accordance with the AASHTO soil classifications. A sieve analysis and an Atterberg limit is required every tenth of a mile or on every street if street lengths are less than one-tenth of a mile. In parking lots, they are required in each representative use area.

An R-valve test will be required for each representative soil type.

If the plastic limit from the soil analysis exceeds 30 and the liquid limit exceeds 45, a swell consolidation test and additional R-valve tests may be required by the Town Engineer in order to properly design the pavement structural section.

Serviceability Index for designs shall be 2.0 after 20 years for streets with less than 750 ADT and 2.5 for streets with an ADT greater than 750.

The minimum section required for streets shall be six inches (6") of non-reinforced Portland Cement concrete pavement on compacted subgrade. For acceptable joint details, see Design Standard No. 14. An acceptable design nomograph for pavement design is shown in Design Aids Nos. 3, 4 and 5, located in the Appendix.

The minimum cross section required for parking lots shall be 4½" of non-reinforced Portland Cement concrete on compacted subgrade.

The pavement design for parking lots may be based on the Portland Cement Association methodology in lieu of CDOT, if desired.

Bikeways

Bikeways shall be a minimum of six inches (6") of Portland Cement concrete on compacted subgrade. Driveway crossings and attached bike paths will be thicker as indicated in Design Standards Nos. 9 and 11. For guidelines on clearance, widths and grades see the CDOT Standard Specifications.

B. PAVEMENT UTILITY CUTS

The City of Hudson shall be notified and shall inspect utility cuts whenever they are made in the public way. The cut shall conform to design standard No. 18 in addition to the following:

Backfilling of Excavations Either in or Within Two Feet (2') of any Paved Surface. If work in the public way creates any excavations that lie in or within two feet (2') of

any existing or future paved surfaces, the excavation shall be backfilled with: 1) the excavated material in layers not to exceed six inches (6") and each layer shall be compacted to 95% (optimum AASHTO T99) and 2) six inches (6") of ABC (CL 6) compacted to 95% (optimum AASHTO T99) shall be placed on top. Aggregate base course meeting Town specifications may also be placed by any procedure which results in 95% compaction. In all cases, moisture content shall be ± 2% of optimum.

Local Asphalt Streets

Local asphalt streets can be a saw cut, neatly jackhammered or wheel cut. Backfill shall be compacted native material, or aggregate backfill with 6 inches of Class 6 material directly under a 5-inch asphalt concrete patch.

Parkways and Other Unpaved Surfaces

If a permit for work in the public way creates any excavations that lie under unpaved areas and parkways, the excavated soil shall be carefully deposited and satisfactorily tamped in uniform layers not greater than six inches (6") in thickness until the backfill reaches the top of the substructure. The remainder of the excavation shall be backfilled in uniform layers not exceeding twelve inches (12") in thickness, and satisfactorily tamped to within one foot (1') of the surface. The backfilling operation shall continue with soil until the backfill remains slightly above the ground level. Excess material shall be disposed of. Granular backfill meeting Town specifications may also be used; however, topsoil shall be used for the final foot of backfill. Cultivated grass areas shall be seeded. It is the responsibility of the permittee to establish a good stand of grass. The area shall be left free from debris and clods. On steep embankments or upon request of the Town Engineer, sod or other erosion control techniques shall be used
for restoration.

Gravel Streets

Gravel streets shall be backfilled with compacted native material or aggregate backfill and surfaced with a 2-inch aggregate surface or with a thickness equal to the previous surface, whichever is greater.

Minor and Major Collector Streets and Arterials (Asphalt)

These streets shall be saw cut at all times. Backfill shall be compacted native material or 6 inches Class 6 material directly under the patch with a 5-inch asphalt concrete or existing asphalt thickness, whichever is greater, or as specified by the Engineer/inspector. Traffic conditions on some arterial roadways may require boring in lieu of trenching.

Concrete Sidewalks, Bikepaths, Driveways, Curbs and Gutters, and Other Structures

Whenever an excavation cuts a concrete sidewalk, bikepath, driveway, curb and gutter, or other structure, a neat saw cut shall be made one foot (1') back from each side of the excavation to undisturbed soil; if the removal is within 5' of a contraction or expansion joint, the concrete shall be removed back to that joint. All broken material shall be removed. Once the excavation is backfilled and subgrade compacted to 95% (optimum AASHTO T99), the surface shall be replaced using a CDOT Class B concrete in accordance with the design standards.

Concrete Streets

The pavement shall be neatly sawn and removed 1 foot back from each side of the excavation; however, in no case shall the repair be less than 5 feet in width. If a construction, contraction, or expansion joint is within 5 feet of the edge of the saw cut, the surface shall be removed back to the joint. All cuts shall be four sided.

Once the excavation is backfilled and subgrade compacted to 95% (optimum AASHTO T99), 6 inches of Aggregate Base Course Class 6 shall be placed. The pavement shall be repaired to the thickness of the existing concrete pavement with a minimum 7 sack mix with 5,000 PSI at 28 days. Test cylinders shall be specified as requested by the Town Engineer.

Notes Pertaining to All Cuts

1. ABC, (Class 6) may be used in lieu of compacting native material in 6-inch lifts.
2. Jackhammering, when allowed, shall be neatly done, resulting in a clean edge and squared off corners.
3. A spreader box or self-propelled paver may be required at the discretion of engineer/inspector.
4. If street excavations by any one contractor total 10% or more of any street surface in a one-block stretch, the Town Engineer may require sealing or overlaying of the entire street.
5. Cold patch is unacceptable on any permanent patch back.

C. STREET GRADING

The intersection of roadway cut slopes with the existing ground shall be rounded in earth cuts, beginning outside the slope stake and extending down the cut slope. The maximum cut and fill slopes after the bench (two foot minimum level area) adjacent to the roadway/pedestrian facilities shall be:

Maximum Cut or Fill Slope 3:1

Recommended Cut or Fill Slope 4:1

Maximum Slope if maintenance to be undertaken by Town is 4:1

Finished pavement cross slopes may not be less than 1% or exceed 4%. 2% is the recommended standard.

D. ALL WEATHER ACCESS

All weather access must be constructed when temporary certificates of occupancy are requested on buildings prior to the public improvements being completed.

All weather access shall meet the following three conditions:

1. Aggregate base course compacted to 95% (optimum AASHTO T99) shall be placed the full width of the street and to the lipline elevation of the gutter.
2. The minimum cross slope shall be .04 FT/FT.
3. The developer shall maintain these standards until the road is paved.

E. COMMERCIAL AND INDUSTRIAL ROAD SECTIONS

Design Standard No. 3-A identifies the minimum street section for commercial and industrial areas. In the event that a larger street section would be required, the engineer will determine applicable street widths.

F. CUL-DE-SACS

The total street length of a cul-de-sac or a loop cul-de-sac, as shown in Design Standards 6A and 6B must not be greater than 500 feet except if one of the following conditions is met:

1. The total cul-de-sac length may be increased to a maximum of 1,000 feet for 1R, 2R, 3R and CN Zone Districts, provided the water supply system for fire protection is approved by the fire protection district.

2. The total length of a cul-de-sac for Zone Districts higher than 1R, 2R, 3R or CN may be increased to a maximum of 750 feet provided the water supply system for fire protection is approved by the fire protection district.

3. It should be noted that for cul-de-sacs serving developments with buildings

exceeding 26 feet in height, the fire department may require a 45 foot radius cul-de-sac bulb to permit ladder fire trucks to turn around. The exact design will be determined by the fire district.

G. SURVEY MONUMENTS

The standard Survey Monument shown in the design standards shall be installed at all street centerline intersections, the center of radius for cul-de-sacs, and at the end of dead end streets. All monuments shall be set within 60 days of completion of the streets. If this is not done, the Town will have the work performed by a Registered Land Surveyor and make a claim against the collateral for the amount of costs plus administration for such work.

V. WATER SYSTEM CRITERIA AND SPECIFICATIONS

1. PURPOSE AND GENERAL REQUIREMENTS

1.1 Purpose

This publication is to provide information to all Engineers, Contractors, Builders, Developers and other interested persons or firms, on the Town requirements with respect to design and construction of water systems within the Town. This publication presents technical specifications for the design and installation of water mains and should be used in conjunction with the Town Rules and Regulations by any firm or individual planning to design or construct water systems within the Town. In all cases in these specifications where reference is made to "Town Engineer," the "Town Engineer" shall mean any representative of the Consulting Engineering firm or other individual designated by the Town to provide inspection of the water system construction.

1.2 General Requirements

1.2.1 All water mains 12" and larger shall be profiled on the construction plans. All water mains of any size which are not under a designed street shall also be profiled on the construction plans. All water mains 16" and larger shall be ductile iron.

1.2.2 All contractors must notify the Town at least 48 hours prior to start of construction.

1.2.3 A pre-construction meeting must be arranged by the contractor and held prior to the start of any work. The Town Engineer, Contractor, and Owner or Owner's Engineer must be represented at this meeting, which will be held at the Town office.

1.2.4 Approved construction plans and a copy of these specifications must be kept on the job site by the Contractor at all times. Approved construction plans will expire six (6) months from the date of approval.

1.2.5 No work shall be backfilled (including bedding material above the spring line of the pipe) until the construction has been inspected and approved for back-filling by the Town Engineer.

1.2.6 The maximum distance between main line gate valves shall be 600 feet. Gate valves shall also be located at all intersections.

1.2.7 SENSUS 2 meters shall be used.

1.2.8 Fire hydrants shall have **NST (National Standard Thread)** and shall be installed and spaced in accordance with the Town of Hudson Fire Code.

1.2.9 Steel pipe installed only with prior approval of the Town Engineer.

1.2.10 Water mains shall be located a minimum distance of 6.0 feet from the lip edge of the gutter plan.

1.2.11 Squeegee bedding shall be used. On-site material is not acceptable without the approval of the Town Engineer.

2. LOCATION OF LINES AND APPURTENANCES

2.1 Water Mains in Streets

When the water mains are placed in streets they shall be placed as follows:

2.1.1 On streets running north and south, the water main shall be placed 10' (ten feet) east of the centerline of the street.

2.1.2 On streets running east and west, the water main shall be placed 10' (ten feet) north of the centerline of the street.

2.1.3 On streets shaped as a "U" or on streets having unusually sharp turns, the water main will conform to the above specifications as near as practical, but the final location shall be as determined by the Engineer or his representatives.

2.2 Water Mains in Easements

In areas where water mains are placed in easements, all water mains shall be located within the easements shown on the contract drawings. All water main easements must be a minimum of 30' (thirty feet) in width for exclusive easements or 50' (fifty feet) for non-exclusive easements. No water line shall be located less than 5' (five feet) from the edge of an easement.

2.3 Valves

Valves shall be located, where possible, at a point on the main which would be intersected by the extension of a property line.

2.4 Fire Hydrants

Fire hydrants shall be located, where possible, on the northeast corner of an intersection a minimum of 18" behind the curb or sidewalk, or a minimum of 24" inside the street right-of-way, and set on the curb return. Where this is not possible, fire hydrants shall be located as directed by the Town Engineer. All fire hydrant street valves shall be 6" and shall be located at, or within 3' (three feet) of, tee from the main line. See "Valve and Fire Hydrant Location Detail".

3. PIPE

3.1 General

All public water mains will be a minimum of 6" in diameter. Sizing shall be determined by the Town Engineer. Pipe in sizes 10" or 14" generally will not be allowed. Additional requirements for type of pipe shall be determined by the Town Engineer.

3.2 Ductile Iron Pipe

Ductile iron pipe shall only be installed with prior approval by the Town Engineer. All ductile iron pipe furnished under this specification shall be manufactured in strict accordance with AWWA standard specification **C-151/A21.51-96** or latest revision thereof with the following additional requirements:

3.2.1 Size of Pipe - This specification shall cover 4", 6", 8", 12" and 16" diameter pipe.

3.2.2 Joint Type - All ductile iron pipe joints shall be "Push on joint single gasket" or "Mechanical joint single gasket." The rubber gasket shall conform to the requirements of AWWA **C-111/A21.11-95**, or latest revision thereof.

3.2.3 Thickness Class - Pipe furnished shall be Class 50 for 6", 8" and 12" diameter, and Class 51 for 4", 20" and larger diameter pipe.

3.2.4 Laying Length - Pipe furnished shall have a normal laying length of 18' or 20'.

3.2.5 Grade of Iron - Iron used in the manufacture of pipe shall have 60/42/10 physicals.

3.2.6 Cement Mortar Lining - All pipe furnished shall have standard thickness cement mortar lining in accordance with AWWA **C-104/A21.4-95** or latest

revision thereof.

3.2.7 Polyethylene Wrapping - Pipe furnished shall have polyethylene wrapping as specified in paragraph 3.6. The polyethylene wrapping shall conform to AWWA **C-105/A21.5-93** or latest revision thereof. See Detail "Polyethylene Wrapping".

3.3 Polyvinyl Chloride (PVC) Pressure Pipe

All polyvinyl pipe furnished under this specification shall be manufactured in strict accordance with AWWA Standard C 900-89 and shall conform to the following additional requirements:

3.3.1 Size of Pipe - This specification shall cover polyvinyl chloride pipe in 4-inch, 6-inch and 8-inch nominal diameters with cast iron pipe equivalent outside diameters.

3.3.2 Joint Type - Pipe joints shall be made using an integral bell with an elastomeric gasket push-on type joint or using machined couplings of a sleeve type with rubber ring gaskets and machined pipe ends to form a push-on type joint.

Solvent cement joints are strictly prohibited.

3.3.3 Class and Type - All sizes of pipe shall be Class 200, dimension ratio 18 (DR 18).

3.3.4 Pipe Lengths - Each length of pipe will be a standard laying length of 20 feet. Random lengths shall not be acceptable.

3.3.5 Manufacturer - Unless otherwise authorized by the Town Engineer, only Johns-Manville "Blue Brute," CertainTeed "Vinyl-Iron," Northstar "Aqua-lite," or Robintech shall be acceptable.

3.4 Steel Pipe

Steel pipe shall only be installed with prior approval of the Town Engineer. Specifications for steel pipe must be submitted for review by the Town Engineer prior to approval.

3.5 Reinforced Concrete Pipe

Reinforced concrete pipe shall be installed in sizes larger than 24" only.

Specifications for RCP must be submitted for review by the Town Engineer prior to approval and use.

3.6 Polyethylene Wrapping

Polyethylene wrapping shall be installed around all ductile iron pipe, fittings, valves, fire hydrant barrels, and rods and clamps and where specified by the Town Engineer. Polyethylene wrapping shall be in accordance with AWWA Specification **C-105/A21.5-93** or latest revision. Minimum thickness of polyethylene wrapping shall be 8 mils.

4. WATER MAIN EQUIPMENT

4.1 Fittings

All fittings shall be ductile iron, cement mortar lined, and shall conform to AWWA **C-110/A21.10-93** for mechanical joints and AWWA **C-111** or ANSI **A21.95** for push on joint gasket or latest revisions thereof.

Fittings shall be wrapped in polyethylene when used with wrapped pipe line.

4.2 Valves

4.2.1 Gate Valves - shall conform to AWWA **C-500-93** (or latest revision) flexible wedge, with a minimum working water pressure of 200 PSIG for valves 12" and smaller. Valve seats, the discs and the stem shall be constructed of bronze. Stem seals shall be with two "O" rings, each of which shall be designed as to allow replacement under full line pressure when the valve is in the full open position. Valves shall have 2" square operating nuts and shall open counter-clockwise (left) unless otherwise directed by the Town Engineer.

4.2.2 Butterfly Valves - shall conform to AWWA **C-504-94** (or latest revision) with a minimum working water pressure of 150 PSIG and shall be supplied with flanged connections and shall be suitable for buried service installation. The pivot axis of the disc shall be mounted in the horizontal position and provided with geared operators and position indicators. Operator manholes shall be provided as shown in the details, Section 12. Valve operators shall have 2" square operating nuts and shall open counter-clockwise (left).

4.2.3 Fire Hydrants - shall conform to AWWA **C-502-94** or latest revision. Hydrants shall have a 6" bell connection, two 2-1/2" hose connections and one 4-1/2" pumper connection. Threads on the pumper and hose connections

shall conform to the "National Standard Screw Threads for Fire Hose Couplings and Fittings" published by the Insurance Services office. Hydrants shall be designed to operate under 150 PSI working pressure and shall open counter-clockwise (left) unless specified otherwise. Fire hydrants shall be cast iron and bronze mounted. Fire hydrants shall have auxiliary 6" gate valve anchored directly to or as near as possible to the main line tee as shown in the Standard Details. The hydrant lateral shall be 6" ductile iron, shall be wrapped in polyethylene, and shall be rodded from tee to hydrant shoe.

4.2.4 Check Valves - shall be of the swing check type and shall be used wherever the flow of water must be in one direction only and reverse flow must be prevented. Check valves shall be of the outside spring and lever type and shall be installed in vaults or manholes. Check valves shall be furnished with flanged end connections and shall be installed in a manner which allows easy access for inspection, adjustment and maintenance.

4.2.5 Valve Boxes and Valve Markers - shall be installed in accordance with the Standard Details. Markers shall be installed to locate all valves on lines in easements or other rights-of-way when not at street intersections. Fire hydrant auxiliary valves shall not be marked unless specifically directed by the Town Engineer.

4.2.6 Combination Air Relief-Vacuum Breaker Valves - shall be installed at each high point on all 16" and larger water mains and at all other locations as directed by the Town Engineer. Air Relief and Vacuum Breaker Valves shall be located in pre-cast concrete manholes in accordance with the Standard Details and shall automatically release air from the lines when the lines are being filled with water, and shall admit air into the lines when water is being withdrawn in excess of the inflow. The valve and body shall be designed to operate under a maximum working pressure of 150 psi. Valves shall be iron body, with bronze trim. Floats shall be stainless steel. One 2-inch valve shall be installed on the stem between the pipe and relief valve or as shown in the Standard Details.

Pipe and fittings used in the relief valve system shall be galvanized steel, standard weight, and connections shall be threaded. Gate valves shall be bronze, with female iron pipe thread ends and shall have handwheels.

4.2.7 Pressure Reducing and Regulating Valves - Pressure reducing and regulating valves shall be of a type capable of maintaining pre-adjusted downstream pressures, varying rates of flow and upstream pressure without causing water hammer. Valves shall be piston type, not spring operated, with flanged end connections, and shall be installed in concrete valve vaults of sufficient size

to provide adequate maintenance and operation. Valves shall have gate valves and pressure gauges on both upstream and downstream sides and shall have bypasses with smaller pressure reducing and regulating valves to handle minimum flows as determined by the Town Engineer. All gate valves in the vaults shall be capable of being operated from above ground by use of 2" square valve keys. All PRV's shall be as manufactured by Cla-Val.

4.2.8 Blow-Off Assemblies - Blow-off assemblies shall be installed at each low point in all water mains and on all major transmission lines. All water mains having dead ends where stagnant water may collect shall be provided with blow-off devices in accordance with the Standard Details. If the main will be temporarily deadened, a blow-off shall be installed. If a fire hydrant is located at the main's temporary end, then that can serve as the blow-off.

4.2.9 Rods and Clamps - All tees, bends, valves, plugs, reducers, and fire hydrants shall be rodded and clamped in accordance with the Standard Details. Rods and socket clamps shall be used on ductile iron and polyvinyl chloride pipe systems. Where polyvinyl chloride pipe is used and the plug or bend is to be rodded, ductile iron pipe shall be installed on either side of the fitting and socket clamps shall be placed on the iron pipe. No socket clamps shall be clamped to polyvinyl chloride pipe. Where mechanical joint iron pipe is used, rods may be bolted through the joint bolt holes. Number and size of rods shall be as indicated in the details. All rods and clamps shall be coated with coal tar epoxy or polyethylene wrapped. In all cases where reducers with a reduction ratio equal to or greater than 2 to 1 are used, special rodding and clamping procedures may be required by the Town Engineer. Mega-Lugs are allowed through 24" sizes.

4.2.10 Thrust Blocks - Concrete thrust blocks shall be installed at all tees, plugs, bends, and fire hydrants in accordance with the Standard Details. Where thrust blocks are used to block plugs or valves or as indicated by the Town Engineer, the valve or plug shall be protected from concrete by an 8 mil thickness of polyethylene. Size of thrust block and dimensions shall be in accordance with the Standard Details. The concrete used for the thrust blocks shall be 3000 psi, 28 day strength. Thrust blocks shall be installed in addition to rods and clamps, on all valves, tees, bends, fire hydrants, and plugs.

4.2.11 Pre-Cast Concrete Vaults and Manholes - All butterfly valve manholes, air relief and vacuum valve vaults, pressure reducing valve vaults, meter vaults, and other vaults shall be pre-cast or poured in place concrete. Design of manholes shall be for traffic loading and shall include aluminum rungs, sump pit, cast iron rings and covers of a pattern approved by the Town Engineer, with the word "water" cast thereon. All vaults and manholes shall be water

tight and all joints, pipe openings, and other places where infiltration could exist shall be sealed from the outside with a mastic waterproof sealant. All inside joints shall be grouted.

5. ENCASEMENT AND CASINGS

5.1 Pipe Casings - shall be used where bores are required under rights-of-way by the using agency. All pipe casings shall be constructed to conform with the details in Section II. The type of casing material and its properties shall have prior approval from the Town Engineer before using.

5.2 Protective Concrete Pads Over Pipe - shall be used over pipe to protect it from traffic and frost when, under unusual circumstances, it becomes necessary to lay pipe at shallow depths. The pads shall be designed such to support loads from traffic without transmitting the impact or load to the pipe. The concrete pads can only be used if prior approval has been given by the Town Engineer.

6. INSTALLATION

6.1 Excavation

6.1.1 General

Excavation for pipelines, fittings, and appurtenances shall be open trench to the depth and in the direction necessary for the proper installation of the same as shown on the approved drawings or as otherwise approved by the Town Engineer. Any water which may be encountered or may accumulate in the excavation shall be pumped out or otherwise removed as necessary to keep the bottom of the excavation free and clear of water during the progress of the work.

6.1.2 Limit of Excavation

Except by expressed written permission of the Town Engineer, the maximum length of open trench shall be 600', or the distance necessary to accommodate the amount of pipe installed in a single day, whichever is smaller. The distance is the collective length at any location, including open excavation, pipe laying and appurtenances, construction and backfill which has not been temporarily resurfaced. No trench shall be left open at any time that the Contractor is not on the job site engaged in construction operations.

6.1.3 Trench Width

The overall trench width shall not be more than 24" nor less than 12" wider than the largest outside diameter of the pipe to be laid therein,

measured at the top of the pipe, exclusive of branches. Excavating and trenching shall be true to line so that a clear space of not more than 12" or less than 6" in width is provided on each side of the largest outside diameter of the pipe for proper placement and densification of the bedding or backfill. For the purpose of this section, the largest outside diameter shall be the outside diameter of the bell, on bell and spigot pipe. All trenching sizes shall be in accordance with the Standard Bedding Details.

6.1.4 Excavation Below Grade

The trench shall be excavated to a minimum depth of 6" below the bottom of the pipe. Before the pipe is laid, the subgrade shall be made by backfilling with an approved material in 3" uncompacted layers. The layers shall be thoroughly tamped as directed by the Town Engineer so as to provide a continuous bearing and support for the pipe at every point between coupling or bell holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18" near the middle of each length of pipe by the withdrawal of pipe slings or other lifting tackle. The finished subgrade shall be prepared accurately by means of hand tools.

6.1.5 Trenching By Hand or Machine

Hand methods for excavation shall be employed in locations directed by the Town Engineer. In other locations, the Contractor may use trench digging machinery or employ hand methods.

6.1.6 Bracing Excavations

All excavations shall be properly supported in the manner as required by Occupational Safety and Health Administration Federal Register Vol. 37, No. 243, Sub-part P, Section 1926.652 or as required by State laws and Municipal ordinances and as may be necessary to protect life, property, the work, or as ordered by the Town Engineer. Excavations shall be braced, sheeted and supported such that they will be safe, and the ground alongside the excavation will not slide or settle. Excavation shall be so braced or sheeted so as to provide conditions under which workmen may work safely and efficiently at all times. The sheeting, shoring and bracing shall be so arranged as not to place any stress on portions of the completed work until the general construction thereof has proceeded far enough to provide ample strength.

Care shall be exercised in the drawing or removing of sheeting,

shoring, bracing and timbering to prevent the caving or collapsing of the excavation faces which are being supported.

6.1.7 Grading and Stockpiling

The Contractor shall control grading in a manner to prevent water from running into excavations. Obstruction of surface drainage shall be avoided and means shall be provided whereby storm and wastewater can be uninterrupted in existing gutters, other surface drains or temporary drains.

6.2 Dewatering

The Contractor shall provide and maintain at all times during construction, ample means and devices with which to promptly remove and properly dispose of all water from any source entering the excavations or other parts of the work. Dewatering shall be accomplished by methods which will insure a dry excavation and preservation of the bottoms of excavations. Said methods may include well points, sump pumps, suitable rock or gravel placed below the required bedding for drainage and pumping purposes, temporary pipelines and other means, all subject to the approval of the Town Engineer.

Dewatering for the water lines shall commence when groundwater is first encountered, and shall be continuous until such time as water can be allowed to rise in accordance with the provisions of this section.

The Contractor shall dispose of the water from the work in a suitable manner without damage to adjacent property or to new construction.

6.3 Foundations and Bedding

6.3.1 Foundations in Poor Soil - If excessively wet, soft, spongy, unstable or similarly unsuitable material is encountered at the surface upon which the bedding material is to be placed, the unsuitable material shall be removed to a depth as determined in the field by the Town Engineer and in accordance with the Standard Bedding Details.

6.3.2 Foundations in Rock - Where rock is encountered, it shall be removed below grade and the trench backfilled with rock uniformly graded between 3/4-inch and 1-1/2-inches to provide a compacted foundation cushion with minimum allowable thicknesses of 3" under the outside diameter of the pipe bell and 6" under the pipe barrel. Material, other than what has been stated, can be used if accepted by the Town Engineer and necessary agencies. Whether or not the foundation material will be considered as rock and require bedding as described above will be determined by the Town Engineer.

6.3.3 Pipe Clearance in Rocks - Ledge rock, boulders and large stones shall be removed to provide a clearance of at least 6" below and on the side of the pipe and fittings.

6.3.4 Bedding Procedure - The pipe shall be carefully bedded as shown in the Standard Bedding Details. The Contractor shall be responsible for accurately shaping the pipe subgrade to fit the bottom of the pipe for the width shown on the Bedding Details. Use of the drag template shaped to conform to the outer surface of the pipe will be required if other methods do not give satisfactory results.

Each joint shall be recessed in bedding material as required by the Bedding Detail in such a manner as to relieve the bell or coupling of the pipe of all load and to insure continuous bearing along the pipe barrel upon the pipe sub-grade.

The pipe bedding, using either squeegee or clean imported sand shall conform to the limits set by the Town Specifications. The bedding material, either squeegee or imported sand, shall be compacted by approved methods to a Standard Proctor Density of 90% in open areas (AASHTO T-180) **and 95% in all Public R.O.W. (AASHTO T-99)**. It shall be brought to an optimum moisture content and shall be placed by hand in layers not exceeding 3" in thickness to the centerline (springline) of the pipe and each layer shall be solidly tamped with the proper tools so as not to injure, damage or disturb the pipe. Backfilling shall be carried on simultaneously on each side of the pipe to assure proper protection of the pipe. Water settling for compaction may be approved by the Town Engineer in the event the foundation and bedding materials are sufficiently granular and sandy in nature that the required compaction will be obtained. From the springline of the pipe to a distance 12" above the top of pipe, the bedding material must be placed in layers not to exceed 12".

The area shown on the details from trench bottom to 12" above this pipe shall be called the "pipe zone."

6.4 Installation of the Water Pipe

6.4.1 General - All pipe shall be laid without break from fitting to fitting. Pipe shall be laid to the line and, where required, grade, as shown on the approved plans and in such a manner as to form a close concentric joint with the adjoining pipe and prevent sudden offsets of the line. Where possible, vertical deflections shall be made at pipe joints and vertical bends shall be

eliminated. Permissible joint deflections are specified in paragraph 6.4.3.7. The interior of the water pipe shall be cleaned of all dirt and superfluous material of all description as the work progresses.

At all times when pipe laying is not in progress, the open end of the pipe shall be closed with a tight fitting cap or plug to prevent the entrance of foreign matter into the pipe. These provisions shall apply during the noon hour as well as overnight.

6.4.2 Alignment and Grade - The water line shall be laid and maintained to the required lines and grades as shown on the plans.

Whenever obstructions not shown on the plans are encountered during the progress of the work and interfere to such an extent that an alteration in the approved plans is required, the Town Engineer shall have the authority to change the plans and order a deviation from the line and grade.

6.4.3 Laying of Pipe

6.4.3.1 Lowering of Water Main Material Into Trench - Proper implements, tools and equipment satisfactory to the Town Engineer shall be provided and used by the Contractor for the safe and convenient performance of the work. All pipe, fittings, valves and hydrants shall be carefully lowered into the trench piece by piece in such a manner as to prevent damage to the water main materials and protective coatings and linings. Under no circumstances shall water main materials be dropped or dumped into the trench.

If damage occurs to any pipe, fittings, valves, hydrants or water main accessories in handling, the damage shall be immediately brought to the Town Engineer's attention.

6.4.3.2 Inspection Before Installation - All pipe and fittings shall be carefully examined for cracks and other defects while suspended and before installation. Spigot ends shall be examined with particular care as this area is the most vulnerable to damage from handling. Defective pipe or fittings shall be laid aside for inspection by the Town Engineer, who will prescribe corrective repairs or rejection.

6.4.3.3 Cleaning of Pipe and Fittings - All lumps, blisters and excessive coating shall be removed from the bell or coupling and spigot

ends of each pipe, and the outside of the spigot and the inside of the bell or coupling shall be wire brushed and wiped clean and dry and free of oil and grease before the pipe is laid.

6.4.3.4 Laying of Pipe - Every precaution shall be taken to prevent foreign material from entering the pipe while it is being placed in the line. If the pipelaying crew cannot put the pipe into the trench and place it without getting earth into it, the Town Engineer may require that before lowering the pipe into the trench, a heavy, tightly woven canvas bag of suitable size, or plastic caps, shall be placed over each end and left there until the connection is made to the adjacent pipe. During laying operations, no debris, tools, clothing or other materials shall be placed in the pipe.

As each length of pipe is placed in the trench, the spigot end shall be centered in the bell or coupling and the pipe forced home and brought to correct line and grade. The pipe shall be secured in place with approved backfill material tamped under it except at the bells or couplings. Precautions shall be taken to prevent dirt from entering the joint space.

6.4.3.5 Cutting of Pipe - The cutting of pipe for inserting valves, fittings or closure pieces shall be done in a neat and workmanlike manner without damage to the pipe or cement lining and so as to leave a smooth end at right angles to the axis of the pipe.

6.4.3.6 Bell or Coupling Ends to Face Direction of Laying - Pipe shall be laid with the bell or coupling ends facing in the direction of laying, unless otherwise specified by the Town Engineer. Where the pipe is laid on a grade of 10% or greater, the laying shall proceed upward with the bell or coupling ends of the pipe upgrade, if the progression of work allows.

6.4.3.7 Permissible Deflection at Joints - Wherever it is necessary to deflect the pipe from a straight line, either in the vertical or horizontal plane, to avoid obstructions or plumb stems or where long radius curves are permitted, the amount of deflection allowed shall not exceed that specified in paragraphs 6.4.4.3 and 6.4.5.2 for mechanical joints and push on joints, respectively, and 4 degrees per joint (or 2 degrees on each side of the coupling) for polyvinyl chloride pipe.

6.4.3.8 Insulation Between Different Metallic Pipe Materials - Whenever it is necessary to join pipe or fittings with dissimilar metal, a method of insulating against the passage of electric current shall be provided and shall be approved by the Town Engineer.

6.4.3.9 Installation of Polyethylene Wrapping (When Specified). See Water Detail.

6.4.3.10 Pipe - Where specified in Section 3.6, all ductile iron pipe shall be wrapped with polyethylene wrapping, minimum 8 mil thickness. Suggested installation procedure for polyethylene tube wrapping is as follows:

Pick up the pipe with a sling or pipe tongs. Slip a polyethylene tube which is approximately 2' longer than the pipe over the plain end and leave it bunched up accordion style.

Lower the pipe into the trench and make up the joint with the preceding pipe. Shallow bell holes are required to allow overlap of the tube at the joints.

Remove the sling or tong from the center of the pipe, raise the bell a few inches and slip the polyethylene tube along the pipe barrel, leaving approximately 1' of the tube bunched up at each end of the pipe for wrapping the joints.

Overlap each joint by first pulling one bunched-up tube over the bell, folding it around the adjacent plain end, and securing it in place with two or three wraps of the polyethylene adhesive tape. Complete the overlap by repeating the same procedure with the bunched-up tube on the adjacent pipe.

Take up the slack tube along the pipe barrel by folding it over the top of the pipe holding the fold in place with polyethylene adhesive tape.

Repair any rips, punctures or other damage to the polyethylene with tape or by cutting open a short

length of tube, wrapping it around the pipe and securing with tape.

6.4.3.11 Fittings - When specified in Section 3.6, all fittings for ductile iron, or polyvinyl chloride pipe shall be wrapped with polyethylene tubing as described above. Installation procedure shall be as follows:

Wrap tees, crosses and other fittings with a flat sheet obtained by splitting open a length of polyethylene tube. Pass the sheet under the valve or fitting and bring it up around the body. Joint the seams by bringing the edges together, folding over twice and securing in place with tape.

Handle slack tube and overlapping at joints in the same manner described above for pipe.

Prepare openings for air reliefs, etc., by making an X-shaped cut in the polyethylene and temporarily folding back the edges. After installation is completed, replace the polyethylene and repair the cut with polyethylene adhesive tape.

6.4.4 Jointing of Mechanical Joint Pipe

6.4.4.1 Cleaning and Assembly of Joint - The last 8" of the outside spigot and inside bell of mechanical joint pipe shall be thoroughly cleaned to remove oil, grease, grit, excess coating and other foreign matter from the joint and then painted with a soap solution made by dissolving ½ cup of liquid soap in 1 gallon of water. The cast iron gland shall be slipped on the spigot end of the pipe with the lip extension of the gland toward the socket, or bell end. The rubber gasket shall be painted with the soap solution and placed on the spigot end with the thick edge towards the gland. All mechanical joints and fittings shall be wrapped in polyethylene wrap; see Standard Detail.

6.4.4.2 Bolting of Joint - The entire section of pipe shall be pushed forward to seat the spigot end in the bell. The gasket shall then be pressed into place within the bell. Care shall be taken to locate the gasket evenly around the entire joint. The cast iron gland shall be moved along the pipe into position for bolting,

all of the bolts inserted, and the nuts screwed finger tight. All nuts shall be tightened with a torque limiting wrench. The torque for various sizes of bolts shall be as follows:

Pipe Size (Inches)	(Inches)	Range of Torque Min. (Ft-#) Max.
3	_	45-60
4-24	¾	75-90
30-36	1	100-120
42-48	1¼	120-150

Nuts spaced 180 degrees apart shall be tightened alternately in order to produce an equal pressure on all parts of the gland.

6.4.4.3 Permissible Deflection in Mechanical Joint Pipe - Whenever it is desirable to deflect mechanical joint pipe in order to form a long-radius curve, the amount of deflection shall not exceed the maximum limits shown in Table 1 at the end of this section.

6.4.5 Jointing Push-on Joint Pipe

6.4.5.1 Cleaning and Assembly of Joint - The inside of the bell coupling and the outside of the spigot end shall be thoroughly cleaned to remove oil, grit, excess coating and other foreign matter. The circular rubber gasket shall be flexed inward and inserted in the gasket recess of the bell socket, or the coupling end of polyvinyl chloride pipe.

A thin film of gasket lubricant shall be applied to either the inside surface of the gasket or the outside of the spigot end of the pipe or both. Gasket lubricant shall be supplied by the pipe manufacturer and approved by the Town Engineer.

The spigot end of the pipe shall be placed into the bell or coupling end, without touching the ground with the spigot end after cleaning. The joint shall then be completed by forcing the plain end to the bottom of the socket. Pipe shall be marked with a depth mark to insure that the spigot end is inserted to the full depth

of the joint. Field-cut pipe lengths shall be marked by painting or file mark. The spigot end shall be ground or filed to resemble manufacture pipe end. Complete assembly instructions shall be provided by the pipe manufacturer.

6.4.5.2 Permissible Deflection in Push-On Joint Pipe - Whenever it is desirable to deflect push-on joint pipe, in order to form a long-radius curve, the amount of deflection shall not exceed the maximum limits shown in Table 2 at the end of this section for cast iron or ductile iron pipe, or 4 degrees coupling for polyvinyl chloride pipe.

6.4.6 Setting of Fittings - Fittings and plugs shall be joined to pipe in the manner specified herein for cleaning, laying and joining pipe.

6.5 Installation of Water Line Appurtenances

6.5.1 Valve Boxes and Valve Vaults - A valve box or valve vault shall be provided for every valve.

A valve box shall be provided for every valve that has no gearing or operating mechanism or in which the gearing or operating mechanism is fully protected with a cast iron grease case. All gate valves 12" and less and all butterfly valves 20" and less shall have valve boxes and all butterfly valves larger than 20" shall have concrete manholes to house the opening. Pressure reducing valves, check valves, and air relief and vacuum breaker valves shall be installed in concrete vaults. The valve box shall not transmit shock or stress to the valve and shall be centered and plumb over the wrench nut of the valve, with the box cover flush with the surface of the finished pavement or embedded in an 18" square by 6" thick concrete pad when placed in an area that is not paved.

A concrete vault shall be provided for all butterfly valve operators as shown in the Standard Details. The valve nut shall be readily accessible for operation through the opening in the vault, which shall be set flush with the finished surface of the pavement, or shall extend 6" above grade in unpaved areas.

6.5.2 Valve Markers - All valves installed on the main transmission line with the exception of those on extended property lines, shall be identified with a 4" steel or 3" flat fiberglass post marker offset as directed by the Town Engineer

and painted yellow, with the distance to the valve and the appropriate identifying initials stenciled in black. Where the valve is to be installed in a vault equipped with a vent pipe, the vent pipe will also serve as a valve marker.

6.5.3 Dead Ends - All dead ends shall be closed with cast iron plugs which shall be rodded to the main line and provided with a kickblock as specified on the Standard Details. Blow-off valves shall be located as specified in Section 4.2.8.

6.5.4 Fire Hydrants

6.5.4.1 Position - All hydrants shall stand plumb and shall have their nozzles parallel with, or at right angles to the main line, unless otherwise directed by the Town Engineer. Hydrants shall be set to established grade, with nozzles at least 18" above the ground, or as directed by the Town Engineer. The bottom flange of the hydrant shall be set 3" above the finished grade. No portion of the fire hydrant may protrude into the sidewalk area.

6.5.4.2 Connection to Main - Each hydrant shall be connected to the main with a 6" ductile iron branch controlled by an independent 6" gate valve located next to mechanical joint tee with a 6" anchor coupling. The branch line shall be rodded and wrapped, and the hydrant shoe and main line tee shall be thrust blocked.

6.5.4.3 Hydrant Drainage - A drainage pit 3' in width and 3' deep shall be excavated below each hydrant and filled completely with coarse gravel or crushed stone mixed with coarse sand, under and around the shoe of each hydrant and to a level 6" above the top of the pipe lateral to allow for proper drainage.

6.5.4.4 Lateral Offsets - 6" ductile iron manufactured offsets may be used on the branch line to allow proper elevation settling of the hydrant shoe.

6.5.4.5 Details - All fire hydrant installations shall be in accordance with the Standard Details.

6.5.5 Anchorage - All plugs, valves, bends, reducers, tees, and fire hydrants shall be anchored by thrust blocks and rods and clamps in accordance with

Sections 4.2.9 and 4.2.10, and with the Standard Details.

6.6 Backfilling

6.6.1 General - All trenches shall be backfilled after pipe, fittings and appurtenances have been installed, inspected and approved by the Town Engineer. Bedding and "pipe zone" backfill shall be installed in accordance with Section 6.3.

Whenever a compaction requirement value is specified herein, the optimum moisture content and Standard Proctor Density shall be determined in accordance with AASHTO T-180 for 90% **and AASHTO T-99 for 95%.**

6.6.2 Density Requirements in Trench - The Contractor shall obtain a Standard Proctor Density of 90% for the total depth of all trenches in open fields and **95% in dedicated rights-of-way**. Backfilling shall be done with good sound earth, sand or gravel, and no oil cake, bituminous pavement, concrete, rock or other lumpy material shall be used in the backfill unless these materials are scattered and do not exceed 6" in any dimension and are not placed within one foot of the 2-1/2' limit. Material of perishable, spongy or otherwise improper nature shall not be used in backfilling and no material greater than 4" in any dimension shall be placed within 1' of any pipe, manhole or structure. Backfilling shall be accomplished in the zone in layers not to exceed 3'. All backfill material shall be subject to the approval of the Town Engineer.

6.6.3 Compacted Fill - Compaction shall be done by use of vibratory equipment, tamping rollers, pneumatic tire rollers or other mechanical tampers of the type and size approved by the Engineer. The backfill shall be placed in horizontal layers of such depths as are considered proper for the type of compacting equipment being used in relation to the backfill material being placed. Each layer shall be evenly spread, properly moistened and compacted to the specified density in Section 6.6.2. Any damage to the pipe as a result of Contractor's operation shall be repaired and/or replaced.

6.6.4 Consolidated Fill - Consolidated fill shall be performed by flooding, pooling or jetting so as to obtain a relative density of the fill material at least equal to that specified in Section 6.6.2. When flooding, pooling or jetting methods are used, material for use as backfill shall be placed and compacted in layers not exceeding 3' in thickness. Flooding, pooling or jetting methods shall be supplemented by the use of vibratory or other compaction equipment when necessary to obtain the required density. Care shall be taken in all consolidat-

ing operations to prevent the movement or floating of the pipe. In the event there is movement or floating, the Contractor shall re-excavate, relay and backfill all pipe so affected. Consolidation methods shall not be used when the backfill material is not sufficiently granular in nature to be self-draining during and after consolidation and foundation materials may be softened or otherwise damaged by applied water.

6.6.5 Procedure at Street Zone - The top 2-1/2' from finish street grade or ground surface, as the case may be, shall be compacted in horizontal layers not exceeding 8" in thickness, using approved hand pneumatic or mechanical type tampers to obtain a Standard Proctor Density of 95%. Flooding and jetting will not be permitted in this upper 2-1/2'. From existing street grade to 2-1/2' below street grade, the material for backfill may contain stones up to 2" in diameter, in quantity not exceeding 20% of the volume where said coarse materials are well distributed throughout the finer material and the specified compaction can be obtained.

6.7 Compaction Tests

When required by the Town Engineer, compaction tests will be taken by an approved testing laboratory at locations designated by the Town Engineer. All expenses involved in these tests will be borne by the Developer/Owner. Results of the tests will be made available to the Town Engineer immediately and copies of test results will be supplied to the Town Engineer once per week. In all cases where the tests indicate compaction less than that required in these specifications, additional compaction and tests will be required until these specifications are met. Probationary acceptance of the lines by the Town will be contingent upon satisfactory compaction results. No hydrostatic testing of the water main will be allowed until satisfactory compaction is obtained. Frequency of testing will be as follows:

- 1 test at every above ground appurtenance (i.e. valve box, manhole)
- 1 test every 200 LF of mainline trench with 50% of tests at subgrade elevation and 50% below grade
- 1 test at every water service

6.8 Final Clean Up

After backfill and compaction has been completed, the right-of-way shall be dressed smooth and left in a neat and presentable condition as close to final grade as possible and to the satisfaction of the Town Engineer.

6.9 Safety Precautions

All excavations shall be performed, protected and supported as required for safety and in the manner set forth in the operation rules, orders and regulations prescribed by the Occupational Safety and Health Administration Federal Register. Barriers shall be placed at each end of all excavations and at such places as may be necessary along excavations to warn all pedestrian and vehicular traffic of such excavations. Lights shall also be placed along excavations from sunset each day to sunrise of the next day until such excavation is entirely refilled.

TABLE 5-1
MAXIMUM PERMISSIBLE DEFLECTION
IN LAYING MECHANICAL-JOINT PIPE

	Maximum Permissible Deflection per Length - Inches				Approx. Radius of Curve Produced by Succession of Joints - Feet			
Size Of Pipe in Inches	**12-ft. Length**	**16-ft. Length**	**18-ft. Length**	**20-ft. Length**	**12-ft. Length**	**16-ft. Length**	**18-ft. Length**	**20-ft. Length**
3	16	22	25		110	145	160	
4	16	22	25		110	145	160	
6	14	19	21		125	170	190	
8	11	14	16		165	220	250	
10	11	14	16		165	220	250	275
12	11	14	16	18	165	220	250	275
14	7	10	11	12	240	320	360	400
16	7	10	11	12	240	320	360	400
18	6	8	9	10	290	380	430	480
20	6	8	9	10	290	380	430	480
24	5	6	7	8	360	480	540	600
30	5	6	7	8	360	480	540	600
36	4	5.5	6	7	430	575	650	720
42	4	5	5.5	6	460	610	690	765
48	4	5	5.5	6	460	610	690	765

TABLE 5-2
MAXIMUM PERMISSIBLE DEFLECTION
IN LAYING PUSH-ON JOINT PIPE DUCTILE IRON OR CAST IRON

	Maximum Permissible Deflection per Length - Inches				Approx. Radius of Curve Produced by Succession of Joints - Feet			
Size Of Pipe in Inches	12-ft. Length	16-ft. Length	18-ft. Length	20-ft. Length	12-ft. Length	16-ft. Length	18-ft. Length	20-ft. Length
3	10	13.5	15	17	175	230	260	290
4	10	13.5	15	17	175	230	260	290
6	10	13.5	15	17	175	230	260	290
8	10	13.5	15	17	175	230	260	290
10	10	13.5	15	17	175	230	260	290
12	10	13.5	15	17	175	230	260	290
14	6	8	9	10	290	380	430	480
16	6	8	9	10	290	380	430	480
18	6	8	9	10	290	380	430	480
20	6	8	9	10	290	380	430	480
24	6	8	9	10	290	380	430	480
30	4	5	6	7	430	575	650	700
36	4	5	6	7	430	575	650	700
42	4	5	6	7	430	575	650	700
48	4	5	6	7	430	575	650	700

7. PROTECTION OF WATER LINES NEAR SANITARY SEWER FACILITIES

7.1 Crossings

Water mains shall be located a minimum of 10 feet horizontally from existing or proposed sanitary sewer lines (centerline distance). Where water mains cross sewer services or sanitary sewers, they shall be above sewers and laid to provide a vertical clear distance of at least 18" between the bottom of the water main and the top of the sewer. When a new water main crosses an existing sewer at a point less than 18" above the sewer, the Town Engineer shall be notified and adjustments shall be made. Stability of the water and sewer lines at a point of crossing is critical and care must

be taken to ensure proper welding and compaction of both water and sewer lines.

Where it is not feasible to install a water main above an existing or proposed sewer, e.g., to maintain minimum cover, the water main shall be laid to provide a vertical clear distance of at least 18" between the bottom of the sewer and the top of the water main. When the clear distance is less than 18", the Town Engineer shall be notified. Refer to Sheet 29 of Appendix III for description of the proper materials and construction techniques.

7.2 Manholes

No water pipe or main shall pass through or, come within 10' horizontally of, any part of a sewer or sewer manhole.

8. INSPECTION AND TESTS

8.1 Pipe Testing Prior to Construction

Before being used in any work under these specifications, and when directed by the Town Engineer, pipe shall be subjected to and shall meet the requirements for testing pipe as established by the American Water Works Association in Specifications C-100, C-200, C-300, C-400 and C-900, depending on the type of pipe. These tests shall be made by the Contractor and shall be witnessed by a reputable testing laboratory. **The Contractor shall deliver the pipe selected for testing to the place and at the time designated by the testing laboratory.** Written test reports will be furnished to the Town Engineer upon request.

The testing laboratory shall select at random for testing as herein specified up to 2% of the number of pipe in each size of pipe furnished, except that in no case shall less than five (5) specimens be tested.

The specimens selected for testing purposes shall be sound pipe having dimensions consistent with the referenced specifications. The lot or lots from which the test samples are taken shall be sufficient to fill the entire order for that size of pipe used in the work under the contract if they pass the tests, shall be so designated and marked.

All pipe shall be subject to inspection at the factory, trench or other point of delivery by the Town Engineer. The purpose of the inspection shall be to cull and reject any pipe that, independent of the physical tests herein specified, fails to conform to the requirements of the referenced specifications, or that may have been damaged during transportation and/or in subsequent handling.

The Town Engineer reserves the right to reject any and all pipe sections that may contain visual imperfections or imperfections of any type that may be considered by the Town Engineer to be detrimental to the operation and life of the pipe.

8.2 Pipeline Testing After Installation

8.2.1 Chlorination - All mains, extensions and private pipe shall be chlorinated in accordance with AWWA C-601, "Disinfecting Water Mains" and the local health authority having jurisdiction prior to the lines being accepted.

The chlorination of the finished pipelines shall be done prior to the hydrostatic testing.

8.2.1.1 Material - Chlorine tablets may be used for disinfection in twelve-inch (12") and smaller. For pipes having a larger diameter, a chlorine slurry is fed into the water filling the pipe. If chlorine tablets are used, they shall be attached to the inside top of the pipe with "Red" permatex just prior to the pipe installation. Hypochlorite may be used and shall conform to Federal specification O-C-114, Type II, Grade B.

8.2.1.2 Method - Flushing and sterilization of lines shall be accomplished in accordance with the requirements of the Colorado State Board of Health. Chlorine dosage shall be at least 50 parts per million, and shall be retained in the line at least 24 hours, after which time the residual at the end of the line and at other representative points in the line shall be at least 10 parts per million. If the residual at the end of 24 hours is less than 10 parts per million, the entire operation shall be repeated.

All valves in the lines being sterilized shall be opened and closed several times during the contact period. After completion of sterilization, the system shall be flushed with clean water until the residual chlorine content is not greater than 1 part per million.

8.2.2 Hydrostatic Pressure Test

8.2.2.1 The hydrostatic test pressure for any type of pipe shall be 150 pounds per square inch based on the elevation of the lowest point in the line of section under test and carried to the elevation of the test gage. All sections of newly laid pipe, subsequent to backfilling, shall be subjected to the hydrostatic pressure test.

The duration of the hydrostatic pressure test shall be at least one (1) hour.

8.2.2.2 Air Removal Before Test - Before applying the specified test pressure, all air shall be expelled from the pipe. If permanent air vents are not located at all high points, the Contractor shall install corporation cocks at such points as the air can be expelled as the line is filling with water. After all the air has been expelled, the corporation cocks shall be closed and test pressure applied. Any cracked or defective pipe, fittings, valves or hydrants discovered in sequence of this pressure test shall be removed and replaced by the Contractor with sound materials in the manner provided under Section 6 of this specification, and the test shall be repeated until results satisfactory to the Town Engineer are obtained.

8.2.2.3 Procedure - Each valved section of pipe shall be slowly filled with water and the specified test pressure shall be applied by means of a pump connected to the pipe in a manner satisfactory to the Town Engineer. The pump, pipe connection, gauges and all other necessary equipment and personnel to complete the test, shall be furnished by the Contractor and shall be approved by the Town Engineer. All corporation cocks and taps to the main line and all connection piping and valves that may be required to make the test, whether or not specified or shown on the construction drawings, shall be installed by the Contractor. The Town will furnish only the calibrated meter.

While the test pressure is maintained, the new pipe will be inspected and any leaks will be repaired. After all leakage has stopped, the pressure of 150 psi shall be maintained for one (1) hour. Allowable leakage for each section between line valves shall not exceed the following values:

Allowable Leakage per 1000 Ft/Pipe Gallons/Hr.		
Inside Diameter	**D.I.**	**PVC**
4	0.37	0.33
6	0.55	0.50
8	0.74	0.66
12	1.10	1.00
16	1.47	----
20	1.84	----

Should the leakage rate be greater than the above set rates, the pipeline shall not be accepted. The pipeline shall be repaired, rechlorinated as described in 8.2.1 and retested.

The Contractor shall ensure that a satisfactory test is completed and shall employ all methods necessary to pass the test, including disconnection from existing watermains and use of a temporary plug, if necessary.

8.2.3 Test Results

The Contractor will be responsible for arranging testing by the appropriate State and/or County Health Department and for presenting certified test results to the Town Engineer prior to acceptance of the lines.

9. RESPONSIBILITY OF THE CONTRACTOR

The Contractor shall be responsible for notifying the Town at least 48 hours prior to start of any construction. If work is suspended for any period of time after initial start-up, the Contractor must notify the Town 48 hours prior to re-start.

At all points of connection of new water mains to existing mains, the Contractor will be responsible for excavating and verifying location of the existing lines, prior to installation of any new construction. If it is necessary to shut down any portions of the existing water system to make such connection, the Contractor will be responsible for notifying all Town customers to be affected by water outage at least 48 hours prior to such outage. All existing water main valves shall be operated only by the Town Engineer. The duration of water outage to the existing Town customers shall be minimized and if directed by the Town

Engineer, the Contractor shall provide temporary water supply to customers by means of tank trucks, temporary connections to charged facilities, etc.

The CONTRACTOR is responsible also for maintaining **As-Recorded** drawings to include all distances between fittings, valves, locations of service tees, all changes, and all important notes. These drawings will be turned over to the Town Engineer and final acceptance of the line by the Town will be contingent upon receipt of formal **As-Recorded** drawings in 24" x 36" size (scale 1" = 100') and submitted in reproducible and print form. Once the construction has been completed and all tests performed and the mains deemed operational by the Town, a walk-through inspection will be performed. Once all corrections to the system are made and approved, the Town will issue a probationary acceptance of the system. Final Acceptance will be issued as outlined in the Rules and Regulations of the Town.

The CONTRACTOR will be held responsible for the proper functioning of the lines for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any malfunction during this period of guarantee shall be remedied by the CONTRACTOR to the satisfaction of the Town Engineer and at no expense to the Town.

10. SERVICE LINES AND APPURTENANCES

10.1 General

Water is conveyed from mains to the plumbing of licensed premises by service lines and their appurtenances. In the context of these Standards, service lines include all pipe and fittings up to the point of entry into a residence as shown in the Standard Details. All water pipe beyond service pipe shall be controlled by the local plumbing codes.

All new or replacement service lines and appurtenant fittings installed in areas being supplied with potable water from the Town shall conform to the following minimum standards which shall be binding regardless of the regulations of any other agency covering like installations.

The corporation stop, the meter, and that portion of the service pipe between the meter and the corporation stop shall all be of the same size.

10.2 Ownership and Maintenance

These water system specifications are intended to be supplemental and subordinate to the Operating Rules of the Town and will be so construed in any conflicting situations.

10.2.1 Ownership - The service pipe and fittings through which a licensee

receives water service from the facilities of the Town shall be owned and installed at the expense of the licensee.

10.2.2 Maintenance - The owner shall maintain all privately owned piping except as set forth under the referenced Operating Rules. This shall include the service pipe and all fittings and fixtures, except the water meter.

The curb stop service box and meter pit shall be kept conveniently accessible, in good working order, and properly capped and clean of debris. Any box or pit not conforming to these standards shall be cleaned, repaired or relocated by the owner of the premises within a reasonable time after notification by the Town. Failure by the owner to comply may cause the Town to do the necessary maintenance work and charge the cost thereof to the premises served.

10.2.3 Frozen Service Pipes and Stub-In Connections The Town will not be responsible for the thawing of frozen service pipe or appurtenances or repair to stub-in connections installed to permit street paving.

10.3 Service Lines

10.3.1 General - Service lines shall be of the size which is adequate to supply the requirements of the property being served. The minimum size line shall be 3/4 inch. The only acceptable materials for a service line are seamless copper tube and ductile iron pipe. Service lines shall be of the same type material from beginning to end, unless the appropriate insulator is installed at the junctions of the dissimilar metals.

10.3.2 Layout and Location - Water service shall be located a minimum of ten feet (10') horizontally from the sewer service. Service lines shall be installed in a continuous straight line and shall enter the property a minimum distance of five feet (5') from the nearest lot corner.

The main to be tapped must extend a minimum distance of eight feet (8') along the front lot line of the property to be served and the service line connection and service must be a minimum distance of five feet (5') into the lot.

In the case of corner lots, the property may be served from the side lot line under the same regulations as above.

If service is requested for lots at the end of a cul-de-sac street, the main to be tapped must be not more than fifty feet (50') from any property line in

the cul-de-sac. The service pipe shall be in a continuous straight line and shall enter the property a minimum distance of five feet (5') from the nearest lot corner.

No water taps will be made prior to hydrostatic testing and acceptance of the water mains by the Town and all service line installations shall be in accordance with AWWA Standard C-800 and these specifications.

10.3.3 Depth - All service pipes shall be installed at least four and one-half feet (4-1/2') below the official street grade and in all other places at least four and one-half feet (4-1/2') below the surface of the ground. If, in the judgment of the Town, the topography of the area indicates the advisability thereof, the service pipe shall be installed at lower depths.

If, after a service pipe has been installed, the grade of the surface of the ground is lowered, the property owner shall have a licensed and bonded plumber lower or relocate his service pipe so as to maintain a minimum cover of four and one-half feet (4-1/2').

10.3.4 Compaction - Prior to any backfilling, the service line and all of its appurtenances from the tap to the dwelling shall be inspected and approved by a representative of the Town. Once approved for backfilling and compaction, the backfill material shall be carefully compacted as specified in Sections 6.6 and 6.7 of these specifications.

10.3.5 Separate Trenches - Service pipes may not be installed in trenches containing conduits which carry any substance other than potable water, and a service line shall be separated laterally from foreign conduits by a minimum of ten feet (10').

EXCEPTION: A SERVICE PIPE MAY BE PLACED IN THE SAME TRENCH WITH OTHER PIPE PROVIDED THE FOLLOWING CONDITIONS ARE MET:

1. The foreign pipe shall be ductile iron.

2. The bottom of the service pipe shall be at least twelve inches (12") above the top of the foreign pipe and shall be placed on a shelf excavated on one side of the common trench.

10.3.6 Combination Service Pipes - A property requiring a domestic service line and a fire protection service line may be served from a single tap in some cases. The fire protection service line shall extend straight from the main

to the property line and shall have a gate valve located two feet (2') minimum from the property line on the street side of the property line. A tee shall be placed on the fire protection service line on the inlet side of the gate valve for the domestic service line. A domestic service tee may not be placed on an existing fire line.

10.3.6.1 Connections to Mains for Fire Sprinkler Lines Sprinkler heads found in department stores, warehouses, etc., are supplied by a fire line. The fire line shall be sized by the local fire department and the persons responsible for the structure it protects. The Town will not size fire lines.

The fire line shall be rodded cast iron or ductile iron pipe. The fire line shall have a valve two feet (2') from the property line on the street side of the property line as shown on Sheet 30 of the Standard Details. The fire line connection may also serve as a domestic service line if the domestic tee is installed at the same location as the fire line.

10.3.7 Pipe Size - Service lines shall be of a size which is adequate to supply the requirements of the property being served. The minimum size allowable for a service line shall be three-quarter inch (3/4").

Adequate size for a service line shall be defined in terms of head loss as follows: The combined pressure drop in the service line and meter between the main and the building shall not exceed 25 p.s.i. at peak demand.

The requirements of the property being served shall be defined as peak demand, as calculated in the AWWA Manual of Water Supply Practices, entitled "Sizing Water Service Lines and Meters," Chapter 4, Page 33, Procedure for Estimating Consumer Demand.

10.3.8 Type of Pipe - All service pipes supplying water from the Town's system shall conform to one of the following specifications. Plastic pipe is not an acceptable service pipe material.

1. Seamless Copper Tube of the type designated as "Type K" (soft) **with insulator** in the industry shall be used for service lines 3/4 inch through three inches (3"). Service lines must be silver soldered. No compression fittings are allowed.

2. Ductile Pipe conforming to the Materials Specification as

outlined in Section 3.2 of these specifications may be used for all service lines larger than three inches (3").

10.3.9 Type of Service Line Material

1. All tapping saddles must be double-strap bronze type.
2. Corporation stops must have AWWA taper CC threads.
3. Curb stops must be Mueller or Ford.
4. Service stop boxes must be Tyler Type 94-E.

10.3.10 Installation

1. No more than one (1) flared coupling on service line at pigtail.
2. Pigtail to house is to be one (1) continuous pipe.
3. Service line must have back flow protection.
4. Lines will be pressure tested before backfilling trench.
5. All service lines will be installed with wire-impregnated red marking tape buried above the pipe 12" maximum below finished grade.

10.4 Pumps

Except where specifically authorized by the Town, the installation of pumps designed to increase water pressure in service lines is prohibited.

10.5 Connections for Water

All connections shall be made in view of a representative of the Town and by a licensed contractor acceptable to the Town.

Connections will be made only after the release of the mains by the Town following installation, submittal of the health release to the Town, payment of appropriate fees, completion of the tap application papers, and installation of the service pipe from main to curb stop by a bonded plumber. Any excavation necessary for tapping shall be completed prior to the arrival of the Town representative.
Connections two inches (2") and smaller shall be made by a corporation stop, where applicable, of the same size as the service line and meter to be installed. Connections

to the main for service pipes larger than two inches (2") shall be by a tee connection.

Connections to all ferrous mains shall be electrically insulated by means of a Town approved insulating fitting. Care shall be taken to properly install corporation stops and to provide enough slack in service lines to protect against pullout problems.

Machined-over-all (MOA) polyvinyl chloride pipe may receive a corporation stop.

In tapping mains it may be necessary to dig out bedding material and to cut or remove part of the polyethylene wrapping. After the taps are made, the polyethylene wrap shall be repaired or replaced by the plumber in such a manner as to protect both the pipe and corporation stop. The polyethylene wrap shall prevent contact between the pipe and corporation stop and backfill. Any bedding material removed during excavation shall be replaced in kind and compacted to the specifications contained herein.

10.6 Taps and Saddles

The size of tap and the tapping method for a given type and size of water line shall be as follows:

Table 5-3
Type of Pipe and Size of Tap

Size of Pipe	**Ductile Iron**				**PVC**			
¾”	1"	1½”	2"	¾”	1"	1½”	2"	
3"	NO	NO	NO	NO	NO	NO	NO	NO
4"	S	S	NO	NO	S	S	NO	NO
6"	DT	S	S	S	DT	S	S	S
8"	DT	DT	S	S	DT	DT	S	S
12"	DT	DT	S	S	DT	DT	S	S
16"	DT	DT	S	S	--	--	--	--
20"	DT	DT	S	S	--	--	--	--

“S” - Tapping saddle required - all saddles shall have the A.W.W.A. Taper on its threads.
“DT” - Direct tap permitted.
“NO” - No tap permitted with or without a saddle. A tee connection may be permitted if specifically authorized by the Water Department.

Tapping saddles with tap size two inches (2") and smaller for the ductile iron pipe shall consist of a bronze body with two (2) bronze straps. Saddles for PVC shall be "full support, wide bearing" type.

Existing steel mains twelve inches (12") in diameter or less, shall be tapped using an approved tapping saddle. Service taps are not allowed on twenty-four inch (24") and larger pipe.

See Section MS-23 of the Material Specifications for further information on tapping saddles.

10.7 Meter

All meters installed for billing purposes shall be under the control of the Town and shall conform to these specifications. No meter shall be installed until the proposed installation has been approved, and the meter tested and numbered by the Town.

Meters used to record usage by the retail consumer are called service meters. Meters used by wholesale customers and which supply water to other service meters are known as master meters. Other temporary meters may exist in the system for the purpose of Town testing.

The characteristics which are of special importance in meters are accuracy and sensitivity, durability, low pressure loss, cost at purchase and installation, and ease and low cost of maintenance.

All meter installation shall be inspected by a Town representative upon completion of the installation, prior to backfilling. Installations which do not comply with these Town Specifications shall be made to conform prior to acceptance by the Town.

10.7.1 Size of Meter - Meters shall be of the same size as the corporation stop and that portion of the service pipe between the meter and the corporation stop. In no case shall a meter smaller than 3/4-inch be installed, except as a replacement for an existing smaller meter.

The Town may allow the installation of a meter of a size smaller than the service pipe in cases where the full capacity of a previously used service pipe is not required provided that the service pipe is reduced to the size of the meter for a distance of not less than ten (10) times the larger pipe diameter on the inlet or supply side of the meter.

10.7.2 Type of Meter - The type of meter installed will be determined by the

ENGINEER at the time of application based upon size, service requirements, location of meter and other conditions which may exist.

10.7.3 Magnetic Drive Displacement Type Water Meters - The displacement meters, known as nutating-disc or oscillating piston meters, are positive in action in that the pistons and discs displace or carry over a fixed quantity of water for each nutation or oscillation when operated under positive pressure. The magnetic drive displacement type water meter shall be either frost-proof case or split case.

Where there is a possibility of freezing, a frost-proof case or housing shall be used. The upper housing for cold climates includes all but the bottom plate. This is bolted on so that should the contents freeze, the bottom plate, or washers or bolts holding it on, will break before the meter as a whole is damaged. The bottom or the bolts can be replaced readily.

Meter sizes through 1 inch to be installed in outside pits or vaults shall conform to the Materials Specification, Section MS-15 of the Denver Water Department Engineering Standards, latest revision.

In warm climates or for indoor meters, the bottom part includes the pipe connections and part of the side of the meter housing and is known as a split case.

Meter sizes 5/8-inch through 1-inch to be installed inside a building and all 1 1/2-inch and 2-inch displacement type meters shall conform to the Materials Specifications, Section MS-15 of the Denver Water Department Engineering Standards, latest revision. Meter sizes 1 1/2-inch and larger shall be brass, two (2) hole, oval flange construction and shall not be slotted. Companion flanges shall be brass.

10.7.4 Compound Meters - Generally, compound meters consist of two meters, one to measure small flows and the other to measure large flows. The two meters are assembled either in one case or, especially for larger flows, in separate cases coupled together. Compound meters are so designed that the small meter operates during low flows and as flows begin to increase, the large meter takes over. When the large meter is in operation, the small meter may or may not be in operation.

Meters in sizes 3 inches through 6 inches, regardless of the type of installation, shall be compound type meters conforming to the Materials Specifications, Section MS-16, of the Denver Water Department Engineering Standards, latest revision.

10.7.5 Outside Meter Settings - Outside meters shall only be allowed by special permission from the Town and shall be installed in a horizontal position and housed in a concrete manhole or vault, and shall conform to the Standard Details.

10.7.6 Inside Meter Setting and Remote Readers - All inside meter settings shall be installed in manner which will allow free access and adequate room for inspection and maintenance and will protect the meter from freezing. Meter sizes 3/4-inch and 1-inch installed inside of buildings shall be approximately forty inches (40") above the floor level, and not more than eighteen inches (18") from the wall through which the service pipe enters the building. Meter sizes 1 1/2-inch and 2-inch installed inside buildings shall comply with the Standard Details.

Inside meter settings will not be allowed in crawl spaces, closets or other places where free and easy access is not provided. Inside settings in partial basements shall comply with the Standard Details, Appendix III, and all other applicable requirements. Meter sizes 1 1/2-inch and 2-inch installed inside buildings shall be provided with a floor drain.

10.7.7 Meter Bypass Lines - A bypass line shall be required for all meters 4-inch and larger unless otherwise specified by the Town, whether installed in an outside or inside setting. Bypass lines shall contain an independent control valve and shall contain no tees, plugs, or other outlets through which water could be withdrawn. Bypass lines permit the consumer to have water while his meter is being repaired or replaced. No bypass lines will be installed for meters 3" and smaller.

10.7.8 Meter Check Valves - Double check valves will be required for all meters 1 1/2-inch and larger unless otherwise specified by the Town, whether installed in an inside or outside setting. Double check valves shall be required on meters smaller than 1 1/2-inch to prevent backflow of water from the property to the main.

10.7.9 Valves For Use With Meters - Gate valves 3-inch and smaller to be used with copper service pipe shall be all bronze, with non-rising stems and solid wedge disc, manufactured in accordance with ASTM Specification B 62-76 and Federal Specification W.W.-V-54 Class A 125 psi W.S.P., 200 psi, W.O.G.

Valves for 1 1/2-inch and 2-inch meters shall be curb stops as shown on the Standard Details.

Valves three inches (3") and larger for use with ductile iron service pipe shall be gate valves with cast iron bodies conforming to the Materials Specifications, Section MS-4A, of the Denver Water Department Engineering Standards, latest revision. All gate valves larger than three inches (3") shall be supported by adjustable steel valve supports.

10.7.10 Meter Couplings - All meters 1 1/2-inches and larger shall be installed with a coupling to allow removal of the meter without disturbing the pipe. Couplings shall conform to the Materials Specifications, Section MS-23, of the Denver Water Department Engineering Standards, latest revision.

10.7.11 Meter Yokes (Line Setters) - A yoke is a metal pipe frame attached to the inlet and outlet sides of the meter providing support, and conveying water to the meter. Meter yokes shall conform to the Materials Specifications, MS-22, of the Denver Water Department Engineering Standards, latest revision.

To assure safety, the water meter setting shall provide a continuous, electrically conductive, path around the water meter. If a bonding jumper is required, it shall be made of copper with fittings suitable for the bonding jumper and the water pipe material. The meter setting installation shall be in compliance with the National Electric Code, Articles 100, 250-81, 250-94, 250-112 and 250-115(a).

10.7.12 Valve and Meter Supports - Meter supports shall be a solid concrete block as shown in the Standard Drawings.

Fabricated metal supports shall be used to support valves four-inches (4") and larger.

10.7.13 Residential Meter Pits and Covers - Meter pits shall consist of four twelve-inch (12") precast concrete rings or one twelve-inch (12") ring and one thirty-six inch (36") ring. The rings shall have a two-inch (2") wall thickness. Meter pit covers shall be airtight with a double cover. The meter pit cover shall have a cast iron, cap type, top lid. The inner lid shall be cast iron, aluminum or rubber. The body of the meter pit cover shall be cast iron or aluminum. Aluminum shall have a polymer coating such as an epoxy.

10.8 Backflow and Backflow Prevention Devices

Backflow, which is the flow of water, or other liquid, or foreign materials into the

distribution mains of the Town's system from another source is strictly prohibited and shall be prevented by the installation of an appropriate, approved backflow prevention device, purchased and installed by the consumer at his own expense.

The type and complexity of the backflow prevention device shall be determined by the Town in accordance with the "Manual of Cross-Connection Control for the Colorado Department of Health," and shall be based upon the degree of hazard caused to the public from contamination by toxic, or non-toxic substances.

A toxic substance is any solid, liquid, or gas which, when introduced into the water supply system, creates a danger to the health and well being of the consumer.

A non-toxic substance is any solid, liquid, or gas of a non-poisonous nature that is potable or edible, and that creates a moderate or minor hazard to the domestic water system. Examples are connections of food processing lines such as syrups, lard, beer, etc., or connections to steam and steam boilers where the steam does not come into contact with poisonous materials.

Devices vary as to function, and may be air gap type, reduced pressure backflow preventive type, pressure vacuum breaker, atmospheric vacuum break, or double check valve type. Backflow prevention devices are characterized by great care in construction details, the use of materials that will give the least possible wear or corrosion, and ready accessibility for inspection and cleaning.

VI. SANITARY SEWER SYSTEM CRITERIA AND SPECIFICATIONS

1. PURPOSE AND GENERAL REQUIREMENTS

1.1 Purpose

This publication is to provide information to all Engineers, Contractors, Builders, Developers and other interested persons or firms, on the Town requirements with respect to design and construction of sanitary sewer systems within the Town. This publication presents technical specifications for the design and installation of the sanitary sewers and should be used in conjunction with the Town Rules and Regulations by any firm or individual planning to design or construct sanitary sewer systems within the Town. In all cases in these specifications where reference is made to "Town Engineer" or "Engineer" shall mean any representative of the consulting engineering firm or other individual designated by the Town to provide inspection of the sewer system construction.

1.2 General Requirements

1.2.1 All contractors must notify the Town at least 48 hours prior to start of construction.

1.2.2 A pre-construction meeting must be arranged by the CONTRACTOR and held prior to the start of any work. The Town Engineer, CONTRACTOR, and OWNER or Owner's Engineer must be represented at this meeting, which shall be held either on the construction site or at the office of the Town Engineer.

1.2.3 Approved plans must be kept on the job site by the CONTRACTOR at all times.

1.2.4 All work shall comply with Acceptable Industry Standards.

1.2.5 Sanitary sewer lines are to be a minimum distance of 5.0' from lip of gutter pan.

1.2.6 Squeegee bedding material shall be used. On-site material will not be acceptable unless approved by the Town Engineer.

1.2.7 Only dry pit lift stations with adequate wet wells and non-submersible pumps will be allowed for installation within the Town.

1.2.8 Underdrains are not allowed to be placed within public rights-of-way.

2. LOCATION OF LINES

2.1 Sewers in Streets and Alleys

When the sewers are placed in streets and alleys, they shall be constructed as follows:

2.1.1 On streets and alleys running north and south, the sewer line shall be placed 5' west of the centerline of the street.

2.1.2 On streets and alleys running east and west, the sewer line shall be placed 5' south of the centerline of the street.

2.1.3 On streets shaped as a "U" or on streets having unusually sharp turns, the sewer line will conform to the above specification as near as practical, but the final location shall be as determined by the Town Engineer or his representatives. Curve sewer mains shall not be allowed without prior approval of the Town Engineer. Design must attempt to minimize the use of manholes.

2.2 Sewers in Easements

In areas where sewer lines are placed in easements, all sewer lines shall be located within the easements shown on the Contract Drawings. All sewer easements must be a minimum of 20' (Twenty Feet) in width, and must be prepared in accordance with the Town Rules and Regulations. Sewers shall be located a minimum of 5' from the edge of the easement. Town Engineer reserves the right to require additional easement and/or more than 5' to the edge of the easement, depending on the depth of the sewer.

2.2.1 Markers

In areas where sewer lines are placed in easements, all manholes and force main valves shall be identified with a 4" steel marker post, offset as directed by the Town Engineer and painted yellow, with the distance to the manhole or valve and the appropriate identifying initials stenciled in black.

3. PIPE

3.1 General

No public sewer main shall be less than eight inches (8") in diameter. Private sewer services may be 4 or 6 inches in diameter. No sewer line shall be less than 4 inches in diameter. The minimum and maximum slopes for sewer lines shall be as shown in

Table 6-1 below. The slope between manholes must be uniform.

TABLE 6-1		
Size of Sewer (Inches)	**Minimum Slope Feet Per Hundred**	**Maximum Slope Feet Per Hundred**
4	2.0	25
6	0.5	20
8	0.4	15
10	0.28	12
12	0.20	11
15	0.15	8.5
18	0.12	6.5
21	0.092	5.0
24	0.08	4.5
27	0.065	3.5
30	0.06	3.2

3.2 Concrete Pipe

Concrete pipe shall be specified by pipe diameter, class or strength, the methods of jointing and any special lining or concrete requirements such as the method of manufacture. The pipe should conform, insofar as appropriate, to the following standard specifications. All concrete pipe shall be epoxy-lined, shall be manufactured with calcareous aggregates and shall be used only with prior approval of the Town Engineer. In general, however, concrete pipe shall not be allowed for sanitary sewer mains.

3.2.1 Non-Reinforced Concrete Pipe - All non-reinforced concrete pipe from 4" to 24" diameter shall be manufactured in strict accordance with "Concrete Sewer, Storm Drain and Culvert Pipe," ASTM C14 or C76 and "Pipe, Concrete (Non-reinforced, Sewer)", Federal Specification SS-P-371c and as modified herein.

3.2.2 Reinforced Concrete Pipe - All reinforced concrete pipe shall be manufactured in strict accordance with "Reinforced Concrete Culvert, Storm Drain and Sewer Pipe," ASTM C76 and "Pipe, Concrete (Reinforced, Sewer)," Federal Specification SS-P-375b and as modified herein.

3.2.3 Joint Material - All joint material shall be manufactured in strict accordance with "Joints for Circular Concrete Sewer and Culvert Pipe,

Using Flexible, Watertight, Rubber Gaskets," ASTM C443.

3.2.4 Physical Properties - Crushing strength requirements for non-reinforced and reinforced concrete pipe and fittings shall equal or exceed the minimum strength, as set forth in ASTM C14-70 (or latest revision thereof) when tested for "Three Edge Bearing" in accordance with ASTM C497-70A (or latest revision thereof) or "Determining Physical Properties of Concrete Pipe and Tile," ASTM C497.

3.2.5 Identification Markings - In addition to any special markings specified in the Contract or order, marking for shipment shall be in accordance with Federal Standard No. 123.

3.2.6 Pipe Lining - All concrete pipe used for sanitary sewers, either reinforced or non-reinforced, shall have an interior PVC lining or a protective epoxy coating to preserve the pipe from corrosive condition. Coatings shall cover the entire internal circumference of the pipe; the method and application shall be approved by the ENGINEER prior to acceptance.

3.3 Plastic Pipe

3.3.1 General - All Polyvinyl Chloride (PVC) Sewer Pipe and Fittings shall be in accordance with ASTM D-3034.

3.3.2 Material - All Polyvinyl Chloride shall meet the requirements for ASTM D-3034, "Standard Specification for Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings."

3.3.3 Test - CONTRACTOR shall submit certified copies of all reports of tests conducted by an independent laboratory before installation of PVC Plastic Pipe. The tests shall conform to the following tests and Standards: The Quick Burst Test, ASTM D-1599, the Flattening Test, Extrusion Test ASTM D-2152, and Pipe Impact Test ASTM D-2444.

3.3.4 Straightness - Maximum allowable ordinate as measured from the concave side of the pipe shall not exceed 1/16" per foot of length. Pipe lengths shall be limited to 20 foot maximum to insure compliance with this requirement.

3.3.5 Joint Type - The pipe joints shall be bell and spigot type with an elastomeric gasket conforming to ASTM D-3212 and F-477. Solvent welded joints are not acceptable.

3.3.6 Pipe Diameter - The pipe diameters shall be per Denver Wastewater Department's specifications.

3.3.7 Fittings and Specials - The fittings and specials shall be in accordance with ASTM D-3034.

3.3.8 Pipe Installation and Field Testing - Pipe shall be installed in full compliance with the recommended practice for "Underground Installation of Flexible Thermoplastic Sewer Pipe," ASTM Designation D-2321. Specifically, the bedding shall be Class "B" as shown in Section 13, Standard Details. The bedding trench shall be brought to proper grade and elevation prior to installation of pipe and assembly joints. The pipe shall be placed and joints made in a dry trench and bedding shall be placed in the trench up to one-half the diameter of the pipe (haunch) without lifting or laterally mis-aligning the pipe.

In addition to the construction and testing procedures outlined in other sections of these specifications, the CONTRACTOR shall be required to install the pipe in such a manner so that the maximum ring deflection of the pipeline under load shall be limited to 5% of the vertical internal pipe diameter. The Town reserves the right to request deflectometer tests to assure that the pipe meets this requirement. Equipment used in the tests shall be direct reading, producing an immediate, continuous record of pipe deflection and shall consist of the following units: a non-rotating sensing element, a remote readout instrument and a strip chart recorder providing a permanent record of the measurements. The Town Engineer shall determine the footage to be tested but in no case shall the test section be less than 400 feet or between manholes, whichever is less. Testing shall be performed at the expense of the OWNER or Developer. All pipe exceeding 5% deflection shall be considered to have reached the limit of its service-ability and shall be relaid or replaced prior to final acceptance at the expense of the CONTRACTOR.

Infiltration-exfiltration tests shall be conducted as detailed in Section 10, Tests and Inspections, of these specifications.

3.4 Cast Iron Pipe

Cast iron pipe shall be used in all areas designated by the Town Engineer and as indicated in these specifications.

3.4.1 Material - Cast iron pipe shall be bell and spigot soil pipe, centrifugally cast and shall conform to Federal Specification WW-P-421 and AWWA Specification C-106. Class of pipe shall be as shown in Table 6-2.

TABLE 6-2	
Size	**Class**
3" to 12"	22
14" to 24"	21

3.4.2 Joints - All cast iron pipe joints shall be made using elastomeric rubber gaskets. Where cast iron pipe is jointed to a pipe of another material, an approved collar or coupling utilizing a rubber seal shall be used. All couplings shall be encased in a concrete collar in accordance with the details in Appendix IV.

4. MANHOLES

4.1 General

All manholes shall be a minimum of 48" in diameter and shall be installed at the end of each sewer line, at all changes in grade, size or alignment and at all intersections. Manholes shall be installed at distances not greater than 400' for sewers 15" inside diameter and less, and 500' for sewers 18" to 30" inside diameter. Longer spacing may be permitted, with prior approval of the Town Engineer, in sewer lines of larger diameter. All manholes in excess of 20' in depth, measured from cover to invert, shall have an intermediate platform located at the center of the depth, in accordance with the details in Appendix IV.

4.2 Standard Manholes

Manholes may be either precast concrete or poured-in-place concrete. All concrete shall be mixed using Type II cement. For poured-in-place manholes, design details and analysis, along with construction procedure, must be submitted to and approved by the Town Engineer prior to start of construction. All manholes shall have an inside diameter at least 2' greater than the outside diameter of the sewer pipes entering/leaving the manhole. In no case shall any manhole have an inside diameter less than 4'. Where a second sanitary sewer line enters a manhole, the invert on the second sewer line shall enter the manhole at least 0.2' higher than the invert of the main sewer line and shall enter the line of flow of the main sewer line with as near a full sweep 90 degree bend as possible. In no case shall a second line be allowed to intersect with this main line at an angle less than 90 degrees, with the outlet portion of the main line. If alignment and slope allow, the sewer main should be laid through the manhole. A drop of 0.1' will be required from invert to outlet where the sewer main cannot be laid through the manhole. A drop of 0.2' shall be required on all

angle manholes. All manholes subject to turbulent flows shall be epoxy-coated (E.G. outside/inside drops, interceptors, outfalls, and 90° manholes).

4.2.1 Base - The base on all manholes shall be a minimum of 8" thick, and the overall outside dimensions shall be one (1') foot greater than the outside dimensions of the manhole constructed thereon. The base shall be constructed of premixed concrete composed of a mix of well-graded, well washed, calcareous aggregate ranging from sand to gravel one and one-half (1-1/2") inches in maximum diameter. The mix shall contain six (6) sacks of Type II cement to the cubic yard and only enough water shall be used in the mix to give it a slump test of 2". Air entrained in the mix when placed shall be between 3% and 5%. Cylinders taken from the mix shall in 28 days have not less than 3,000 pounds crushing strength per square inch. Base reinforced steel or wire mesh shall be in accordance with the details in Section 13. The CONTRACTOR shall be responsible for taking and testing cylinders as required by the Town Engineer.

4.2.2 Concrete Manholes - Concrete manholes shall be constructed of precast concrete rings composed of concrete meeting ASTM C33-54T, or latest revision thereof. Cement used shall meet ASTM C150. The concrete mix shall be made with Type II cement with a cement factor of six (6) sacks per cubic yard. The coarse aggregate shall be no less than 40% of the combined mix. The minimum core strength in 28 days shall be 4,500 psi. Concrete manholes shall consist of one or more concentric rings according to the depth of the manhole. The top cone shall be eccentric and shall be approximately one (1') foot below finished grade on the street in order that the manhole level can be brought to the finished grade with concrete grade rings by the CONTRACTOR when final grade on the street is established.

Aluminum or plastic steps shall be firmly embedded in the walls of all manholes. They shall be placed in a straight line 12" O.C. vertical on the straight side of the manhole. Steps must be positioned to allow no more than 18" spacing from the rim to the first step, and 12" spacing thereafter. Steps shall conform to the details shown in Appendix IV. Manhole covers shall be of close-grained gray iron semi-steel in the solid cover of a design conforming to the details shown in Appendix IV. They shall be equal to the City of Denver Standard Traffic Pattern and weigh approximately 400 pounds. Covers shall be solid, and shall be machined so that they will not rock under traffic. Aluminum manhole rings and covers shall generally not be allowed. Any requirement to use aluminum rings and covers must be submitted to and approved by the Town Engineer prior to start of this work. If aluminum manhole rings and covers are allowed, they must be

bolted down.

Manhole rims shall be positioned 1/4 inch below finished pavement grade or 4 inches below gravel surface.

Where manholes must be raised up to finished street grade, no more than 12" of rings shall be used. If greater than twelve inches (12") is necessary to bring the manhole to finished grade, additional barrel sections should be added. All manhole rings shall be embedded in bituminous mastic (Ram-Neck or equal) and shall be watertight. Mortar mixed with Type II cement shall be used on the inside of ring joints. The word "Sewer" shall be boldly cast in a readily visible location on the cover. The bench shall slope at 2" per foot toward the sewer line in the manhole. The total chimney length shall not exceed 20".

4.3 Drop Manholes

Drop manholes shall be constructed exactly the same as regular manholes except the manhole base shall be extended upstream far enough to form a base for the concrete encasing the sewer pipe drop entering the bottom of the manhole. The drop entering the manhole shall be completely encased in concrete up to the spring line of the pipe of the main sewer line.

All manholes in which the drop is 18" or greater must be constructed with an outside drop as specified above. A cleanout must be placed in the manhole at the level of the main sewer line. All drop manholes shall be constructed in accordance with the details in Appendix IV with the specific variation of the detail determined in advance by the Town Engineer. All drop manholes must be completely lined with coal tar epoxy.

TABLE 6-3

PVC-DS DRAIN & SEWER ASTM D-2729 SOLID & PERFORATED	SIZE	O.D.	MIN. WALL	WEIGHT PER 100 FT.
	3"	3.250"	.070"	45.45

4.4 Service Connection to Manholes

In general sewer service lines will not be allowed to connect to manholes. Certain exceptions, however, may be made by the Town Engineer. Two service lines will be allowed to connect to a manhole located on the end of a sewer main in a cul-de-sac.

The service line must be installed prior to placing the manhole base. No sewer service shall connect to the main line closer than 7' to the centerline of the uphill manhole.

4.5 Plastic Pipe Connections to Manholes

Where plastic pipe is used, all connections to manholes shall be sealed by approved methods. Placing the concrete manhole base directly around the plastic pipe will not be satisfactory. Approved rubber gaskets, bonding material, or other sealants must be used in accordance with the details in Appendix IV.

5. CLEANOUTS

Cleanouts shall not be used in public streets, unless so directed by the Town Engineer. All cleanouts shall be constructed in accordance with the details in Appendix IV. Cleanouts shall be installed on private sewer services under the following guidelines:

5.1 At all changes in direction requiring bends on commercial services.

5.2 Not more than 100' of continuous sewer line shall be installed without at least one cleanout.

5.3 Cleanouts shall be located such that all portions of the line can be cleaned by rodding.

6. ENCASEMENT AND CASINGS

6.1 Concrete Encasements

Concrete encasements shall be installed under the following conditions:

6.1.1 Where sewer lines are at a depth too shallow to sustain traffic load or any other load to which they are subjected. The depth may range from 0 to 4 feet, depending on the loading conditions.

6.1.2 At all locations where infiltration is likely to be high.

6.1.3 At locations where horizontal movement of the sewer mains may be experienced, i.e., below stream beds.

6.1.4 At all crossings under gulches, channels, creeks, and stream beds. These encasements shall be reinforced.

6.1.5 At potable water supply crossings. See Section 9.

6.1.6 At any location designated by the Town Engineer.

All concrete encasements shall be reinforced in accordance with the details in Appendix IV and shall be of a length to completely span the condition encountered.

6.2 Pipe Casings

Pipe casings shall be used where bores are required under rights-of-way by the using agency. All pipe casings shall be constructed to conform with the details in Appendix IV.

7. (RESERVED FOR FUTURE)

8. INSTALLATION OF SEWER PIPE

8.1 Excavation

Excavation for pipelines, fittings, and appurtenances shall be open trench to the depth and in the direction necessary for the proper installation of the same as shown on the approved drawings or as otherwise approved by the Town Engineer. Any water which may be encountered or may accumulate in the excavation shall be pumped out or otherwise removed as necessary to keep the bottom of the excavation free and clear of water during the progress of the work.

Tunneling may be permitted as indicated by economy of construction or necessity of preserving existing improvements. If the earth in the tunnel sloughs off, the roof of the tunnel shall be broken down, and the trench excavated as an open trench.

8.2 Limit of Excavation

Except by expressed written permission of the Town Engineer, the maximum length of open trench shall be 600 feet or the distance necessary to accommodate the amount of pipe installed in a single day, whichever is smaller. The distance is the collective length at any location, including open excavation, pipe laying and appurtenances, construction and backfill which has not been temporarily resurfaced. No trench shall be left open at any time that the CONTRACTOR is not on the job site engaged in construction operations.

8.3 Trench Width

The overall trench width shall not be more than 16" or less than 12" wider than the

largest outside diameter of the pipe to be laid therein, measured at a point 12" above the top of the pipe, exclusive of branches. Excavating and trenching shall be true to line so that a clear space of not more than 12" or less than 6" in width is provided on each side of the largest outside diameter of the pipe in place. For the purpose of this section, the largest outside diameter shall be the outside diameter of the bell, on bell and spigot pipe. All trenching sizes shall be in accordance with the Standards Bedding Details.

Where the trench width, measured at a point 12" above the top of the bell of the pipe, is wider than the maximum set forth above, the trench area around the pipe shall be backfilled with 2,500 psi concrete to form a cradle for the pipe as shown in the Standard Bedding Details. Special care shall be used when pouring the concrete cradle around the pipe so no displacement will occur. In the event of movement, the CONTRACTOR shall remove and replace all pipe and cradle affected.

8.4 Excavation Below Grade

The trench shall be excavated to at least 4" and not more than 6" below specified grade. Before the pipe is laid, the subgrade shall be made by backfilling with an approved material in 3" uncompacted layers. The layers shall be thoroughly tamped as directed by the Town Engineer so as to provide a continuous bearing and support for the pipe at every point between coupling holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18" near the middle of each length of pipe by the withdrawal of pipe slings or other lifting tackle. The finished subgrade shall be prepared accurately by means of hand tools.

The subgrade beneath the centerline of the pipe shall be finished to within 0.03 feet of a straight line between pipe joints or batter boards; all tolerances shall be above the specified grade.

8.5 Correction of Faulty Grades

Where excavation is inadvertently carried below subgrade and/or foundation elevations, suitable provision shall be made at the expense of the CONTRACTOR for adjustment of same, as directed by the Town Engineer to meet requirements incurred by the deeper excavation beneath pipe or structures. Over-depth excavation in such location shall be rectified by backfilling with approved sand and/or graded gravel, and shall be compacted to provide a firm and unyielding subgrade and/or foundation, as directed by the Town Engineer.

8.6 Trenching by Hand or Machine

Hand methods for excavation shall be employed in locations directed by the Town

Engineer. In other locations, the CONTRACTOR may use trench digging machinery or employ hand methods.

8.7 Bracing Excavations

All excavations shall be properly supported in the manner as required by OSHA Federal Register Vol. 37 No. 243, Sub-part P, Section 1926.652 or as required by state laws and municipal ordinances and as may be necessary to protect life, property, and the work or as ordered by the Town Engineer. Excavations shall be braced, sheeted and supported so that they will be safe, and the ground alongside the excavation will not slide or settle. Excavations shall be so braced or sheeted so as to provide conditions under which workmen may work safely and efficiently at all times. The sheeting, shoring and bracing shall be so arranged as not to place any stress on portions of the completed work until the general construction thereof has proceeded far enough to provide ample strength.

Care shall be exercised in the drawing or removing of sheeting, shoring, bracing and timbering to prevent the caving or collapsing of the excavation faces which are being supported.

8.8 Grading and Stockpiling

The CONTRACTOR shall control grading in a manner to prevent water from running into excavations. Obstruction of surface drainage shall be avoided and means shall be provided whereby storm and waste water can be uninterrupted in existing gutters, other surface drains, or temporary drains.

8.9 Dewatering

The CONTRACTOR shall provide and maintain at all times during construction, ample means and devices with which to promptly remove and properly dispose of all water from any source entering the excavations or other parts of the work. Dewatering shall be accomplished by methods which will ensure a dry excavation and preservation of the final lines and grades of the bottoms of excavations. Said methods may include well points, sump pumps, suitable rock or gravel placed below the required bedding for drainage and pumping purposes, temporary pipelines and other means, all subject to the approval of the Town Engineer.

Dewatering for the sewer lines shall commence when groundwater is first encountered, and shall be continuous until such time as water can be allowed to rise in accordance with the provisions of this section.

The CONTRACTOR shall dispose of the water from the work in a suitable manner

without damage to adjacent property. No water shall be drained into work, built or under construction, without prior consent of the Town.

8.10 Foundations in Poor Soil

If excessively wet, soft, spongy, unstable or similarly unsuitable materials are encountered at the surface upon which the bedding material is to be placed, the unsuitable material shall be removed to a depth as determined in the field by the Town Engineer and in accordance with the Bedding Details.

8.11 Foundations in Rock

Where rock is encountered, it shall be removed below grade and the trench backfilled with clean imported sand, squeegee, or 3/4" rock to provide a compacted foundation cushion with minimum allowable thicknesses of 3" under the outside diameter of the pipe bell and 6" under the pipe barrel. Whether or not the foundation material will be considered as rock will be at the discretion of the Town Engineer.

8.12 Pipe Clearance in Rocks

Ledge rock, boulders, and large stones shall be removed to provide a clearance of at least 6" below the pipe and fittings.

8.13 Bedding Procedure

The pipe shall be carefully bedded as shown in the Bedding Details in Appendix IV. The CONTRACTOR shall be responsible for accurately shaping the pipe subgrade to fit the bottom of the pipe for the width shown on the Bedding Details. Use of a drag template shaped to conform to the outer surface of the pipe will be required if other methods do not give satisfactory results.

Each joint shall be recessed in bedding material as required by the Bedding Detail in such a manner as to relieve the bell of the pipe of all load and to ensure continuous bearing along the pipe barrel upon the pipe subgrade.

8.13.1 Class A Bedding (Concrete Arch or Cradle) - Class A Bedding shall be used when additional supporting strength of the pipe is required. The lower portion of the pipe shall be supported by means of a concrete arch or cradle. Class A bedding will not be allowed for flexible pipe such as steel, corrugated steel, plastic and ductile iron pipe. Class A Bedding shall comply with the details in Appendix IV.

8.13.2 Class B Bedding (Granular) - Class B Bedding material shall consist of a well graded mixture of mineral aggregate. The aggregate shall be

squeegee with the maximum amount of fines passing a No. 200 screen not to exceed 5% by weight. The aggregate shall comply to ASTM C-33 or ASTM D-448, gradation #6 or #67. If the excavation for bedding is below the water table, the sub-bedding material shall consist of 3/4-inch to 1-1/2 inch rock. Class B Bedding shall comply with the details in Appendix IV.

8.14 Installation of the Sanitary Sewer Line

8.14.1 General - All pipe shall be laid without break from structure to structure, with the socket ends of the pipe upgrade. Pipe shall be laid to the line and grade shown on the approved plans and in such a manner as to form a close concentric joint with the adjoining pipe and prevent sudden offsets of the flow line. The interior of the sewer pipe shall be cleaned of all dirt and superfluous material of all descriptions as the work progresses.

At all times when pipe laying is not in progress, the open end of the pipe shall be closed with a tight fitting cap or plug to prevent the entrance of foreign matter into the pipe. These provisions shall apply during the noon hour as well as overnight. In no event shall the sewers be used as drains for removing water which has infiltrated into the trenches.

8.14.2 Alignment and Grade - The sewer line shall be laid and maintained to the required lines and grades as shown on the Plans.

Whenever obstructions not shown on the Plans are encountered during the progress of the work and interfere to such an extent that an alteration in the approved Plans is required, the Town Engineer shall have the authority to change the Plans and order a deviation from the line and grade.

8.14.3 Placing of Sewer Pipe in the Trench

8.14.3.1 When placing the sanitary sewer pipe in the ditch, the recommended practice for installing sewer pipe ASTM C12-77 or latest revision thereof shall be used. Pipe shall be laid true to line and grade as shown on Plans approved by the Town Engineer.

All pipe shall be protected during handling against impact shocks and free fall and no pipe shall be placed in the sewer line that has been damaged while lowering into the ditch. Bell holes shall be dug under the bells of all pipe, regardless of the type of bedding used in the ditch and the entire length of barrel of all sewer pipe shall rest firmly on the bedding

material used in the ditch and the weight of the sewer pipe in no case shall be supported by the bells of the pipe.

After lowering into the ditch, both the bell and spigot shall be thoroughly cleaned and free from any foreign material.

8.14.3.2 When manufacturer's prefabricated joints are used in the laying of clay or other sanitary sewer lines, such lines shall be joined using lubricants, primers, adhesives, solvents, etc., recommended by the manufacturers of said manufactured joints. All factory fabricated joints shall be placed, fitted, joined and adjusted in such a workmanlike manner as to obtain the degree of water tightness required and in compliance with recommended methods of the manufacturer, and as approved by the Town Engineer.

8.14.3.3 Where cast iron sewer pipe is used in a sanitary sewer line, it shall be as designated under sewer pipe in these specifications. The method of placing and joining cast iron sanitary sewer pipe in the trench shall be in accordance with specifications of the pipe manufacturer on this operation, and as approved by the Town Engineer.

8.14.4 Pipe Fittings

8.14.4.1 General - Pipe fittings shall include branches of every type and stoppers. Fittings shall be furnished and installed at the locations, to the grades and of type and size shown on the Plans and in conformance with these specifications. Branches shall be installed in accordance with the standard details.

8.14.4.2 Branches - Branches of type shown on the Plans shall be furnished with connections of the sizes specified and shall be securely and completely fastened to the barrel of the pipe in the process of manufacture. In the case of pipe 15" or greater in diameter, in addition to other fastening material of approved quality, there shall be a reinforcing collar of cement mortar around the outside of the joint, and there shall be no exposure of cement mortar on the interior surface of the pipe. Wye branches shall have their axis approximately 45 degrees (unless otherwise specified on the Plans) to the longitudinal axis of the pipe, measured from the socket end. All branches shall terminate in sockets and the barrel of the branch shall be of sufficient length to permit making a proper joint when the

connecting pipe is inserted in the branch socket.

The quality of pipe fittings shall conform to the applicable provisions of these specifications, and Section 3. Joints for fittings shall conform to applicable pipe material.

8.14.4.2.1 Installation of Branches - Pipe wyes, and other types of branches shall be furnished and installed along with the sewer. Wyes of size specified on the Plans shall be installed for all sewer house connections and for future sewer house connections as shown on the Plans, or specified in the detailed specifications. The longitudinal barrel of branch fittings to be placed in line and grade with the sanitary sewer mains shall be of the same diameter, quality and type as said sewer. Installation, earthwork and bedding for branches shall conform to the applicable provisions set forth for said sewer pipe. Unless otherwise specified, the branch of wye fittings shall be inclined upward at an angle not greater than 45 degrees from a horizontal line. No wye for sewer house connection branches shall be placed closer than 7 feet , in the downstream side, to the centerline of any structure or manhole.

The CONTRACTOR shall hand tamp the backfill under every wye branch when installed.

8.14.4.3 Stoppers - Pipe stoppers shall be 3/4" in thickness and shall have a factory-made plasticized polyvinyl chloride compound joint material cast and bonded to the pipe. The material shall be molded and cured to a uniform hardness and compressibility and form a tight compression coupling when assembled. The material used for the compression joint shall conform with the type of pipe material specified.

Neoprene (synthetic rubber) stoppers shall be equal to those manufactured by Pacific Clay Products, Gladding McBean and Company or approved equal. The joint formed by the stopper and pipe shall be a tight compression coupling when assembled.

All joints for stoppers shall be adequate to withstand the internal pressure of the leakage and/or infiltration test; however, joints shall be made in such a manner that they may

be removed without injury to the socket.

8.14.5 Pipe at Manholes or Structures - Pipe joint of the same inside diameter as the adjoining pipe shall be placed at the inlet and outlet to each manhole or structure as shown on the details.

Pipe bells shall not be cast into manholes or structures. The bell shall be cut off so that no recess or offset appears on the exposed face from the inside wall of the pipe to the outside wall of the pipe (to be a plain end, flush with the inside wall of the manhole or structure, or as shown on the details.)

8.14.6 Underdrain - If the Town Engineer deems it advisable to install a French drain or a French drain and an underdrain under the sanitary sewer line, to lower the level of groundwater in the area, he shall do so by including such installations in his Contract Drawings. All underdrain branch lines shall be 3" O.D. so as to prohibit cross connection to sanitary sewer.

8.15 Backfilling

8.15.1 General - All trenches shall be backfilled after pipe, fittings and appurtenances have been installed, inspected and approved by the Town Engineer. Bedding and "pipe zone" backfill shall be installed in accordance with Section 8.13.

Whenever a relative compaction requirement value is specified herein, the optimum moisture content and relative density shall be determined in accordance with AASHTO T-180 for 90% **and AASHTO T-99 for 95%**.

8.15.2 Density Requirements in Trench - The CONTRACTOR shall obtain a Standard Proctor Density of 90% for the total depth of all trenches in open fields and **95% in dedicated rights-of-way**. Backfilling shall be done with good sound earth, sand or gravel, and no oil cake, bituminous pavement, concrete, rock or other lumpy material shall be used in the backfill unless these materials are scattered and do not exceed 6" in any dimension and are not placed within 1 foot of the 1-1/2 foot limit. Material of perishable, spongy or otherwise improper nature shall not be used in backfilling and no material greater than 4" in any dimension shall be placed within 1 foot of any pipe, manhole or structure. All backfill material shall be subject to the approval of the Town Engineer.

8.15.3 Compacted Fill - Compaction shall be done by use of vibratory equipment, tamping rollers, pneumatic tire rollers or other mechanical tampers of the type and size approved by the Engineer. The backfill shall be placed in

horizontal layers of such depths as are considered proper for the type of compacting equipment being used in relation to the backfill material being placed. Each layer shall be evenly spread, properly moistened and compacted to the density specified in Section 8.15.2. Any damage to the pipe as a result of CONTRACTOR'S operation shall be repaired and/or replaced.

8.15.4 Consolidated Fill - Consolidated fill shall be performed by flooding, pooling or jetting so as to obtain a density of the fill material at least equal to that specified in Section 8.15.2. When flooding, pooling or jetting methods are used, material for use as backfill shall be placed and compacted in layers not exceeding 3 feet in thickness. Flooding, pooling or jetting methods shall be supplemented by the use of vibratory or other compaction equipment when necessary to obtain the required density. Care shall be taken in all consolidating operations to prevent the movement or floating of the pipe. In the event there is movement or floating, the CONTRACTOR shall re-excavate, relay and backfill all pipe so affected. Consolidation methods shall not be used when the backfill material is not sufficiently granular in nature to be self-draining during and after consolidation and foundation materials may be softened or otherwise damaged by applied water.

8.15.5 Procedure at Street Zone - The top 2-1/2 feet from finish street grade or ground surface, as the case may be, shall be compacted in horizontal layers not exceeding 8" in thickness, using approved hand pneumatic or mechanical type tampers to obtain a Standard Proctor Density of 95%. Flooding and jetting will not be permitted in this upper 2-1/2 feet. From existing street grade to 2-1/2 feet below street grade, the material for backfill may contain stones up to 2" in diameter, in quantity not exceeding 20% of the volume where said coarse materials are well distributed throughout the finer material and the specified compaction can be obtained.

8.16 Compaction Tests

When required by the Town Engineer, compaction tests will be taken by an approved testing laboratory at locations designated by the Town Engineer. All expenses involved in these tests will be borne by the Developer/Owner. Test results must be made available to the Town Engineer immediately and copies of results submitted once a week. In all cases where the tests indicate compaction less than that required in these specifications, additional compaction and tests will be required until these specifications are met. Probationary acceptance of the lines by the Town will be contingent upon satisfactory compaction results. All compaction tests and

acceptance of test results must be taken and reviewed prior to testing for infiltration and/or exfiltration. Frequency of testing will be as follows:

- 1 test at every above ground appurtanace (manholes)
- 1 test every 200 LF of mainline trench with 50% of the tests at subgrade elevation and 50% below subgrade
- 1 test at every sewer service

8.17 Final Clean Up

After backfill has been completed, the right-of-way shall be dressed smooth and left in a neat and presentable condition and as close to its original condition as possible, and to the satisfaction of the Town Engineer.

8.18 Safety Precautions

All excavations shall be performed, protected and supported as required for safety and in the manner set forth in the operation rules, orders and regulations prescribed by the OSHA Federal Register.

Barriers shall be placed at each end of all excavations and at such places as may be necessary along excavations to warn all pedestrian and vehicular traffic of such excavations. Lights shall also be placed along excavations from sunset each day to sunrise of the next day until such excavation is entirely refilled.

9. PROTECTION OF WATER SUPPLIES

9.1 Water Supply Inter-Connections

There shall be no physical connection between a public or private potable water supply system and a sewer, or appurtenance thereto which would permit the passage of any sewage or polluted water into the potable supply.

9.2 Relation to Water Works Structures

While no general statement can be made to cover all conditions, it is generally recognized that sewers must be kept remote from public water supply wells or other water supply sources and structures.

9.3 Relation to Water Mains

Sewers shall be located a minimum of 10 feet horizontally from existing or proposed

water mains (centerline distance). Where sewer lines cross water mains, the sewer pipe shall be a minimum of 18" clear distance vertically below the water main. If this clear distance is not feasible, the crossing must be designated and constructed so as to protect the water main. Minimum protection shall consist of the installation of an impervious and structural sewer. For example:

9.3.1 One length of ductile iron water pipe at least 18 feet long centered under the water main. Joints between the sewer pipe and the ductile iron pipe shall be encased in a concrete collar at least 6" thick and extending at least 6" either side of the joint.

9.3.2 Concrete, PVC, or vitrified clay sewer pipe with reinforced concrete encasement. Encasement shall be in accordance with the details in Appendix IV and extend a distance of 10 feet either side of the water main.

In all cases, suitable backfill or other structural protection shall be provided to preclude settling and/or failure of the higher pipe.

10. TESTS AND INSPECTION

10.1 Pipe Testing Prior to Construction

10.1.1 General - Before being used in any work under these specifications, pipe shall be subjected to and shall meet the requirements of the following hydrostatic pressure tests and loading test. These tests shall be made by the CONTRACTOR and shall be witnessed by a reputable testing laboratory. The CONTRACTOR shall deliver the pipe selected for testing to the place and at the time designated by the testing laboratory. Written test reports will be furnished to the Town Engineer upon request.

The testing laboratory shall select at random for testing as herein specified up to 2% of the number of pipe in each size of pipe furnished, except that in no case shall less than five (5) specimens be tested.

The specimens selected for testing purposes shall be sound pipe having dimensions consistent with these specifications. The lot or lots from which the test samples are taken shall be sufficient to fill the entire order for that size of pipe used in the work under the Contract if they pass the tests, and shall be so designated and marked.

All pipe shall be subject to inspection by the Town Engineer at the factory, trench or other point of delivery. The purpose of the inspection shall be to

cull and reject any pipe that, independent of the physical tests herein specified, fails to conform to the requirements of these specifications, or that may have been damaged during transportation and/or in subsequent handling.

TABLE 6-4

Thickness of Barrel	Minimum Testing Time
Up to and including 1"	7 minutes
Over 1" and including 1-1/2"	9 minutes
Over 1-1/2" and including 2"	12 minutes
Over 2" and including 2-1/2"	15 minutes
Over 2-1/2" and including 3"	18 minutes
Over 3"	21 minutes

10.1.2 Hydrostatic Test - In lieu of the standard ASTM absorption test, the following hydrostatic pressure test shall be substituted:

The hydrostatic pressure test shall precede the loading test by not less than one (1) hour or more than three (3) hours and shall be applied to all the specimens received for test in each size of the pipe. When subjected to an internal hydrostatic pressure of 10 pounds per square inch for the time specified in Table 6-4, the accumulated moisture on the exterior surface of the pipe shall not run down the side in such quantity that it will exceed 10 milliliters.

10.1.3 Loading Test - The loading test shall be the three-edge bearing. The loading test shall conform to the applicable provisions of the ASTM for each type and class of pipe specimens selected for testing, except that loading to test ultimate strength will not be required.

The net inside length of the pipe from the bottom of the socket to the spigot end of the pipe shall be used as the divisor to calculate the load per linear foot.

10.1.4 Acceptance or Rejection on Result of Test - If all, or the minimum, designated percentage or number of the specimens tested meet the requirements of the test, then all of the pipe in the lot, shipment or delivery corresponding to the sizes and classes so tested shall be considered as complying with the test. If, however, 10% or more of the specimens tested fail to meet the requirements of the test, or if more than one specimen fails to meet the requirements of the test when the number to be tested is less

than ten, then a second selection of pipe shall be made for the test. The number of specimens to be tested in the second selection of pipe shall be five (5) for each specimen of the first selection that failed to meet the requirements.

If 90% or more of the specimens tested, including those first tested, meet the requirements of the test, all of the pipe in the lot, shipment or delivery corresponding to the sizes and classes so tested shall be considered as complying with that test; otherwise, all pipe of these sizes and classes shall be rejected.

10.1.5 Inspection Independent of Tests - The following imperfections in a pipe or special fitting will be considered injurious and cause for rejection without consideration of the test results hereinabove specified:

- A single crack in the barrel of the pipe, extending through the entire thickness, regardless of the length of such crack.
- A single crack which extends through one-fifth of the barrel thickness and is over 3" long.
- Any surface fire crack which is more than 1/32" wide at its widest point.
- Lumps, blisters, pits or flakes on the interior surface of a pipe or fittings.
- When the bore or socket of the pipe varies from a true circle more than 3% of its nominal diameter.
- When a pipe or fitting, designated to be straight, deviates from a straight line more than 1/16" per linear foot. The deviation shall be measured from a straight edge at a point midway between the ends of the pipe.
- A piece broken from either the socket or spigot end.
- Tramp clays, grog or other foreign matter that have fused permanently to the exterior or interior surface of the pipe or fitting.
- If, when placed in a vertical position, the pipes do not give a metallic ring when struck with a hammer.

10.2 Test for Leakage and Infiltration After Construction

10.2.1 General- It is the intent of the sewer specifications that the completed sewer pipes of all types, along the manholes and other appurtenances, shall be watertight.

At the option of the Town Engineer, each section of sewer between two successive manholes shall be tested for leakage and/or infiltration. These

tests shall be performed subsequent to acceptance of compaction test results by the Town Engineer.

Even though a section may have previously passed the leakage or infiltration test, each section of sewer may be tested subsequent to the last backfill compacting operation in connection therewith, where, in the opinion of the Town Engineer, heavy compaction equipment or any of the operations of the CONTRACTOR or others may have damaged or affected the required watertight integrity of the pipe, structure and appurtenances. The CONTRACTOR shall furnish all materials required for the tests. Tests shall be made in the presence of the Town Engineer.

If the leakage and/or infiltration rate as shown by the tests specified herein is greater than the amount specified, the pipe joints shall be repaired or, if necessary, the pipe shall be removed and relaid by the CONTRACTOR. The sewer will not be considered acceptable until the leakage and/or infiltration rate, as determined by test, is less than the allowable.

The CONTRACTOR may at his option air test or water test for leakage except where (a) in the opinion of the Town Engineer excessive groundwater is encountered, then the infiltration test shall be made, or (b) where the difference in elevation between the invert of the upper structure and the invert of the lower structure is more than 10 feet, then the air test shall be made.

10.2.2 Leakage Tests

10.2.2.1 Water Test - Each section of sanitary sewer between two successive structures may, at the direction of the Town Engineer, be tested by closing the lower end of the sewer to be tested and the inlet sewer of the upper structure with plugs or stoppers and filling the pipe and structure with water to a point 4 feet above the invert of the open sewer in the upper structure, or to a height of 10 feet above the invert of the sewer in the lower structure, whichever gives the least hydrostatic pressure on the lower structure.

The total leakage shall be the decrease in volume of water in the upper structure. The leakage shall not exceed 0.23 gallons per hour per inch of nominal diameter of pipe per 100 feet of sewer pipe being tested or as indicated in Table 6-5. The length of house connection shall not be used in computing the length of sewer main being tested.

If the leakage, as shown by the test, is greater than allowed, the pipe shall be overhauled and, if necessary, replaced and relaid until the joints and pipe shall hold satisfactorily under this test. All tests must be completed before street or trench is resurfaced, unless otherwise directed by the Town Engineer. The CONTRACTOR shall furnish all labor and materials for making the tests required.

TABLE 6-5	
ALLOWABLE LIMITS OF EXFILTRATION (LEAKAGE) 295 GAL/INCH DIA/MI/DAY (AT 10' HEAD) OR 0.23 GAL/INCH DIA/100'/HR	
Pipe Diameter (Inches)	**Maximum Allowable Loss In Gals/Hr/100' of Pipe**
8	1.9
10	2.3
12	2.6
15	3.5
18	4.2
21	4.9
24	5.6
27	6.3
30	7.0
33	7.6
36	8.3

10.2.2.2 Air Test Procedure - Each section of sanitary sewer between two successive manholes may, at the direction of the Town Engineer, be tested by plugging all pipe outlets with suitable test plugs. Air shall be slowly added until the internal pressure is raised to 4.0 psi. The compressor used to add air to the pipe shall have a blow-off valve set at 5 psi to assure that at no time the internal pressure in the pipe exceeds 5 psi. The internal pressure of 4 psi shall be maintained for at least two minutes to allow the air temperature to stabilize after which the air supply shall be disconnected and the pressure allowed to decrease to 3.5 psi. The time in minutes that is required for the internal air pressure to drop from 3.5 psi to 2.5 psi shall be measured and the results compared with the values listed in Table 6-6.

TABLE 6-6		
Pipe Diameter (Inches)	**Minimum Distance Test Time in Minutes**	**Between Manholes (Feet)**
8	4	340
10	5	260
12	6	230
15	7	170
18	9	150
21	10	120
24	11	110
27	13	100
30	14	90
33	16	80
36	17	70

The above tabulated values shall be used for the respective diameter pipes except where the distance between successive manholes is less than the above tabulated values, in which case the following formula will be used to determine the test time:

$T = .000183\ d^2L$
T = Test time in minutes
d = Inside diameter of pipe in inches
L = Distance between successive manholes in feet

If the pressure drop from 3.5 psi to 2.5 psi occurs in less time than the above tabulated or calculated values, the pipe shall be overhauled and, if necessary, replaced and relaid until the joints and pipe shall hold satisfactorily under this test.

10.2.3 Test for Infiltration - If, in the construction of a section of the sewer between structures, excessive groundwater is encountered, the test for leakage described in Section 10.2.2 shall not be used, but instead, the end of the sewer at the upper structure shall be closed sufficiently to prevent the entrance of water, and pumping of groundwater shall be discontinued for at least three days after which the section shall be tested for infiltration. The infiltration shall not exceed 0.16 gallons per hour, per inch of diameter, per 100 feet of main-line sewer being tested or as indicated in

Table 6-7 and does not include the length of house laterals entering that section. Where any infiltration in excess of this amount is discovered before completion and acceptance of the sewer, the sewer shall be immediately uncovered and the amount of infiltration reduced to a quantity within the specified amount of infiltration before the sewer is accepted, at the expense of the CONTRACTOR. Should, however, the infiltration be less than the specified amount, the CONTRACTOR shall stop any individual leaks that may be observed when ordered to do so by the Town Engineer. The CONTRACTOR shall furnish all labor and materials for making the tests required. All tests must be completed before street or trench is resurfaced, unless otherwise directed by the Town Engineer.

See following sheet for Table 6-7.

TABLE 6-7

ALLOWABLE LIMITS OF INFILTRATION 200 GAL/INCH DIA/MI/DAY OR 0.16 GAL/INCH DIA/100' HR		ALLOWABLE LIMITS OF INFILTRATION FOR MANHOLE STRUCTURES	
Diameter of Sewer (Inches)	**Infiltration Gal/Hr/100' (Gallons)**	**Diameter of Manhole (Inches)**	**Infiltration Gal/Vertical Ft/Hr**
8	1.3	41	0.07
10	1.6	48	0.08
12	1.9	60	0.10
15	2.4	72	0.12
18	2.8		
21	3.3		
24	3.8		
27	4.3		
30	4.8		
36	5.7		

10.3 Tests for Alignment and Grade, and Damaged or Defective Pipe in Place

After the pipe has been installed, tested for leakage, backfilled, manhole raised to grade, and the trenches reinforced, the Town Engineer and a representative of the

Contractor will "lamp" all lines. All defective portions of the new facilities will be noted to the CONTRACTOR after the lamping operation is complete. A minimum 3/4 "moon" will be required. "Bellied" lines will be rejected. All lines should be flushed and manholes cleaned by the CONTRACTOR prior to "lamping." At the request of the Town Engineer, the line will be "balled" to remove dirt, rocks or other foreign matter not removed during the flushing operation. No flushed water or materials shall be discharged to existing sewer lines.

In areas where there are still some questions as to the condition of the sewer line, the Town Engineer may require that pictures be taken of the interior of that part of the sewer line under question. After the pictures have been interpreted by the CONTRACTOR and the Town Engineer, should the sewer line be interpreted to be defective, the cost of taking the pictures shall be borne by the CONTRACTOR. Should the sewer line be interpreted as being a good sewer line, the cost of taking the pictures shall be borne by the Town. However, the Town reserves the right to require pictures be taken of any curved line approved for installation. In all such cases, the pictures will be taken at the expense of the CONTRACTOR and will become the property of the Town after interpretation.

Final acceptance of the lines will not be granted until all tests are successful and all items listed for correction by the Town Engineer have been accomplished.

11. RESPONSIBILITY OF THE CONTRACTOR

Prior to the start of any work where sewer mains to be installed tie into existing Town sewer systems, the nearest manhole to the point of tie-in shall be plugged with a plumber's plug on the outlet side by the CONTRACTOR. This plug shall remain in place until the main has been deemed acceptable for service by the Town Engineer. Its purpose is to prevent any mud, water, or other materials from entering the existing line during construction. The CONTRACTOR shall be responsible for pumping and cleaning these manholes and removing the plug when so instructed by the Town Engineer.

The CONTRACTOR is responsible also for maintaining As-Recorded drawings to include all distances between manholes and location of wyes or service tees.

These drawings will be turned over to the Town Engineer and final acceptance of the line by the Town will be contingent upon receipt of formal As-Recorded drawings in 24" x 36" size (scale: 1" = 100') and submitted in reproducible and print form. Once the sanitary sewer construction has been completed and all tests performed and the mains deemed operational by the Town, a walk through inspection will be performed. Once all corrections to the system are made and approved, the Town will issue a probationary acceptance of the system. Final acceptance will be issued as outlined in the Rules and Regulations of the Town.

The CONTRACTOR will be held responsible for the proper functioning of the lines for up to one (1) year from the date of probationary acceptance of the lines by the Town. Any

malfunction during this period of guarantee shall be remedied by the CONTRACTOR to the satisfaction of the Town Engineer and at no expense to the Town.

12. SEWER SERVICES

Installation of any and all service lines, from the main line to the property line must be inspected by the Town, who shall be notified by the CONTRACTOR at least 48 hours prior to installation.

Concrete, cast iron, or plastic sewer services will be acceptable if they conform to the specifications previously mentioned. All methods of joining the sewer service to the existing wye or tie at the main line, or to the ground iron stack at the building must be approved by the Town in advance. In all cases where existing wyes or ties cannot be met, or are not available, mechanical methods must be used to tap the main line.

No sewer service taps shall be made prior to the acceptance of the completed main-line by the Town Engineer. Where all taps are made, the CONTRACTOR must keep accurate records indicating the exact location of the tap. Installation of service pipe must conform to the specifications previously mentioned.

Multiple sewer connections must be made within or under any building. Any sewer service line exiting a building must be connected directly to a Town sewer main with no intermediate connections.

All sewer services must be bedded with squeegee, 4" below and 6" above the pipe. No horizontal bends will be allowed in the street. At the connection to the house service, no more than 3 bends totaling 135° will be allowed. Calder couplings may be used, but the pipe deflection from these couplings may not exceed 2°. No 90° bends will be allowed. All sewer services will be installed with 6" wide wire-impregnated green or metallic-backed marker tape buried above the pipe 12" maximum below final grade.

3. PRESSURIZED SEWER SYSTEM CRITERIA AND SPECIFICATIONS

13.1 Purpose and General Requirements

13.1.1 Purpose

This publication is to provide information to all Engineers, Contractors, Builders, Developers and other interested persons or firms, on the Town requirements with respect to design and construction of pressure sewer systems within the Town. This publication presents technical specifications for the design and installation of raw sewage and effluent mains and should be used in conjunction with the Town Rules and Regulations by any firm or individual planning to design or construct raw sewage and effluent systems within the Town. In all cases in these

specifications where reference is made to "Town Engineer," the "Town Engineer" shall mean any representative of the Consulting Engineering firm or other individual designated by the Town to provide inspection of the raw sewage and effluent system construction.

13.1.2 General Requirements

It is the intent of these specifications to coincide and be similar to Water System Criteria Specifications with the exception of the following provisions:

13.1.2.1 All mains shall be profiled on the construction plans. All mains shall be PVC pipes.

13.1.2.2 Approved construction plans and a copy of these specifications must be kept on the job site by the Contractor at all times. Approved construction plans will expire six (6) months from the date of approval.

13.1.2.3 No work shall be backfilled (including bedding materials) above the spring line of the pipe until the construction has been inspected and approved for backfilling by the Town Engineer.

13.1.2.4 The details for the water system specifications are to be used in construction of pressurized sewer systems.

13.1.2.5 The maximum distance between main line valves shall be 1500 feet. Valves shall also be located at all intersections.

13.1.2.6 Squeegee bedding shall be used. On-site material is not acceptable without the approval of the Town Engineer.

13.2 Location of Lines and Appurtenances

13.2.1 Mains in Streets

When mains are placed in streets they shall be placed as follows:

13.2.1.2 The main shall be placed 10' (ten feet) minimum horizontally from any domestic water main.

13.2.2 Mains in Easements

In areas where mains are placed in easements, all mains shall be located

within the easements shown on the contract drawings. All main easements must be a minimum of 30' (thirty feet) in width for exclusive easements or 50' (fifty feet) for non-exclusive easements. No line shall be located less than 5' feet (five feet) from the edge of an easement.

13.2.3 Valves

Valves shall be located, where possible, at a point on the main which would be intersected by the extension of a property line. Gate valves shall be used on sewage effluent mains and plug valves shall be used on raw sewage mains. Appropriate valve trim and seats shall be employed to prevent corrosion.

13.3. Pipe

13.3.1 General

Sizing shall be determined by the Town Engineer. Pipe in sizes 10" or 14" generally will not be allowed. Additional requirements for type of pipe shall be determined by the Town Engineer.

13.3.2 Polyvinyl Chloride (PVC) Pressure Pipe

All polyvinyl pipe furnished under this specification shall be manufactured in strict accordance with AWWA Standard C900-89 and shall conform to the following additional requirements:

13.3.2.1 Size of Pipe - This specification shall cover polyvinyl chloride pipe in 6-inch and 8-inch nominal diameters with cast iron pipe equivalent outside diameters.

13.3.2.2 Joint Type - Pipe joints shall be made using an integral bell with an elastomeric gasket push-on type joint or using machined coupling of a sleeve type with rubber ring gaskets and machined pipe ends to form a push-on type joint.

Solvent cement joints are strictly prohibited.

13.3.2.3 Class and Type - All sizes of pipe shall be Class 200, dimension ratio 14 (DR 14) or as directed by the Town Engineer.

13.3.2.4 Pipe Lengths - Each length of pipe will be a standard laying length of 20 feet. Random lengths shall not be acceptable.

13.3.2.5 Manufacturer - Unless otherwise authorized by the Town Engineer, only Johns-Manville "Blue Brute," CertainTeed "Vinyl-Iron," Northstar "Aqua-lite," or Robintech shall be acceptable.

13.3.2.6 Fittings - All fittings shall be ductile iron, cement mortar lined, and shall conform to AWWA **C-110/A21.10-93** for mechanical joints and AWWA **C-111-71/A21.11-95** for push on joint gasket or latest revisions thereof. Other linings may be used when authorized by the Town Engineer.

Fittings shall be wrapped in polyethylene.

13.4 Main Equipment

13.4.1 Buried valves shall be open-left (counter-clockwise) and shall have valve boxes similar to domestic water valves except the valve box lid shall be labeled "Sewer".

13.4.2 Above ground valves shall be open-left (counter-clockwise) and be equipped with an appropriate hand-wheel or lever operator.

13.4.3 Maker posts shall be 4" steel posts painted green with a 12" long yellow section beginning 6" below the top which will contain the stenciled letting.

13.4.4 Warning signs shall be placed along pressurized sewer systems at the direction of the Town Engineer to warn the public that pressurized sewer system is non-potable water.

VII. ROADWAY AND DRAINAGE CONSTRUCTION SPECIFICATIONS

By adoption of these Engineering Standards, the Town of Hudson adopts the current edition of Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction as revised, and the Colorado Department of Transportation's Construction Manual as revised.